

GUIDEBOOK

# *53 rd. Annual Field Conference Of Pennsylvania Geologists*

**BEDROCK AND GLACIAL GEOLOGY OF THE  
NORTH BRANCH SUSQUEHANNA LOWLAND  
AND THE EASTERN MIDDLE ANTHRACITE FIELD**



October 6, 7, and 8, 1988

Hazleton, Pa.

Hosts : Bloomsburg University  
Pennsylvania Geological Survey  
Eckley Miners' Village

Guidebook for the  
53rd Annual Field Conference of Pennsylvania Geologists

BEDROCK AND GLACIAL GEOLOGY OF THE NORTH BRANCH  
SUSQUEHANNA LOWLAND AND THE EASTERN MIDDLE ANTHRACITE FIELD  
NORTHEASTERN PENNSYLVANIA

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October 6-8, 1988

Hosts: Bloomsburg University

Pennsylvania Geological Survey

Eckley Miners' Village

Headquarters Motel:

Genetti Motor Lodge, Hazleton, PA

Cover: The "Molly Maguires" at Eckley Miners' Village. (Artwork  
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Guidebooks distributed by:

Field Conference of Pennsylvania Geologists, Inc.  
c/o Department of Environmental Resources  
Bureau of Topographic and Geologic Survey  
P.O. Box 2357  
Harrisburg, PA 17120

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## PREFACE

Welcome to the 53rd Annual Field Conference of Pennsylvania Geologists! And welcome back to Hazleton and Genetti's! This is the third Field Conference in the past 20 years to be held in the "Mountain City" (the others were in 1969 and 1978), but the first in which the local geology is a major focus.

Our main objectives in convoking this conference on the geology of the North Branch Susquehanna Lowland and the Eastern Middle Anthracite field are: 1) to present a revised chronology of pre-late Wisconsinan glaciations in north-eastern Pennsylvania; 2) to examine some new structural data concerning the Berwick anticlinorium and the enigmatic "Light Street thrust fault"; 3) to look at stratigraphic details in the upper Mauch Chunk and lower Pottsville Formations that pertain to the existence of a "sub-" or "mid-Pottsville" disconformity; and 4) to relate geology and physiography to the historical and technological development of mining and transportation in the region.

The field trip area includes rocks that range from Silurian to Pennsylvanian in age (Table 1). Although we will see many of these units from the buses at 55 miles an hour, only the Tonoloway, Marcellus, Mahantango, Mauch Chunk, Pottsville, and Llewellyn Formations are the subject of actual Stops. Those interested in more details on the bedrock geology should consult Atlases 174c and 164cd of the Pennsylvania Geological Survey.

We are indebted to the following individuals for locality information and for permission to enter private property: Louis Pagnotti, III, Jack Beadle, and George Senick (retired) of Pagnotti Enterprises and the Jeddo-Highland Coal Company; Louis Beltrami and Chuck Soroka of Beltrami Enterprises; Fred Barletta and Joseph Bove of A. Barletta and Sons; Gerald Gatti, Jr., and Gordon Fletcher of Coal Contractors, Inc.; and Clark E. Travelpiece of Pennsylvania Power and Light Company.

This guidebook is dedicated to the memories of George H. Crowl (1910-1987) and Dennis E. Marchand (1939-1981), both of whom contributed greatly to our present understanding of the complex Pleistocene geology of the Susquehanna River region.

Table 1. Generalized Description of Bedrock Units

| System                 | Geologic unit           | Thickness<br>(feet) | Dominant<br>lithologies                                                |
|------------------------|-------------------------|---------------------|------------------------------------------------------------------------|
| Pennsylvanian          | Llewellyn Formation     | 1,500               | Interbedded conglomerate, sandstone, shale, claystone and coal         |
|                        | Pottsville Formation    |                     |                                                                        |
|                        | Sharp Mtn. Member       | 100-150             | Quartzitic conglomerate and sandstone; minor shale, claystone and coal |
|                        | Schuylkill Member       | 100                 |                                                                        |
|                        | Tumbling Run Member     | 0-125               |                                                                        |
| Mississippian          | Mauch Chunk Formation   |                     |                                                                        |
|                        | Upper member            | 500-600             | Gray conglomerate and red mudstone                                     |
|                        | Middle member           | 2,000               | Red sandstone and mudstone                                             |
|                        | Lower member            | 500                 | Gray sandstone and red mudstone                                        |
|                        | Pocono Formation        | 600-650             | Quartzitic sandstone                                                   |
| Mississippian-Devonian | Specht's Kopf Formation | 0-500               | Quartzitic sandstone                                                   |
| Devonian               | Catskill Formation      |                     |                                                                        |
|                        | Duncannon Member        | 1,100               | Interbedded red and gray sandstone, shale, and siltstone               |
|                        | Sherman Creek Member    | 2,500               |                                                                        |
|                        | Irish Valley Member     | 1,800-2,000         |                                                                        |
|                        | Trimmers Rock Formation | 2,500               | Siltstone, shale, and sandstone                                        |
|                        | Harrell Formation       | 100                 | Grayish-black shale                                                    |
|                        | Mahantango Formation    |                     |                                                                        |
|                        | Tully Member            | 50-60               | Argillaceous limestone and shale                                       |
|                        | Lower member            | 1,100-1,200         | Shale, locally fossiliferous                                           |
|                        | Marcellus Formation     | 300                 | Grayish-black shale                                                    |
|                        | Onondaga Formation      | 50-175              | Shale and limestone                                                    |
| Devonian-Silurian      | Old Port Formation      | 150                 | Limestone, shale and chert                                             |
|                        | Keyser Formation        | 125                 | Limestone, nodular and fossiliferous in part                           |
| Silurian               | Tonoloway Formation     | 200                 | Laminated limestone                                                    |
|                        | Willis Creek Formation  | 600-700             | Calcareous shale and limestone                                         |
|                        | Bloomsburg Formation    | 500                 | Red mudstone and siltstone                                             |
|                        | Mifflintown Formation   | 200                 | Limestone and shale                                                    |
|                        | Keefer Formation        | 40                  | Quartzitic sandstone                                                   |
|                        | Rose Hill Formation     |                     |                                                                        |
|                        | Upper member            | 120                 | Shale, limestone, and sandstone; locally hematitic                     |
|                        | Centre Member           | 60                  |                                                                        |
|                        | Lower member            | 720                 |                                                                        |
|                        | Tuscarora Formation     | 350                 | Quartzitic sandstone                                                   |

# GLACIAL GEOLOGY OF THE ANTHRACITE AND NORTH BRANCH SUSQUEHANNA LOWLAND REGIONS

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## INTRODUCTION

The study area lies within the Valley and Ridge province of northeastern Pennsylvania (Figure 1). The field work delineating ice margin positions was carried out from the eastern end of the Southern Anthracite field to the lowland east of Bald Eagle Mountain. The primary studies on the glacial geology of the region have involved the tracing and retracing of the "Terminal Moraine" (Lewis, 1884; Crowl and Sevon, 1980), the extent of "extramorainic drift" (Williams, 1917), the extent of pre-Wisconsinan deposits (Leverett, 1934), and the outwash terrace sequence along the Susquehanna River (Peltier, 1949). In the last two decades, quadrangle mapping of glacial deposits has been undertaken by the Pennsylvania Geologic Survey around the Pocono Plateau, around Williamsport, and along the Susquehanna Valley lowland. In the 60 years since Leverett did field work in the Anthracite region itself, no other geologist had worked in that area because it was generally assumed that the extensive strip mining had destroyed the glacial record. Field work in the Anthracite region during the last few years has shown that the pre-Wisconsinan glacial deposits are almost never exposed except in the strip mines. Those exposures have permitted a clear delineation of the extent of glaciation in the Anthracite region. Future work will hopefully develop a clear sequence and age for the glaciations that covered the Anthracite and adjacent regions. The strip mine exposures are ephemeral and

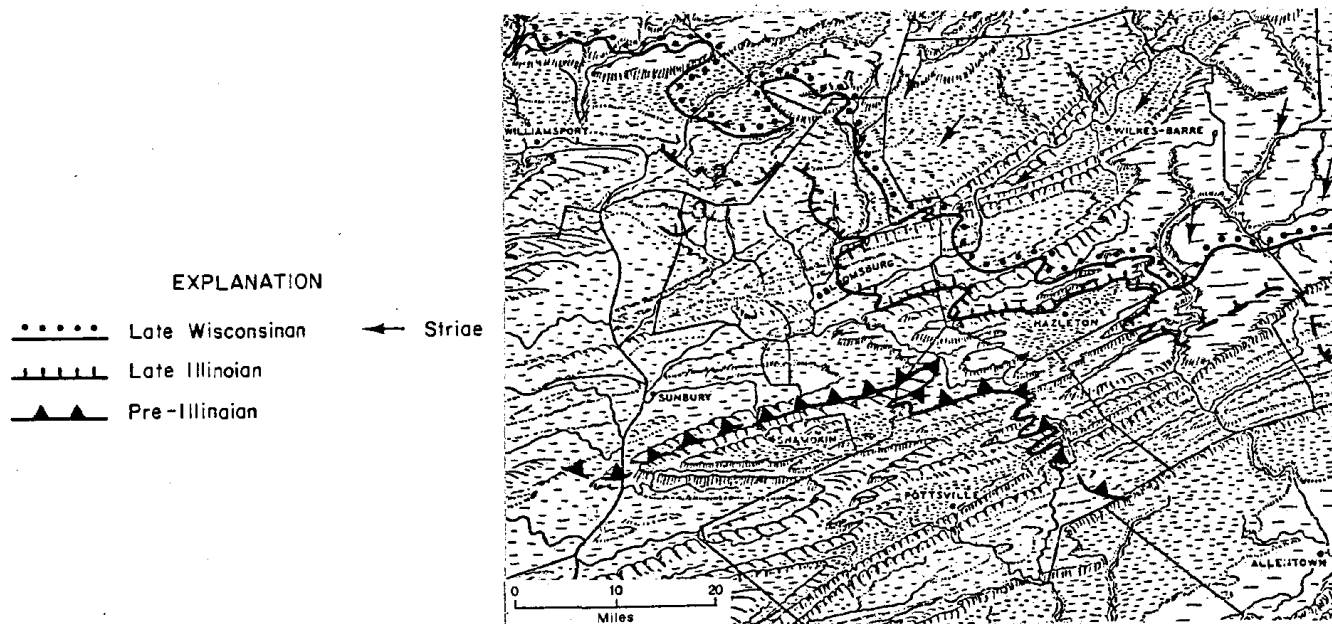


Figure 1. Location map showing late Wisconsinan margin (Crowl and Sevon, 1980), late Illinoian margin (Braun, this study), pre-Illinoian margin (Braun, this study), and representative striae within the late Wisconsinan margin. Physiographic map modified from Deasy and Griess (1963).

will require sustained effort in coming years to avoid irretrievably losing information pertaining to the Pleistocene history of northeastern Pennsylvania.

## LATE WISCONSINAN GLACIATION

### Introduction

The limit of the most recent Wisconsinan glaciation or the "Terminal Moraine" was first delineated by Lewis (1884). In recent years, the margin was retraced, assigned a late Wisconsinan age, and labeled with the time-stratigraphic term Woodfordian (Crowl and others, 1975; Sevon and others, 1975; Crowl and Sevon, 1980), a name derived from the time-stratigraphy of the Lake Michigan lobe (Willman and Frye, 1970). From bog bottom radiocarbon data, Crowl and Sevon (1980) suggested an age of about 15 Ka for ice recession from the late Wisconsinan margin. More recent radiocarbon work (Cotter, 1983; Cotter and others, 1985) shows the late Wisconsinan margin to be about 18-20 Ka in age, identical to the currently accepted age for the margin in Ohio and on Long Island, New York. Wisconsinan drift in southern New York has been termed Olean drift and used in a time-stratigraphic sense (MacClintock and Apfel, 1944) for what has been considered the oldest Wisconsinan drift in that area (Denny and Lyford, 1963; Muller, 1977). Crowl and Sevon (1980) used the term Olean drift for all drift north of the "Terminal Moraine" in northeastern Pennsylvania and assigned it a late Wisconsinan age.

### The late Wisconsinan margin: a model for older margins

The well-defined late Wisconsinan margin shows how ice interacts with the landscape of northeastern Pennsylvania and can be used as a model for the form of earlier ice margins. The overall trend of the late Wisconsinan margin across northeastern Pennsylvania is N60W (Figure 1). Hilltop striae on the Appalachian and Pocono plateaus within 30 miles (50 km) of the margin indicate a regional ice flow direction of N-S to S20W. Where ice entered the Valley and Ridge province, especially within the North Branch Susquehanna area, striae within 20 miles (30 km) of the margin show ice flow to be parallel or near parallel to bedrock strike (sample striae shown on Figure 1).

The local relief of northeastern Pennsylvania is typically about 650-1,000 feet (200-300 m) from valley floor to adjacent ridgetop. This local relief caused lobation of the ice front along the general trend of the ice margin (Figure 1). Where ice flowed around and approximately parallel to major strike ridges in the Valley and Ridge, the ridges caused a 2- to 5-mile (3-8 km) re-entrant in the ice front. Conversely, in the strike valleys the ice front projected as a lobe 2-5 miles (3-8 km) farther than where the ice front crossed the ridges. In the narrow deep valleys of the Appalachian plateau, narrow valley glacier-like ice lobes projected 5-8.5 miles (8-14 km) down valley from where the ice front crossed the ridgetops.

The types of deposits and landforms along the late Wisconsinan margin can also be used as a model for earlier glaciations. The margin generally does not display true knob and kettle (hummock and swale) morainal topography (distinct end moraine with greater than 10 feet (3 m) of local relief of Crowl and Sevon, 1980). Distinctive knob and kettle topography occurs only across the Pocono plateau and adjacent to some major strike ridges in the Valley and Ridge. Along most of the margin there is either no morainal topography at all (ground moraine

of Crowl and Sevon, 1980) or less than 10 feet (3 m) local relief morainal topography (indistinct end moraine of Crowl and Sevon, 1980). Strike valleys draining away from the late Wisconsinan margin to either side of the Pocono plateau contain prominent heads of outwash (frontal kames or kame fans). Outwash deposits at the margin approach 200 feet (60 m) in thickness and bury the preglacial landscape causing local stream derangement. Outwash valley trains slope gently away from the margin. Where valleys draining away from the ice are relatively narrow, as on the Appalachian plateau and along the Lehigh River, outwash deposits have been mostly removed by postglacial erosion.

### Summary

To summarize, the late Wisconsinan margin shows that ice leaves a relatively straight margin across northeastern Pennsylvania with lobation of generally only 2-5 miles (3-8 km) along the margin caused by local preglacial relief. Most of the late Wisconsinan margin is not marked by morainal topography. The most distinctive features along the margin are large heads of outwash in the broad strike valleys of the Valley and Ridge. It is reasonable to assume that pre-late Wisconsinan glaciers entered northeastern Pennsylvania from the same general direction and left the same basic set of landforms and deposits as the late Wisconsinan advance. The older borders should be approximately parallel to the late Wisconsinan border as is the case in northwestern Pennsylvania (Shepps and others, 1959). The earlier borders should be most clearly delineated by local stream derangements and remnants of large heads of outwash within the strike valleys of the Valley and Ridge. Verification of this hypothesis will be presented later in the section on late Illinoian glaciation.

### THE EARLY WISCONSINAN - DOES IT EXIST IN NORTHEASTERN PENNSYLVANIA?

#### The development of the concept of multiple Wisconsinan advances

Beginning in the 1950's, the existence of extensive early and mid-Wisconsinan glacial till deposits was proposed by workers in the eastern Great Lakes region, New England, and eastern Canada (Dreimanis, 1960). A similar record, based on loess stratigraphy, was proposed in the western Great Lakes region (Frye and Willman, 1960). The first deep ocean sediment records also indicated more than one cold period within the Wisconsinan (Emiliani, 1955). A review article by Goldthwait and others (1965) developed a time-distance diagram showing an early and a mid-Wisconsinan advance reaching to or beyond the late Wisconsinan limit in the eastern Great Lakes area. In northwestern Pennsylvania the inner phase of the Illinoian (Shepps and others, 1959) was reassigned to the mid-Wisconsinan (White and Totten, 1965; White, 1969; White and others, 1969) on the basis of a 40 Ka radiocarbon date on peat under what was formally named the Titusville Till. Craft (1976) questioned this age assignment due to uncertainties about the stratigraphic sequence at the site and suggested an earliest late Wisconsinan age for the Titusville Till.

Willman and Frye (1970) added till units to their early Wisconsinan (Altonian) and late Wisconsinan (Woodfordian) intervals. Dreimanis and Karrow (1972) named a series of formal time-stratigraphic divisions for the Wisconsinan in the eastern Great Lakes region. The effect was to codify a three-part Wisconsinan history with ice reaching near to or beyond the 20 Ka late Wisconsinan border at about 35 Ka (mid-Wisconsinan) and at about 55 Ka (early

Wisconsinan). Dreimanis and Goldthwait (1973) reviewed the different types of stratigraphic evidence for a three part Wisconsinan in the eastern Great Lakes. Frye and Willman (1973) reviewed stratigraphic evidence for four advances of ice (three Altonian and one Woodfordian) within the Wisconsinan of the Lake Michigan lobe. Shackleton and Opdyke's (1973) marine oxygen isotope data showed distinctly colder periods in the middle and early Wisconsinan, but these earlier cold periods were not as cold as the late Wisconsinan. Sevon and others (1975) used a relative climate change diagram that also showed that the late Wisconsinan was colder than the early Wisconsinan and then went on to propose that early Wisconsinan glaciation was more extensive than the late Wisconsinan in eastern Pennsylvania.

The growing consensus by the mid 1960's was that one or more early Wisconsinan advances reached beyond the late Wisconsinan limit. It was in this context that workers in eastern Pennsylvania in the 1960's and 1970's proposed the presence of early Wisconsinan deposits outside of the late Wisconsinan limit.

#### The development of the concept of early and/or mid-Wisconsinan advances beyond the late Wisconsinan margin in eastern Pennsylvania

The existence of an early and/or mid-Wisconsinan glacial advance beyond the late Wisconsinan margin in eastern Pennsylvania was first proposed by Connally (unpublished, 1972) and Sevon (1973, 1974). Additional areas of early Wisconsinan were described by Cowl and others (1975), Sevon and others (1975), and Cadwell (unpublished), in the region that had been mapped as Illinoian by Leverett (1934). Sevon and others (1975) assigned an early Wisconsinan age to the deposits and gave three lines of evidence to support that assignment:

1. The drift does not possess a Sangamon weathering profile typical of Illinoian drift, either in depth of oxidation or concentration of iron oxide, but is weathered to a greater depth and possesses a thicker soil profile than late Wisconsinan drift.
2. The drift has not been as extensively eroded as Illinoian drift, but has been sufficiently eroded and colluviated that almost all original constructional topography has been destroyed.
3. The areal distribution of the drift indicates deposition by an ice advance of less magnitude than that of the Illinoian, but locally of greater magnitude than that of the late Wisconsinan.

Due to uncertainty as to the precise age of the early Wisconsinan material, the time-stratigraphic term Altonian, as defined in Illinois (Willman and Frye, 1970) was used. The term covers a longer time interval of the early Wisconsinan than the more narrowly defined time-stratigraphy developed for areas adjacent to Pennsylvania by Dreimanis and Karrow (1972).

Bucek (1975), in mapping the Pleistocene geology of the Williamsport area, proposed a series of rock-stratigraphic and soil-stratigraphic units for the late Wisconsinan, the early Wisconsinan, and the Illinoian. The Altonian aged rock-stratigraphic unit was named the Warrensville Till, suggested to be 35 Ka old, and was tentatively correlated with the Titusville Till in northwestern Pennsylvania.

Marchand (Marchand and others, 1978) suggested that early Wisconsin ice tongues extended down the North Branch Susquehanna to Sunbury and down the West Branch Susquehanna to New Columbia (7 miles, or 11 km, above Lewisburg). He noted that the early Wisconsin ice carried a high percentage of red Catskill sandstone and shale fragments compared to other glaciations. Supposedly, some early Wisconsin ice-contact-stratified drift exists, but no specific sites were mentioned. Early Wisconsin outwash, loess, and colluvium have been severely eroded and altered by Woodfordian glacial and periglacial activity. No evidence of recessional or terminal moraines exists, suggesting no stillstand or readvance of the early Wisconsin ice when it was outside of the Woodfordian margin.

Crowl and Sevon (1980), in retracing the late Wisconsin margin, noted a number of small patches of early Wisconsin drift outside of the Woodfordian border. Berg and others (1980) mapped long narrow tongues of early Wisconsin ice extending down strike valleys away from the late Wisconsin margin. Detailed study of soils in till derived from redbeds at two sites previously identified as early Wisconsin (Levine, 1981; Levine and Ciolkosz, 1983) showed that several different parameters mutually suggested a stage of soil development between that of the late Wisconsin and the Illinoian.

#### Problems with the early Wisconsin as delineated in eastern Pennsylvania

The first problem with the delineation of the early Wisconsin is with the map pattern of long narrow lobes extending down strike valleys (Figure 2), a style of ice margin first used by Leverett (1934) for his Illinoian border (Figure 3). From the distribution of supposed early Wisconsin drift, long narrow lobes were mapped extending as far as 18.5 miles (30 km) down strike valleys to either side of the Pocono plateau (Crowl and others, 1975; Sevon and others, 1975). A series of narrow lobes extending down some but not all strike valleys were mapped across the remainder of the Valley and Ridge by Sevon (Figure 2; Berg and others, 1980). This pattern of long narrow lobes differs markedly from the 2-5 miles (3-8 km) or so lobation of the late Wisconsin (Woodfordian) ice described earlier. For the early Wisconsin ice not to overtop adjacent strike ridges, the ice can only thicken less than 650-825 feet (200-250 m) in the 18.5 miles (30 km) up-ice from the margin. This is a far smaller thickening up-ice than suggested by ice surface gradients measured from the late Wisconsin lobes (Crowl and Sevon, 1980). It is also far smaller an ice surface gradient than is observed on present day ice sheets (Nye, 1952a; Weertman, 1961, 1973; Paterson, 1969) and would require the ice to be more fluid than is presently observed or considered theoretically possible by glaciologists (Nye, 1952b, 1957; Paterson, 1969).

A further problem in the mapped distribution of early Wisconsin deposits occurs in the strike valley to the south of the Pocono plateau and along the North Branch Susquehanna. There, where ice flow is parallel to strike, the early Wisconsin material only occupies the north side of each valley (Figure 3). That side is underlain by the Catskill redbeds and is a rolling upland that is higher than the adjacent shale and carbonate lowland. From the mapped distribution of deposits, the ice only flowed in a narrow tongue along the higher Catskill belt and not along the adjacent lower shale and carbonate belt, a physically impossible situation (Figure 3). Alternatively, ice occupied the whole strike valley but only left deposits on the Catskill and did not erode the more weathered Illinoian deposits that are common in the adjacent shale and carbonate lowland, another highly improbable situation.



Figure 2. Map showing long narrow tongues of early Wisconsinan projecting down strike valleys from the late Wisconsinan margin (modified from Berg and others, 1980). The map also shows the maximum extent of pre-Illinoian ice from Leverett (1934) and Braun's current study. Williams' (1917) pre-Illinoian margin is essentially the same as the western part of Leverett's pre-Illinoian margin and Leverett's limit of questionable drift in the eastern part of the region.

Another problem with the mapped pattern of the early Wisconsinan deposits is that there are often areas of Illinoian deposits 325 feet+ (100+ m) across scattered among the areas of early Wisconsinan deposits (Figure 4). In redbed areas, Illinoian patches are scarce within the discontinuous early Wisconsinan veneer, while in non-redbed areas Illinoian patches are common and the early Wisconsinan patches are scarce. This map pattern implies that early Wisconsinan ice did not effectively scour the preexisting Illinoian deposits and often did not deposit any material on top of the Illinoian deposits. In fact, there is no published description of a site where early Wisconsinan material overlies Illinoian material, even though Illinoian material often lies side by side with early Wisconsinan material at the ground surface.

This patchwork quilt of younger and older deposits is not what is observed within the late Wisconsinan margin. There are no known patches of early Wisconsinan or Illinoian deposits at the ground surface within the area of late Wisconsinan ice cover in northeastern Pennsylvania. The late Wisconsinan ice effectively removed all older material right up to the very edge of its advance. This suggests that either the early Wisconsinan ice was uniquely "light footed" (non-erosive) and selective in its deposition or that the material mapped as early Wisconsinan is really Illinoian. If there were no early Wisconsinan patches, what would be left is a patchwork quilt of different lithofacies of Illinoian age.

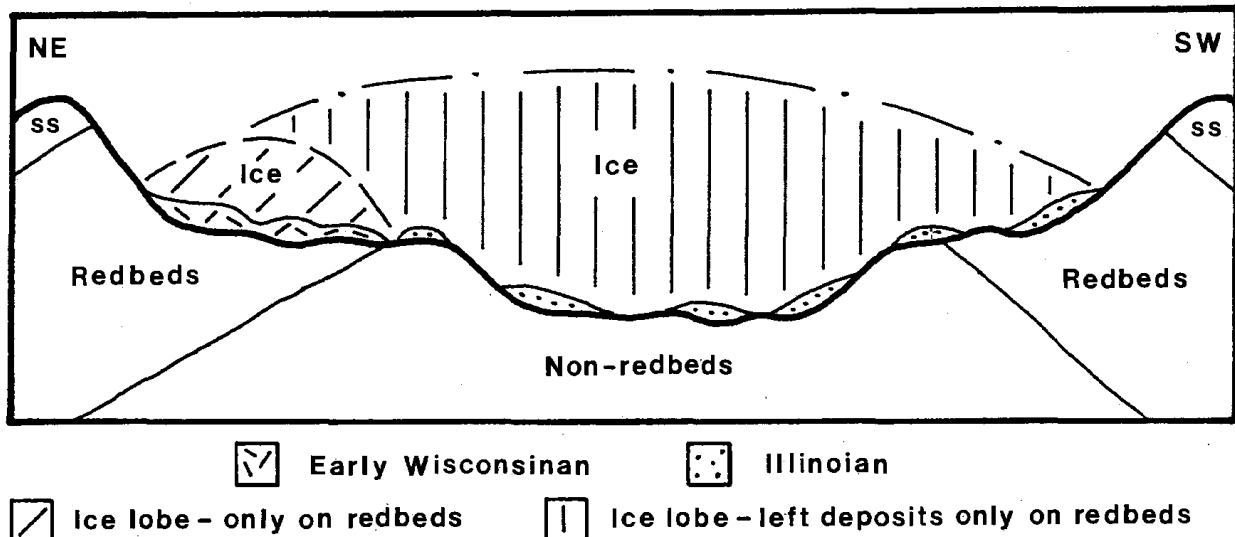


Figure 3. Diagram showing the distribution of different aged glacial deposits within a strike valley. The early Wisconsinan deposits are primarily on redbeds, while the Illinoian deposits are primarily on non-redbeds. - - - Early Wisconsinan ice lobe just covering deposits of that age; - - - Early Wisconsinan ice lobe covering the whole strike valley but leaving deposits only on the redbeds.

The second problem with the way the early Wisconsinan has been delineated is that nearly all areas mapped as early Wisconsinan-aged drift are on redbeds or in material dominated by redbed fragments from the Catskill or Mauch Chunk Formations. In the strike valleys to either side of the Poconos and in the North Branch Susquehanna lowland, 95+ percent of the mapped early Wisconsinan drift patches are directly on redbeds (Crowl and others, 1975; Sevon and others, 1975; Berg, 1976; Inners, 1978; Crowl and Sevon, 1980; Inners, 1981). In the West Branch Susquehanna lowland between Bald Eagle Mountain and the Appalachian Plateau, 90+ percent of the mapped early Wisconsinan drift patches are on redbeds east of Williamsport (Bucek, 1975; Wells and Bucek, 1980; Crowl and Sevon, 1980) and 80+ percent of the early Wisconsinan drift is on redbeds west of Williamsport (Faill and others, 1977). Most of the areas mapped as early Wisconsinan outside of the redbed areas are still dominated by redbed fragments in the drift.

Even the continuity of early Wisconsinan deposits differs between the red and non-redbed areas. Within the redbed areas, early Wisconsinan drift is mapped as a discontinuous veneer mantling at least 25 percent to as much as 75 percent of the landscape. Adjacent to the redbed areas, early Wisconsinan drift is mapped as isolated patches mantling less than 5 percent of the landscape. Overall, the map pattern shows that material identified as early Wisconsinan is nearly always redbed material and suggests that what is being mapped is a lithofacies variation rather than an age variation.

Furthermore, the soils considered thus far as characteristic of early Wisconsinan weathering are derived from redbed material (Crowl and others, 1975; Sevon and others, 1975; Bucek, 1975; Marchand and others, 1978; Levine, 1981; Levine and Ciolkosz, 1983). The early Wisconsinan-aged Warrensville Till type locality is on the Catskill redbeds (Bucek, 1975). The proposed soil-



Figure 4. Map of the patch work quilt of early Wisconsin and Illinoian deposits. Early Wisconsin deposits predominate on redbed areas, while Illinoian deposits predominate on non-redbed areas. (Simplified from Wells and Bucek, 1980).

stratigraphic units developed in the till are the Leck Kill, Meckesville, and Albrights series, all dominated by redbed parent material (Bucek, 1975). Marchand suggested that early Wisconsinan ice carried a high percentage of red Catskill fragments and that is reflected in the soils developed from early Wisconsinan till (Marchand and others, 1978). In a comparison of soil development in till of various ages, the two early Wisconsinan-aged soils are redbed derived (Leck Kill series). The five Illinoian-aged soils had no specified parent material (Levine, 1981; Levine and Ciolkosz, 1983), but are located on non-red bedrock. Using clay accumulation data, Levine and Ciolkosz (1983) developed a regression equation to predict the absolute age of early Wisconsinan and Illinoian soils. While the 41,000 BP predicted age for the early Wisconsinan soils was reasonable, again the four early Wisconsinan soils used were redbed derived. The three Illinoian soils used had no specified parent material but are located on non-red bedrock. Thus far, there has been no published characterization of a non-redbed, non-truncated, early Wisconsinan-aged soil in eastern Pennsylvania.

This consistent association of supposed early Wisconsinan age with redbed material suggests an alternative hypothesis: that what is being differentiated is parent material rather than time. The intermediate degree of weathering of the "early Wisconsinan" material could be caused by a slower production of oxides and fine clay in the hematitic redbed parent material as compared to a more rapid production of oxides and fine clay in the non-redbed, non-hematitic parent material. The bright orange-red color (2.5-7.5 YR) characteristic of Illinoian aged material may be a product of very fine iron oxide particles (Ciolkosz, personal communication). If such particles are produced more slowly in the redbeds, then the material would look less "bright" and therefore younger. That this is the case is suggested by the bright orange-red weathering of non-red clasts within redbed dominated till exposed in strip mine exposures in the Anthracite region.

The contention that redbed till retards apparent weathering intensity is further supported by reexamination of a large kame delta near Weatherly. The deposit was originally designated as Illinoian in age (Leverett, 1934) and more recently designated as early Wisconsinan in age (Crowl and others, 1975; Sevon and others, 1975). Exposures in the eastern end of the delta, proximal to the ice, show sand and gravel capped by redbed diamicton (lodgement and/or flow till) that exhibits weathering intermediate between that of early Wisconsinan and Illinoian tills. Soils mapping (USDA), verified by field checking, shows the central and least eroded part of the kame delta has a deeply weathered Allenwood soil surrounded by a periphery of less weathered Tunkhannock soil. On the south and west sides of the deposit, erosion appears to have truncated the weathering profile, leaving the less weathered material at the surface. On the east side of the deposit, it is the redbed diamicton cover that has produced a less weathered appearance than in the center of the deposit. That the same sand and gravel deposit exhibits deep weathering where exposed at the ground surface and markedly less deep weathering where covered by a veneer of redbed till, implies that the till is retarding the relative degree of weathering development.

To summarize, there are three basic problems with the early Wisconsinan as delineated in eastern Pennsylvania. The first problem is that the map pattern of long narrow extremely low gradient ice tongues in the strike valleys is physically impossible. The second problem is that the patchwork quilt map pattern

of early Wisconsinan and Illinoian deposits requires the early Wisconsinan ice to be uniquely selective in its erosion and deposition. A more reasonable explanation is that the patchwork quilt represents different lithofacies of Illinoian deposits. The third problem is that the supposed early Wisconsinan intermediate degree of weathering is consistently observed on redbed material and not on non-redbed material. This suggests that what is being differentiated is parent material rather than time. The redbed material may be retarding relative weathering development and be Illinoian rather than early Wisconsinan in age.

#### Evidence outside of Pennsylvania for limited extent of early Wisconsinan ice

Evidence is mounting from areas outside of Pennsylvania that early and mid-Wisconsinan ice had limited extent and did not reach south of the Great Lakes. The sedimentology and paleontology of the classic Scarborough Bluffs section near Toronto, Canada indicates no ice advanced south of Lake Ontario until the late Wisconsinan (Eyles and Eyles 1983; Eyles and Westgate, 1987; Westgate and others, 1987). Many sites in Illinois and Ohio with paleosols on supposed mid or early Wisconsinan deposits have recently been reclassified as Illinoian (Kempton, 1985; Totten, 1987). At diverse sites in the western United States, extending from the Yellowstone region to the Sierra Nevada, recent work indicates little ice extent in the early to mid-Wisconsinan (Atwater and others 1986; Baker 1986, Dorn and others, 1987; McCoy 1987; Oviatt and others, 1987). High resolution oxygen isotope records from deep sea cores show a continuous trend in the oscillatory record from minimum ice volume in the early Wisconsinan to maximum ice volume in the late Wisconsinan (Figure 5; Shackleton and others, 1983; Pisias and others, 1984; Martinson and others, 1987). Calculation of ice volume for specific parts of the Wisconsinan record show that early Wisconsinan ice volume was 34 percent less than that of the late Wisconsinan (Shackleton, 1987). Sea level changes derived from the oxygen isotope records (Shackleton, 1987) and raised coral reef studies (Figure 5; Bloom and others, 1974) show sea level lowering to be greatest in the late Wisconsinan. These studies, taken together, strongly support the contention that glaciers were most extensive in the late Wisconsinan and, by inference, support the view that early or mid-Wisconsinan ice did not extend south of the late Wisconsinan terminus in Pennsylvania.

### ILLINOIAN

#### Previous work on the Illinoian drift of eastern Pennsylvania

Older glacial deposits south of the late Wisconsinan margin (Terminal Moraine of Lewis, 1884) were recognized as early as 1880 (Cook) but were often thought to be related to a farther temporary advance of the Wisconsinan glaciation (Wright, 1892; Williams, 1895, 1917). Leverett (1934) correlated some of the older glacial deposits closest to the "Terminal Moraine" with the Illinoian of Illinois on the basis that they were distinctly more weathered and eroded than the Wisconsinan material but less weathered and eroded than glacial material farther to the south of the Wisconsinan border. Leverett mapped a series of long lobes of Illinoian ice extending down various strike valleys (Figure 6). Some lobes are so long and narrow as to require impossibly low ice gradients and would be today considered physically impossible by glaciologists (Nye, 1952a; Weertman, 1961, 1973; Paterson, 1969).

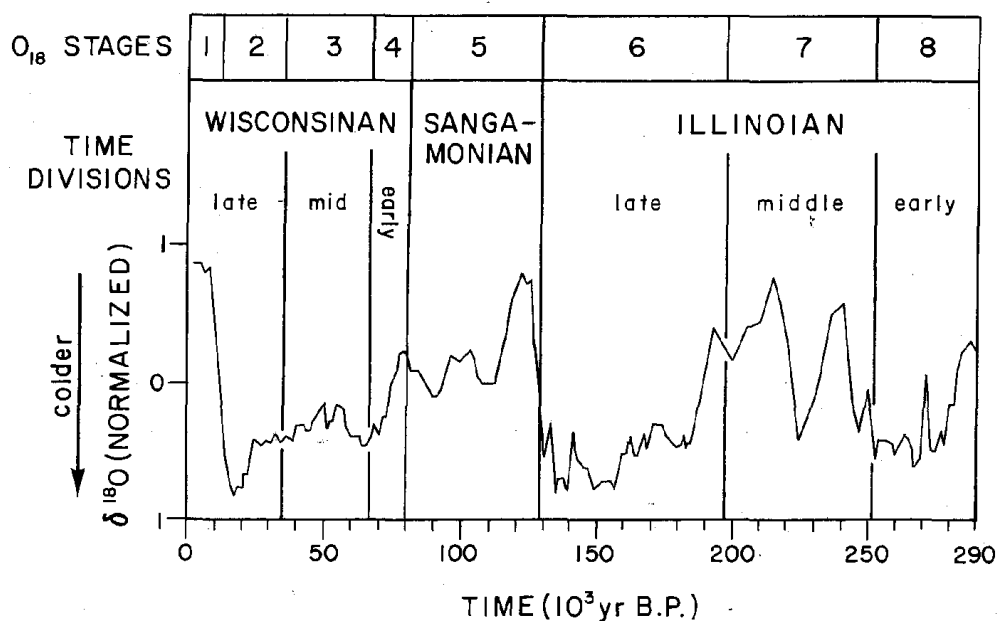
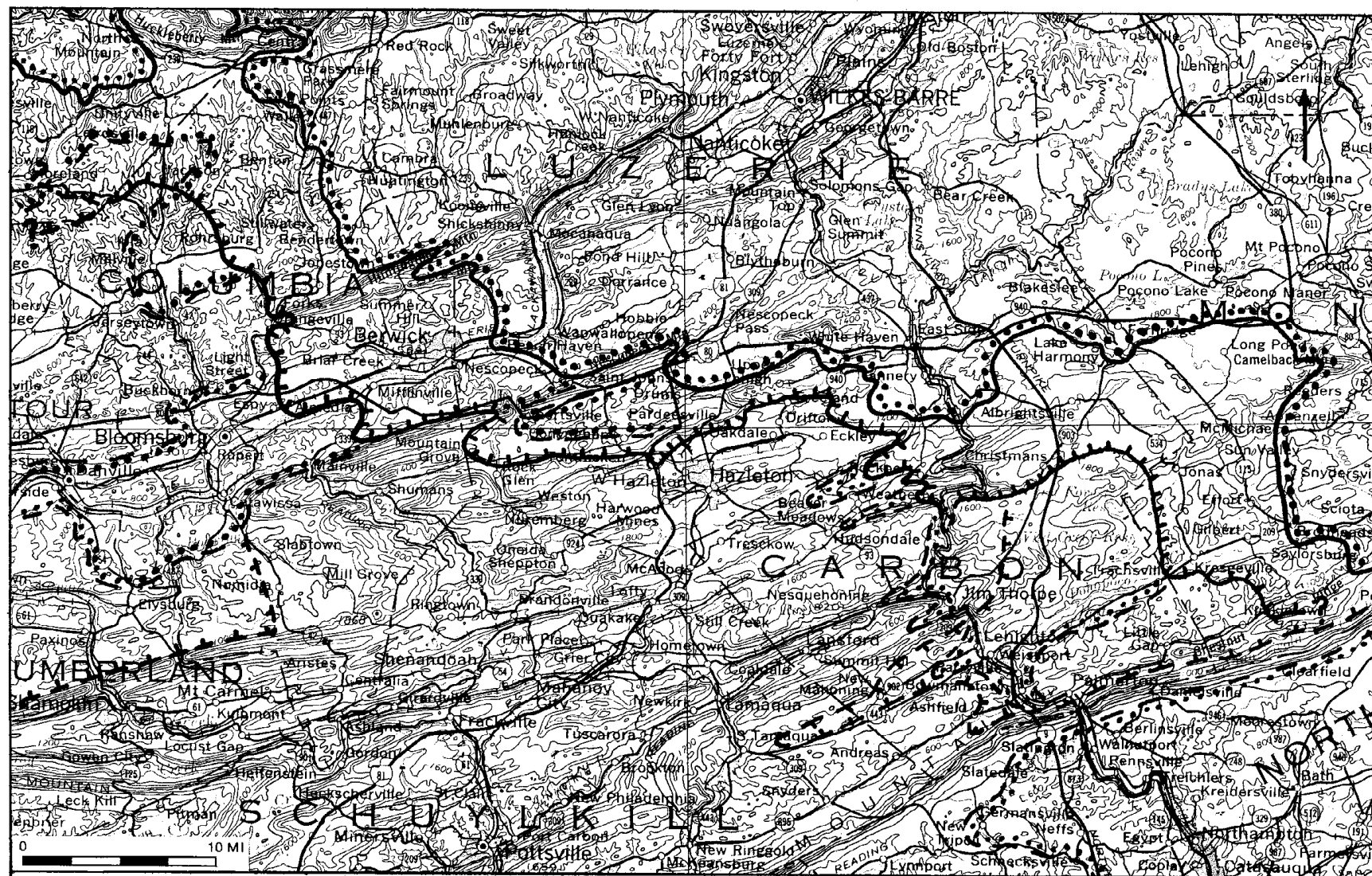


Figure 5. Paleotemperature curve from the marine oxygen isotope record for the Wisconsinan and Illinoian stages. The late Wisconsinan is distinctly colder than the early and mid Wisconsinan. A similar pattern is shown for the middle to late Illinoian. (Modified from Pisias and others, 1984, Martinson and others, 1987, and Richmond and Fullerton, 1986).

Sevon and others (1975) emphasized that while the Illinoian of Illinois could not be directly traced into Pennsylvania, the Illinoian age assignment was reasonable from the degree of weathering and erosion of the deposits. A series of long tongues of ice, even longer than the early Wisconsinan ice tongues discussed before, have been mapped projecting down the strike valleys of the region (Figure 6; Sevon and others, 1975; Berg and others, 1980). Again, many of the tongues require impossibly low ice gradients and cannot mark an actual ice margin. The longest tongues project into the Juniata River valley and were placed on the map by Sevon (personal communication) to accommodate diamicton deposits at the ends of the tongues thought at the time to be glacial till. Kaktins (1986) demonstrated that the diamicton in question is not glacial in origin. Detailed reconnaissance by Crowl (unpublished) demonstrated that the valleys covered by the longest tongues were never glaciated.

For the Illinoian-aged deposits in the Williamsport area, a formal rock-stratigraphic name was proposed, the Muncy drift, and formal soil-stratigraphic units were proposed, the Allenwood and Washington soil series (Bucek, 1975; Wells and Bucek, 1980). Marchand (Marchand and others, 1978) proposed that there are two different Illinoian-aged drifts in the region around the confluence of the North and West Branches of the Susquehanna. The drifts were differentiated on the basis of the relative degree of weathering and soil development. The older Laurelton drift has been correlated with the 260 Ka marine isotope stage 8 (Harden and Taylor, 1983), placing it in the early Illinoian of Richmond and Fullerton (1986). The younger White Deer drift would then be placed in the 140 Ka late Illinoian of Richmond and Fullerton (1986). Carter (1979) further examined two of Marchand's sites and agreed that there was a distinct difference in the degree of soil development and the age of the



## EXPLANATION

 Late Wisconsinan  
 (Crowl and Sevon, 1980)

 Late Illinoian  
 (Braun)

## ILLINOIAN

 (Leverett, 1934)  
 (Sevon, 1980)

Laurelton and White Deer drifts. Soil development on the Illinoian drift was further examined by Levine (1981) and Levine and Ciolkosz (1983) and absolute age predictions were given that were too young, 86-91 Ka, probably because of prior weathering of the parent material.

#### Delineation of a late Illinoian Margin

Work by my students and I since 1982 has delineated a 52-mile- (85-km-) long late Illinoian ice margin that runs 2-11 miles (3-18 km) southwest of and sub-parallel to the late Wisconsinan ice margin (Figure 6). The margin, herein called the Bloomsburg Margin due to its prominent expression there, has been traced southeast across the Anthracite region to the Pocono plateau and northwest into the Muncy Hills, east of Muncy. The Bloomsburg Margin is essentially identical to the late Wisconsinan margin in regard to its overall trend, its degree of lobation, its thick frontal kame deposits in valleys, its derangement of local preglacial stream patterns, and its relative lack of expression in upland areas. The kame deposits often are 100 feet (30 m) and at times 200 feet (60 m) thick and are as massive or more massive than the late Wisconsinan kames. The Bloomsburg Margin is the only place that the North Branch Susquehanna has been forced from its preglacial channel by blockage from glacial deposits (Figure 6). This margin differs from the late Wisconsinan margin in that it is deeply weathered and eroded though in places constructional topography remains.

The sand and gravel is so deeply weathered that in the upper 7-16 feet (2-5 m) of the deposit, stratification has been destroyed and the material is texturally a diamicton (Braun and Kaktins, 1986). Under the diamicton a 3-7 foot- (1-2 m-) transition zone with partially preserved bedding occurs and then bright red oxidized stratified sand and gravel continues for another 16-33 feet (5-10 m) below that. Marchand (Marchand and others, 1978) thought that the weathering in the sand and gravel at Bloomsburg was equivalent to either his pre-Illinoian Penny Hill or early Illinoian Laurelton drift.

The Bloomsburg Margin is considered late Illinoian in age primarily because at Bloomsburg and several other sites the gently sloping top surface of the frontal kame (head of outwash) retains its original constructional form. That form would have been lost and other younger glacial drift would have been deposited on top of the surface had it been overridden by another glaciation. The top surface of the kames is in places capped by late Wisconsinan loess or colluvium showing that it had experienced little erosion during the late Wisconsinan. That the Bloomsburg Margin is unaffected by later glacial activity indicates that it was formed by the last glaciation to reach beyond the late Wisconsinan border. This does not necessarily make the margin late Illinoian in age but the older a deposit is, the less likely it is for any original constructional form to be retained as progressive fluvial erosion dissects the landscape.

The great depth of weathering of the Bloomsburg Margin would tend to suggest the possibility of an older than late Illinoian age. The exceptional depth of weathering though may be related to the unique character of the deposit

- ◀ Figure 6. Map showing the Illinoian margin of Leverett (1934), the Illinoian margin of Sevon and others (1975), and Berg and others (1980), and the late Illinoian margin of this study. The late Wisconsinan margin of Crowl and Sevon (1980) is shown for comparison.

rather than an exceptional age of weathering. The kames are exceptionally well drained sand and gravel deposits, often occupying hilltop or drainage divide landscape positions, and especially at Bloomsburg, contain an abundance of readily weatherable gray sandstone and shale clasts. This would tend to produce deeper weathering more rapidly than on nearby till areas that are less well drained.

If the degree of weathering can be demonstrated to be greater than late Illinoian, either early Illinoian or pre-Illinoian, then there would be no evidence for a late Illinoian or even any Illinoian advance into the region.

#### Present conception of the age, number, and extent of Illinoian glaciations

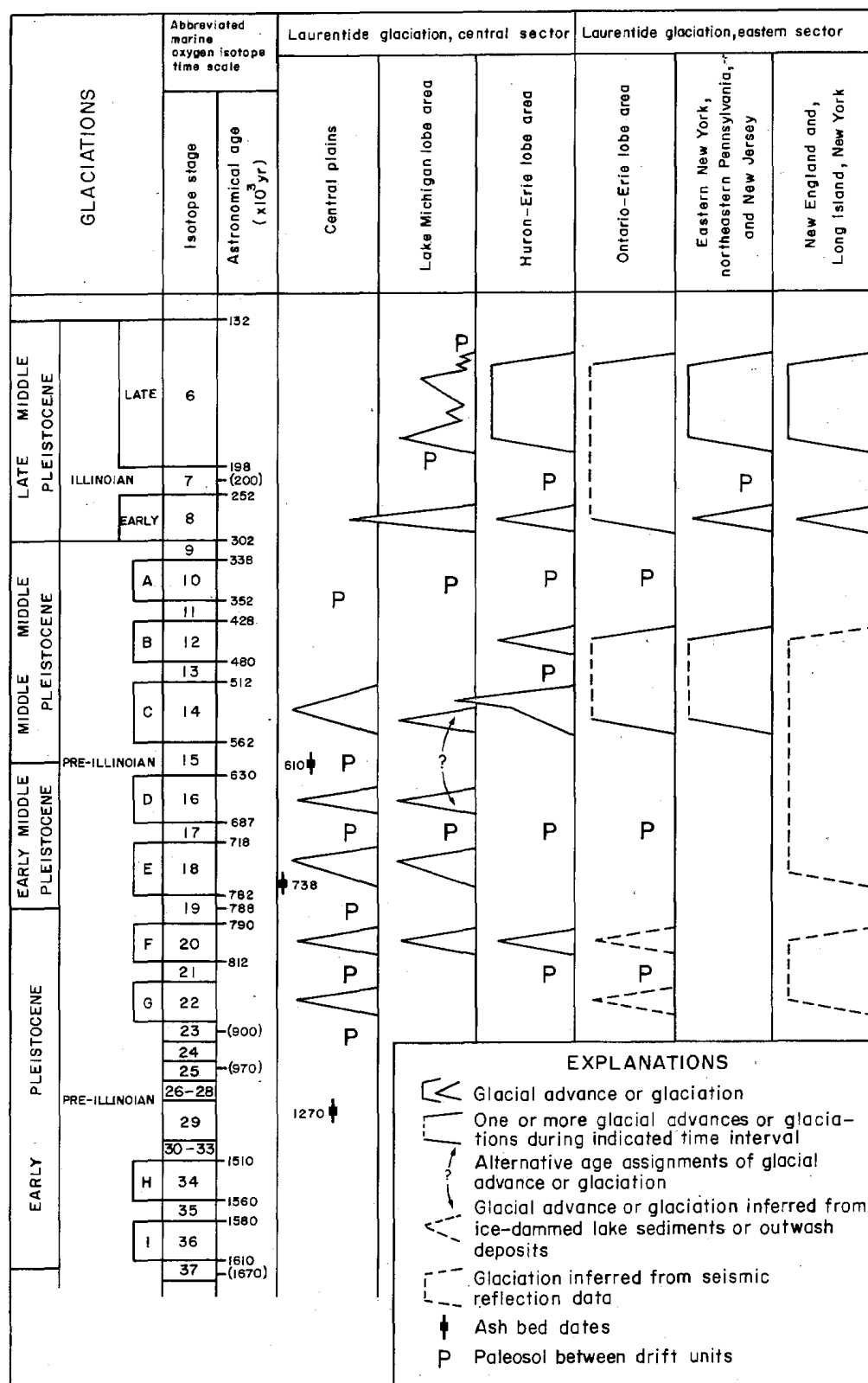
Present thinking on the age and number of Illinoian glaciations is presented in the final report of the International Geological Correlation Programme, Glaciations in the Northern Hemisphere (Sibrava and others, eds., 1986). The Illinoian is subdivided into the late Illinoian (Figure 5; Table 2), 132-198 Ka with a glacial maximum at about 140 Ka, and the early Illinoian, 198-302 Ka with a glacial maximum between 250-270 Ka (Richmond and Fullerton, 1986; Martinson and others, 1987). These age brackets are from correlation of U.S. glacial advances with the marine oxygen isotope stages and are not from actual dating of glacial deposits though a growing number of dated glacial deposits do fall near the appropriate glacial maximums (Richmond and Fullerton, 1986). The Illinoian marine oxygen isotope record shows, as it did for the Wisconsinan, an oscillatory trend in the increase in ice volume as a glacial maximum is approached (Figure 5; Shackleton and Opdyke, 1973; Pisias and others, 1984; Martinson and others, 1987). The Illinoian has been defined to contain two such glacial maxima rather than one as in the Wisconsinan. Calculations of relative ice volume from the oxygen isotope data suggest that late Illinoian ice volume was 5 percent greater than the late Wisconsinan (Woodfordian) and that the early Illinoian ice volume was 20 percent less than the late Wisconsinan (Shackleton, 1987). Only the late Illinoian, at about 140 Ka, would have been of sufficient volume to extend a relatively short distance beyond the late Wisconsinan border.

#### PRE-ILLINOIAN DEPOSITS

#### Previous work on the maximum extent and age of ice south of the late Wisconsinan margin

In the 1880's several workers identified glacial material well southwest of the Wisconsinan margin (extramorainic drift) but not until Williams (1895, 1917) did anyone map an ice margin across the whole region (Figure 2). Williams (1893) thought the ice that formed his margin was similar in age to the ice that formed the Wisconsinan margin. He used the term Kansan for his margin but maintained there was little time difference between the Kansan and Wisconsinan (Williams, 1898). Leverett (1934) revised Williams' work and mapped the glacial deposits outside the Wisconsinan margin throughout Pennsylvania. Leverett recognized older, more weathered and eroded glacial material southwest of his Illinoian border (Figure 2). He thought the scanty deposits of older drift were from a single pre-Illinoian glaciation. Since there was no superposition of two older drifts as there was in the Central Plains, he could find no way to determine whether the pre-Illinoian drift was Kansan or Nebraskan. He noted that the older drift had been named Jerseyan in New Jersey and used that name as an

Table 2. Illinoian and older Pleistocene time divisions, marine isotope stages, and Central Plains to New England glacial advance record. (Modified from Richmond and Fullerton, 1986).



alternative term for the pre-Illinoian drift in eastern Pennsylvania. Leverett also recognized "areas of questionable location" of pre-Illinoian deposits farther to the south and east of his pre-Illinoian boundary (Figure 2).

Sevon and others (1975) observed no evidence for pre-Illinoian glaciation in northeastern Pennsylvania, but also did not reexamine Leverett's pre-Illinoian sites. They thought that strip mining had either destroyed or made difficult to interpret possible pre-Illinoian deposits in the Anthracite region and did not examine that area. In the Susquehanna lowlands, the Penny Hill drift, first described by Peltier (1949), was thought to be pre-Illinoian in age by Marchand (Marchand and others, 1978). The Penny Hill drift has been correlated with the 330 Ka marine oxygen isotope stage 10 (Harden and Taylor, 1983), placing it in the pre-Illinoian stage of Richmond and Fullerton (1986).

#### Present delineation of the maximum extent of pre-Illinoian ice

Due solely to strip mine exposures, a pre-Illinoian ice margin can be traced for 20 miles (30 km) across the Anthracite region about 12-20 miles (20-30 km) southwest of and sub-parallel to the late Wisconsinan margin. Delineation of the extent of pre-Illinoian ice was essentially a process of walking out stripping exposures until there was no more evidence of glacial deposits. Once the glacial deposits disappeared, the strippings were examined for several miles farther to check for isolated patches of glacial material. Within the pre-Illinoian margin glacial deposits were typically exposed every few 100 yards (100 m) along strike in the strippings. In the Hazleton area continuous exposures of glacial deposits 30-100 feet (10-30 m) high and as long as 1.8 mile (3 km) exist in abandoned strip pits.

Near the pre-Illinoian limit, all sites mentioned by Williams (1917) and Leverett (1934) were reexamined between Shamokin and Tamaqua. Study of Williams' work showed that the effect of periglacial activity in eroding and transporting material down slope was unknown. Reexamination of many of his sites showed that what he had called "Pottsville conglomerate drift" is actually late-Wisconsinan colluvium. Many sites where he observed anthracite beds being overturned and moved southward are actually classic examples of creep and relict solifluction. The freshness of the coal under the "Pottsville drift" is the primary reason he thought the glaciation of the area was similar in age to the Wisconsinan glaciation to the north. The truncation of the coal is Wisconsinan in age but from periglacial rather than glacial activity. While Leverett (1934) better recognized the influence of slope processes, some of his sites are also colluvium where a mixture of both Pottsville and Llewellyn fragments gives the colluvium a till-like diamicton texture. Between the pre-Illinoian and late Illinoian margins now delineated, the remainder of Williams' (1917) and Leverett's (1934) sites and strip mines will be examined during the next few years.

The pre-Illinoian deposits within the Anthracite fields are readily separable from other non-glacial surficial deposits. The pre-Illinoian till is consistently dominated by redbed fragments and has a "redbed-red" matrix, material brought in from the Mauch Chunk lowlands that lie to the north and east of the Anthracite fields. At three sites, well-developed striated pavement has been observed under the redbed till. Colluvium in the Anthracite region is dominated by Pottsville conglomerate fragments from the adjacent strike ridges with a secondary component of reddish weathered, originally organic-rich, sandstone and shale fragments from the Llewellyn Formation.

Local proglacial lakes were impounded along the pre-Illinoian margin in strike valleys adjacent to the Anthracite fields near Ringtown and near Barnesville. Ice receding from the pre-Illinoian limit impounded lakes within Anthracite basins near Nuremburg, Beaver Meadows, Eckley, Freeland, and probably other yet to be discovered sites where streams drain east or northeast. In those areas, in addition to till, sand and gravel, sand, and clay deposits as thick as 100 feet (30 m) overlie the coal seams.

Exposures with multiple till units occur in strip mines near Freeland but appear to be temporary oscillations of a single glacial advance because there is no paleosol development between the tills. There does appear to be paleosol development in colluvium overlying pre-Illinoian till in strip mines to the east of Nesquehoning.

The margin is considered to be pre-Illinoian in age because it lies beyond the late Illinoian margin. A pre-Illinoian age is also suggested by the degree of landscape modification that has totally erased surface evidence of the glaciation. Only in strike valley floor strip mines are glacial deposits exposed under as much as 65 feet (20 m) of colluvium. Intervening strike ridges show extensive areas of tors (Inners, 1988) and no evidence of glaciation.

As yet, no evidence for multiple pre-Illinoian advances has been observed in the Anthracite region. Marchand (Marchand and others, 1978) observed apparent superposition of two pre-Wisconsinan glacial drifts but interpreted both to be Illinoian in age. It is likely that there were multiple pre-Illinoian advances into northeastern Pennsylvania because such advances are recorded elsewhere along the periphery of the Laurentide ice sheet (Table 2).

#### Present conception of pre-Illinoian glaciations

Glaciation began in the Northern Hemisphere, as indicated by the marine oxygen isotope record, at about 2.5 Ma and reached its first maximum at about 2.4 Ma (Shackleton and others, 1984). In the Central Plains, the Laurentide continental glacier first reached south of the late Wisconsinan margin at about 2.14 Ma (underlies the 2.01 Ma Pearlette B volcanic ash bed, Hallberg, 1986) and correlates with a marine oxygen isotope maxima of the same age (Shackleton and others, 1984). Ongoing studies in the Central Plains (Hallberg, 1986) show that deposits referred to as Kansan and Nebraskan have been miscorrelated and are the result of as many as seven pre-Illinoian glaciations (Figure 7; Johnson, 1986). The result is that the terms Nebraskan, Aftonian, Kansan, and Yarmouth have been abandoned (Hallberg, 1986; Johnson, 1986; Richmond and Fullerton, 1986).

The proposed subdivision of the pre-Illinoian (Richmond and Fullerton, 1986) is given in Table 2. The nine glaciations, A to I, noted within the pre-Illinoian are primarily recorded where alpine glacial deposits interstratify with volcanics in western North America (Hamilton, 1986; Fullerton, 1986a; Richmond, 1986a, 1986b). In the Central Plains during the pre-Illinoian five advances of the main Laurentide glacier beyond the late Wisconsinan margin are recorded and are separable on the basis of buried paleosols and three different datable ash beds (Hallberg, 1986). Ice volume calculations from the marine oxygen isotope record (Figure 7) through stage 19 at 782 Ka indicate that ice volume was about 15 percent greater in stage 12, 428-480 Ka, and stage 16, 630-687 Ka. This correlates with pre-Illinoian glaciation B and D recorded in the alpine record and in Laurentide glacier records in the Indiana-Ohio area (Fullerton, 1986b) but glaciation B is not yet recorded in the Central Plains

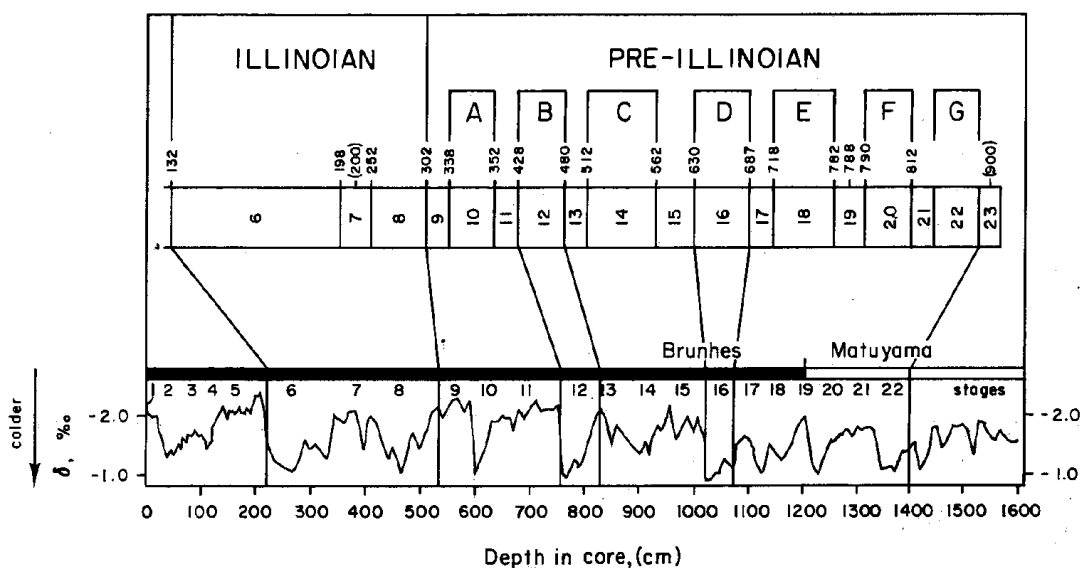


Figure 7. Paleotemperature curve is shown for the first 22 stages of the marine oxygen isotope record for the last 900 Ka, from the Wisconsinan through the seventh pre-Illinoian glaciation. Lettered periods are times of glacial advance. (Modified from Shackleton and Opdyke, 1973, and Richmond and Fullerton, 1986).

(Hallberg, 1986). The possibility exists that Central Plains glaciation C is actually B.

It is likely that the pre-Illinoian deposits south of the late-Wisconsinan and late Illinoian margins in eastern Pennsylvania are B and/or D glaciations. The projected ice volumes, 15 percent greater than late Wisconsinan and 10 percent greater than late Illinoian would place the pre-Illinoian margin about twice as far from the late Illinoian margin as the late Illinoian is from the late Wisconsinan and that is what is observed. Also the B and D glaciations are relatively young pre-Illinoian advances, less than 700 Ka, and would be more likely to be preserved in the eroding moderate relief Valley and Ridge than older advances. Paleomagnetic sampling at two sites gives a weak suggestion that the glacial sediments retain a normal polarity and thereby are younger than 788 Ka. The magnetic declination of all samples at the two sites was in the two northern quadrants but the variance was as great as 150 degrees.

#### SUMMARY

New data from on going field work in the Anthracite region and adjacent parts of the Valley and Ridge province in northeastern Pennsylvania dictates revision of the currently accepted sequence and extent of glaciations.

The sequence developed from work prior to 1980 is:

1. late Wisconsinan - nearly straight N60W margin.
2. early Wisconsinan - narrow tongues project 12-20 miles (20-30 km) from late Wisconsinan border. Early Wisconsinan deposits have a supposedly intermediate degree of weathering that permits their separation from late Wisconsinan and Illinoian deposits.

3. Illinoian - narrow tongues project 25-55 miles (40-90 km) down strike valleys to either side but not within the Anthracite region.
4. No positive evidence for pre-Illinoian.

The early Wisconsin advance is now deleted because:

1. No rational ice margin can be constructed from the distribution of supposed early Wisconsin deposits.
2. Areas of deeply weathered Illinoian material are often interspersed with areas of supposed early Wisconsin material.
3. Intermediate weathering is almost always on redbeds, suggesting parent material determines the degree of weathering rather than time.
4. Evidence from areas outside of Pennsylvania indicates that early Wisconsin ice was of limited extent and did not extend south of the late Wisconsin border.
5. The marine oxygen isotope record indicates that early Wisconsin ice volume was 34 percent less than late Wisconsin ice volume.

A 52-mile- (85-km) long late Illinoian ice margin, here named the Bloomsburg Margin, has been delineated crossing the Anthracite region 2-11 miles (3-18 km) southwest of and sub-parallel to the late Wisconsin margin. The Bloomsburg Margin is marked by thick kame deposits that cause local stream derangements within each strike valley, a situation analogous to that of the nearby late Wisconsin margin. The margin is unaffected by later glacial activity, indicating that it was formed by the last glaciation to reach beyond the late Wisconsin border. The marine oxygen isotope record suggests that, during the Illinoian, only the late Illinoian ice at 140 Ka was of sufficient volume to extend a short distance beyond the late Wisconsin margin. Much of the area previously mapped by Leverett (1934) and Marchand (Marchand and others, 1978) as having been covered by Illinoian ice is beyond the Bloomsburg margin and should be assigned a pre-Illinoian age.

Due solely to strip mine exposures, a pre-Illinoian ice margin can be traced for 20 miles (30 km) across the Anthracite region about 12-20 miles (20-30 km) southwest of and sub-parallel to the late Wisconsin margin. The margin marks the maximum extent of observable glacial deposits. The margin is considered to be pre-Illinoian in age because it is beyond the late Illinoian margin and because erosion has totally erased surface evidence of the glaciation. Only in strike valley floor strip mines are glacial deposits exposed under as much of 65 feet (20 m) of colluvium. The marine oxygen isotope record suggests that pre-Illinoian ice was of sufficient volume to reach beyond the late-Illinoian margin at about 440 Ka and 640 Ka.

Because of complexities in the distribution of deposits and questions about their age, the further development of a detailed rock-stratigraphic and soil-stratigraphic terminology is of questionable utility at the present time. The rock and soil-stratigraphic terms assigned to the early Wisconsin should be reassigned to the late Illinoian or abandoned.

## ACKNOWLEDGMENTS

Field work and write up of results was partially supported by a Bloomsburg Faculty Research Grant for 1986-1987 and Faculty Release Time Grant for the Spring of 1988. Thanks is expressed for permission to examine strip mine exposures by the Barletta, Beltrami, Bethlehem, and Pagnotti mining companies. Jon Inners provided much appreciated field assistance for many aspects of the project during the last several years. Parts of the project area were examined by Scott Coslett, Gene Crossley, Rich Kanaskie, Jeff Leberfinger, Dave Miller, Joe Miller, Eric Myer, Bill Shannon, Brian Shavor, Jeff Slivka, Keith Springman, Paul Stratman, and John Strecker in their senior research projects. Bill Sevon and Ed Ciolkosz provided helpful technical reviews of the paper.

## REFERENCES CITED

- Atwater, B. F., Adam, D. P., Bradbury, J. P., and others, 1986, A fan dam for Tulare Lake, California, and Implication for the Wisconsin glacial history of the Sierra Nevada: *Geological Society of America Bulletin*, v. 97, p. 97-109.
- Baker, R. G., 1986, Sangamonian(?) and Wisconsinan paleoenvironments in Yellowstone National Park: *Geological Society of America Bulletin*, v. 97, p. 717-736.
- Berg, T. M., 1975, Geology and mineral resources of the Brodheadsville quadrangle, Monroe and Carbon Counties, Pennsylvania: *Pennsylvania Geological Survey*, 4th ser., Atlas 205a, 60 p.
- \_\_\_\_\_, 1980, Geologic map of Pennsylvania: *Pennsylvania Geological Survey*, 4th ser., Map 1.
- Braun, D. D., Miller, D. S., Miller, J. C., and Inners, J. D., 1984, Abandoned valley of the North Branch Susquehanna River at Mifflinville, Pennsylvania: Evidence for a pre-late Wisconsinan ice margin (abs.): *Geological Society of America Abstracts with Programs*, v. 15, no. 1, p. 5.
- Braun, D. D., 1985, Pre-late Wisconsinan glaciation in the Valley and Ridge of northeastern Pennsylvania (abs.): *Geological Society of America Abstracts with Programs*, v. 16, no. 1, p. 7.
- Braun, D. D., and Kaktins, T., 1986, Diamicts from the weathering of pre-Wisconsinan glaciofluvial and fluvial deposits in central Pennsylvania (abs): *Geological Society of America Abstracts with Programs*, v. 17, no. 1, p. 6.
- Bloom, A. L., Broecker, W. S., Chappell, J. M. A., Matthews, R. K., and Mesolella, K. J., 1974, Quaternary sea level fluctuations on a tectonic coast: New 230Th/234U dates from the Huon Peninsula, New Guinea: *Quaternary Research*, v. 4, p. 185-205.
- Bucek, M. F., 1975, Pleistocene geology and history of the West Branch of Susquehanna River Valley near Williamsport, Pennsylvania: unpublished Ph.D. dissertation, The Pennsylvania State University, 197 p.
- Carter, B. J., 1979, Soil genesis and classification studies in Pennsylvania, Part II: Genesis of soils developed in pre-Wisconsinan glacial till: unpublished Masters thesis, The Pennsylvania State University, 136 p.
- Cook, G. H., 1880, Annual report of the State Geologist for the Year 1880: *Geologic Survey of New Jersey*, 547 p.
- Cotter, J. F. P., 1983, The minimum age of the Woodfordian deglaciation of northeastern Pennsylvania and northwestern New Jersey: unpublished Ph.D. dissertation, Lehigh University, 151 p.
- Cotter, J. F. P., Ridge, J. H., Evenson, E. B., Sevon, W. D., Sirkin, L., and Stuckenrath, S., 1985, The Wisconsinan history of the Great Valley, Pennsylvania and New Jersey, and the age of the "Terminal Moraine": in Evenson, E. B. (ed.), *Friends of the Pleistocene Field Conference*, 48th, Guidebook, p. 1-59.
- Craft, J. L., 1976, Stop III: White City sand and gravel pit, Titusville, PA, in Ward, A. N., Jr. (ed.), *Bedrock and glacial geology of Northwestern Pennsylvania in Crawford, Forest, and Venango Counties: Annual Field Conference of Pennsylvania Geologists*, 41st, Titusville, PA, Guidebook, p. 28-32.
- Crowl, G. H., Connally, G. G., and Sevon, W. D., 1975, The late Wisconsinan glacial border in northeastern Pennsylvania: *Friends of the Pleistocene Field Conference*, 38th, Guidebook, 22 p.

- Crowl, G. H., and Sevon, W. D., 1980, Glacial border deposits of late Wisconsinan age in north-eastern Pennsylvania: Pennsylvania Geological Survey, 4th ser., General Geology Report 71, 68 p.
- Deasy, G. F., and Grless, P. R., 1963, Atlas of Pennsylvania Coal and Coal mining, Part II, Anthracite: Mineral Industries Experiment Station, The Pennsylvania State University, Bulletin 80, 123 p.
- Denny, C. S., and Lyford, W. H., 1963, Surficial geology and soils of the Elmira-Williamsport region, New York and Pennsylvania: U.S. Geological Survey Professional Paper 379, 60 p.
- Dorn, R. I., Turrin, B. D., Jull, A. J. T., Linick, T. W., and Donahue, D. J., 1987, Radiocarbon and Cation-ratio ages for rock varnish on Tloga and Tahoe moraine boulders of Pine Creek, eastern Sierra Nevada, California, their paleoclimatic implications: Quaternary Research, v. 28, p. 38-49.
- Dreimanis, A., 1960, Pre-classical Wisconsin in the eastern portion of the Great Lakes region, North America: 21st International Geological Congress, Part IV, Chronology and Climatology of the Quaternary, p. 108-119.
- Dreimanis, A., and Karrow, P. F., 1972, Glacial history of the Great Lakes-St. Lawrence region, the classification of the Wisconsin(an) Stage, and its correlatives, 24th International Geological Congress, Section 12, The Quaternary, p. 5-15.
- Dreimanis, A., and Goldthwait, R. P., 1973, Wisconsin glaciation in the Huron, Erie, and Ontario lobes: Geological Society of America Memoir 136, p. 71-106.
- Emillani, C., 1955, Pleistocene temperatures: Journal of Geology, v. 74, p. 109-126.
- Eyles, C. H., and Eyles, N., 1983, Sedimentation in a large lake: a reinterpretation of the late Pleistocene stratigraphy at Scarborough Bluffs, Ontario, Canada: Geology, v. 11, p. 146-152.
- Eyles, N., and Westgate, J. A., 1987, Restricted regional extent of the Laurentide Ice Sheet in the Great Lakes basins during early Wisconsin glaciation: Geology, v. 15, p. 537-540.
- Fall, R. T., Wells, R. B. and Sevon, W. B., 1977, Geology and mineral resources of the Salladasburg and Cogan Station quadrangles, Lycoming County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 133cd, 44 p.
- Frye, J. C. and Willman, H. B., 1960, Classification of the Wisconsinan Stage in the Lake Michigan glacial lobe: Illinois Geological Survey Circular 285, 16 p.
- \_\_\_\_\_, 1973, Wisconsinan climatic history interpreted from Lake Michigan Lobe deposits and soils: Geological Society of America Memoir 136, p. 135-152.
- Fullerton, D. S., 1986, Stratigraphy and correlation of glacial deposits from Indiana to New York and New Jersey, In Sibrava, V., Bowen, D. Q., and Richmond, G. M. (eds.), Quaternary glaciations in the Northern Hemisphere: Quaternary Science Review, v. 5, p. 23-38.
- \_\_\_\_\_, 1986, Chronology and correlation of glacial deposits in the Sierra Nevada, California, In Sibrava, V., Bowen, D. Q., and Richmond, G. M. (eds.), Quaternary glaciations in the Northern Hemisphere: Quaternary Science Review, v. 5, 514 p.
- Goldthwait, R. P., Dreimanis, A., Forsyth, J. L., Karrow, P. F., and White, G. W., 1965, Pleistocene deposits of the Erie Lobe, In Wright, H. E., Jr., and Frey, D. G. (eds.), The Quaternary of the United States: Princeton, NJ, Princeton University Press, p. 85-97.
- Hallberg, G. R., 1986, Pre-Wisconsin glacial stratigraphy of the Central Plains region in Iowa, Nebraska, Kansas, and Missouri: In Sibrava, V., Bowen, D. Q., and Richmond, G. M. (eds.), Quaternary glaciations in the Northern Hemisphere: Quaternary Science Review, v. 5, p. 11-16.
- Hamilton, T. D., 1986, Correlation of Quaternary glacial deposits in Alaska: In Sibrava, V., Bowen, D. Q., and Richmond, G. M. (eds.), Quaternary glaciations in the Northern Hemisphere: Quaternary Science Review, v. 5, p. 171-180.
- Harden, J. W., and Taylor, E. M., 1983, A quantitative comparison of soil development in four climatic regimes: Quaternary Research, v. 20, p. 342-359.
- Inners, J. D., 1978, Geology and mineral resources of the Berwick quadrangle, Luzerne and Columbia Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 174c, 34 p.
- \_\_\_\_\_, 1981, Geology and mineral resources of the Bloomsburg and Mifflinville quadrangles and part of the Catawissa quadrangle, Columbia County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 164cd, 152 p.

- \_\_\_\_\_, 1988, Tors and surficial weathering phenomena in the Pottsville conglomerate of the Hazleton area: *Pennsylvania Geology*, v. 18, no. 2, p. 2-7.
- Johnson, W. H., 1986, Stratigraphy and correlation of the glacial deposits of the Lake Michigan Lobe prior to 14 ka BP, in Sibrava, V., Bowen, D. Q., and Richmond, G. M. (eds.), *Quaternary glaciations in the Northern Hemisphere: Quaternary Science Review*, v. 5, p. 17-22.
- Kaktins, T., 1986, Fluvial terraces of the Juniata Valley in central Pennsylvania: unpublished Master's thesis, The Pennsylvania State University, 279 p.
- Kempton, J. P., Berg, R. C., and Follmer, L. R., 1985, Revision of the stratigraphy and nomenclature of glacial deposits in central northern Illinois, in *Illinoian and Wisconsinan stratigraphy and environments in northern Illinois: the Altonian revised: Illinois Department of Energy and Natural Resources Guidebook 19*, p. 1-20.
- Leverett, F., 1934, Glacial deposits outside the Wisconsin terminal moraine in Pennsylvania: *Pennsylvania Geological Survey*, 4th ser., General Geology Report 7, 123 p.
- Levine, E. R., 1981, Time as a factor in the genesis of soils formed from glacial till in northeastern Pennsylvania: unpublished Master's thesis, The Pennsylvania State University, 110 p.
- Levine, E. R., and Ciolkosz, E. J., 1983, Soil Development in till of various ages in northeastern Pennsylvania: *Quaternary Research*, v. 19, p. 85-99.
- Lewis, H. C., 1884, Report on the terminal moraine in Pennsylvania and western New York: *Pennsylvania Geological Survey*, 2nd ser., Report Z, 299 p.
- MacClintock, P., and Apfel, E. T., 1944, Correlation of the drifts of the Salamanca re-entrant, New York: *Geological Society of America Bulletin*, v. 55, p. 1143-1164.
- Marchand, D. E., 1978, Quaternary deposits and Quaternary history, in Marchand, D. E., Ciolkosz, E. J., Bucek, M. F., and Crowl, G. H., *Quaternary deposits and soils of the central Susquehanna Valley of Pennsylvania: Agronomy Ser. No. 52*, The Pennsylvania State University, p. 1-19.
- Martinson, D. G., Pisias, N. G., Hay, J. D., Imbrie, J., Moore, T. C., and Shackleton, N. J., 1987, Age dating and the orbital theory of the ice ages: development of a high resolution 0 to 300,000-year chronostratigraphy: *Quaternary Research*, v. 27, p. 1-27.
- McCoy, W. D., 1987, Quaternary aminostratigraphy of the Bonneville Basin, western United States: *Geological Society of America*, v. 98, p. 99-112.
- Muller, E. H., 1977, Quaternary geology of New York, Niagara Sheet: *New York State Museum Map and Folio Ser. 25*.
- Nye, J. F., 1952a, A method of calculating the thickness of ice sheets: *Nature*, v. 169, p. 529-530.
- \_\_\_\_\_, 1952b, The mechanics of glacier flow: *Journal of Glaciology* v. 2, no. 12, p. 82-93.
- \_\_\_\_\_, 1957, The distribution of stress and velocity in glaciers and ice sheets: *Royal Society Annual Proceedings*, v. 256, p. 559-584.
- Oviatt, C. G., McCoy, W. D., and Reider, R. G., 1987, Evidence for a shallow early or middle Wisconsin-age lake in the Bonneville basin, Utah: *Quaternary Research*, v. 27, p. 248-262.
- Paterson, W. S. B., 1969, *The physics of glaciers*: Oxford, Pergamon, 250 p.
- Peltier, L. C., 1949, Pleistocene terraces of the Susquehanna River, Pennsylvania: *Pennsylvania Geological Survey*, 4th ser., General Geology Report 23, 158 p.
- Pisias, N. G., Martinson, D. G., Moore, T. C., Jr., and others, 1984, High resolution stratigraphic correlation of benthic oxygen isotopic records spanning the last 300,000 years: *Marine Geology*, v. 56, p. 119-136.
- Prime, F., Jr., 1879, The outer moraine of Wisconsin drift: *American Philosophical Society Proceedings*, v. 18, p. 85.
- Richmond, G. M., 1986a, Stratigraphy and chronology of glaciations in Yellowstone National Park, in Sibrava, V., Bowen, D. Q., and Richmond, G. M. (eds.), *Quaternary glaciations in the Northern Hemisphere: Quaternary Science Review*, v. 5, p. 83-98.
- \_\_\_\_\_, 1986b, Stratigraphy and correlation of the glacial deposits of the Rocky Mountains, the Colorado Plateau and the Ranges of the Great Basin: in Sibrava, V., Bowen, D. Q., and Richmond, G. M. (eds.), *Quaternary glaciations in the Northern Hemisphere: Quaternary Science Review*, v. 5, p. 99-128.
- Richmond, G. M., and Fullerton, D. S., 1986, Summation of quaternary glaciations in the United States of America, in Sibrava, V., Bowen, D. Q., and Richmond, G. M. (eds.), *Quaternary glaciations in the Northern Hemisphere: Quaternary Science Review* v. 5, p. 183-196.

- Sevon, W. D., 1973, "Early" Wisconsinan drift in Lycoming County, Pennsylvania (abs.): Geological Society of America Abstracts with Programs, v. 4, no. 1, p. 43-44.
- \_\_\_\_\_, 1974, Relative age and sequence of glacial deposits in Carbon and Monroe Counties, Pennsylvania (abs.): Geological Society of America Abstracts with Programs, v. 5, no. 2, p. 218.
- \_\_\_\_\_, 1975, Geology and mineral resources of the Christmans and Pohopoco Mountain quadrangles, Carbon and Monroe Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 195ab.
- Sevon, W. D., Crowl, G. H., and Berg, T. M., 1975, The late Wisconsinan drift border in northeastern Pennsylvania: Annual Field Conference of Pennsylvania Geologists, 40th, Bartonsville, PA, Guidebook, 108 p.
- Shackleton, N. J., 1987, Oxygen isotopes, ice volume and sea level: Quaternary Science Review, v. 5, p. 183-190.
- Shackleton, N. J., and Opdyke, N. D., 1973, Oxygen isotope and paleomagnetic stratigraphy of Equatorial Pacific core V28-238: oxygen isotope and paleomagnetic temperature and ice volumes on a 10,000 year and 100,000 year time scale: Quaternary Research, v. 3, p. 39-55.
- Shackleton, N. J., Imbrie, J., and Hall, M. A., 1983, Oxygen isotope record of East Pacific core VI, 9-30: Implications for the formation of deep water in the late Pleistocene North Atlantic: Earth and Planetary Science Letters, v. 65, p. 233-234.
- Shackleton, N. J. and Hall, M. A., 1984, Oxygen and carbon isotope stratigraphy of Deep Sea Drilling Project Hole 552A: Plio-Pleistocene glacial history, in Roberts, D. G., and others, Initial reports of the Deep Sea Drilling Project: U.S. Government Printing Office, Washington, D. C., v. 81, p. 599-609.
- Shepps, V. C., White, G. W., Droste, J. B., and Stiller, R. F., 1959, Glacial geology of northwestern Pennsylvania: Pennsylvania Geological Survey, 4th ser., General Geology Report 32, 59 p.
- Sibrava, V., Bowen, D. Q., and Richmond, G. M. (eds.), 1986, Quaternary glaciations in the Northern Hemisphere: Quaternary Science Review, v. 5, 514 p.
- Totten, S. M., 1987, Stratigraphy of tills in northern Ohio, in Pre-Woodfordian stratigraphy of north-central Ohio: Midwest Friends of the Pleistocene Field Conference, 34th, Guidebook, p. 1-25.
- Wells, R. B. and Bucek, M. F., 1980, Geology and mineral resources of the Montoursville North and Huntersville quadrangles, Lycoming County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 143cd, 68 p.
- Weertman, J., 1961, Equilibrium profile of ice caps: Journal of Glaciology, v. 3, no. 30, p. 953-964.
- \_\_\_\_\_, 1973, Position of ice divides and ice centers on ice sheets: Journal of Glaciology, v. 12, no. 12, p. 353-360.
- Westgate, J. A., Chen, F. J., and Delorme, L. D., 1987, Lacustrine ostracodes in the late Pleistocene Sunnybrook diamicton of southern Ontario, Canada: Canadian Journal of Earth Science, v. 24, p. 1244-1253.
- White, G. W., 1969, Pleistocene deposits of the north-western Allegheny Plateau, U.S.A.: Quarterly Journal of the Geological Society of London, v. 124, p. 131-151.
- White, G. W. and Totten, S. M., 1965, Wisconsinan age of the Titusville Till (formerly called "inner Illinoian"), northwestern Pennsylvania: Science, v. 148, p. 234-235.
- White, G. W., Totten, S. M., and Gross, D. M., 1969, Pleistocene stratigraphy of northwestern Pennsylvania: Pennsylvania Geological Survey, 4th ser., General Geology Report 55, 88 p.
- Willman, H. B., and Frye, J. C., 1970, Pleistocene stratigraphy of Illinois: Illinois State Geological Survey, Bulletin 94, 204 p.
- Williams, E. H., Jr., 1894, The age of the extramoraline fringe in eastern Pennsylvania: American Journal of Science, v. 47, p. 34-37.
- \_\_\_\_\_, 1895, Notes on the southern ice limit in eastern Pennsylvania: American Journal of Science, v. 49, p. 174-185.
- \_\_\_\_\_, 1898, Notes on Kansan drift in Pennsylvania: American Philosophic Society Proceedings, v. 37, p. 84-87.
- \_\_\_\_\_, 1917, Pennsylvania glaciation first phase: Woodstock, VT, 101 p.
- Wright, G. F., 1892, The extramoraline drift of the Susquehanna Valley: American Geologist, v. 10, p. 219.

PRE-FOLDING, BEDDING-PARALLEL TRANSPORT IN THE ROSE HILL  
FORMATION, BLOOMSBURG AND DANVILLE, PENNSYLVANIA

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Olive green shales of the Rose Hill Formation that fall stratigraphically between the Centre and Cabin Hill hematitic sandstones (Cotter, 1988) are well-exposed to the east of Mahoning Creek near Danville and on both sides of Fishing Creek at Bloomsburg (Figure 8). Both areas lie in the axial region of the Berwick anticlinorium.

The Rose Hill shales in these areas are characterized by the presence of numerous striated surfaces that are parallel to bedding. The striated surfaces are actually fault surface veins composed of quartz and chlorite. The striations can be used to determine the bearing of slip on the surfaces. Chattermarks consistently indicate that the sense of motion on the slip surfaces is one with the upper plate moving to the north.

That the slip surfaces predate the formation of the Berwick anticlinorium can be demonstrated both at Danville and Bloomsburg. At Danville, striations plunge to the south-southeast on the south limb of the anticline (Figure 9a). The plunge of striations decreases toward the anticlinal axis (Figure 9b) and becomes essentially horizontal at the fold axis (Figures 9c and 9d). The same pattern is observed at Bloomsburg, with south-southeast bearing striations on the south limb of the fold decreasing in plunge as the fold axis is approached. This sequence of decreasing plunge of the linear structures is shown in Figures 10b through 10e. The northern limb of the anticline is also exposed in Bloomsburg

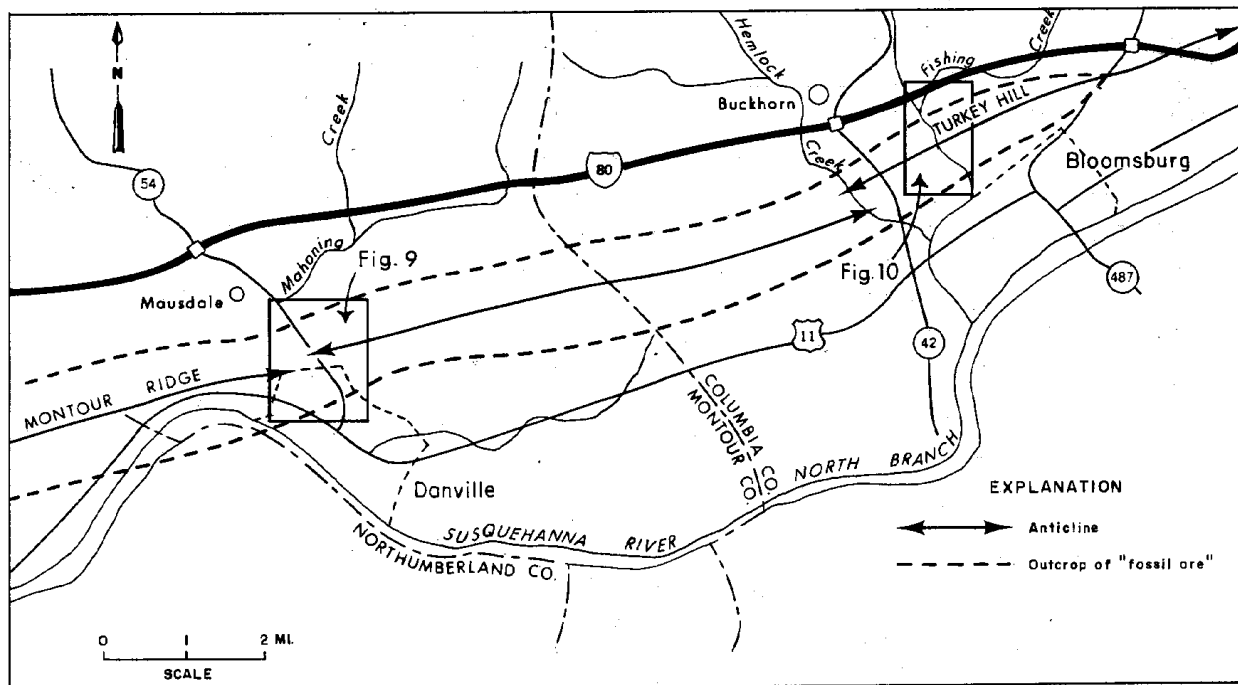


Figure 8. Generalized location map of Danville (Mahoning Creek gap) and Bloomsburg (Fishing Creek gap) outcrops.

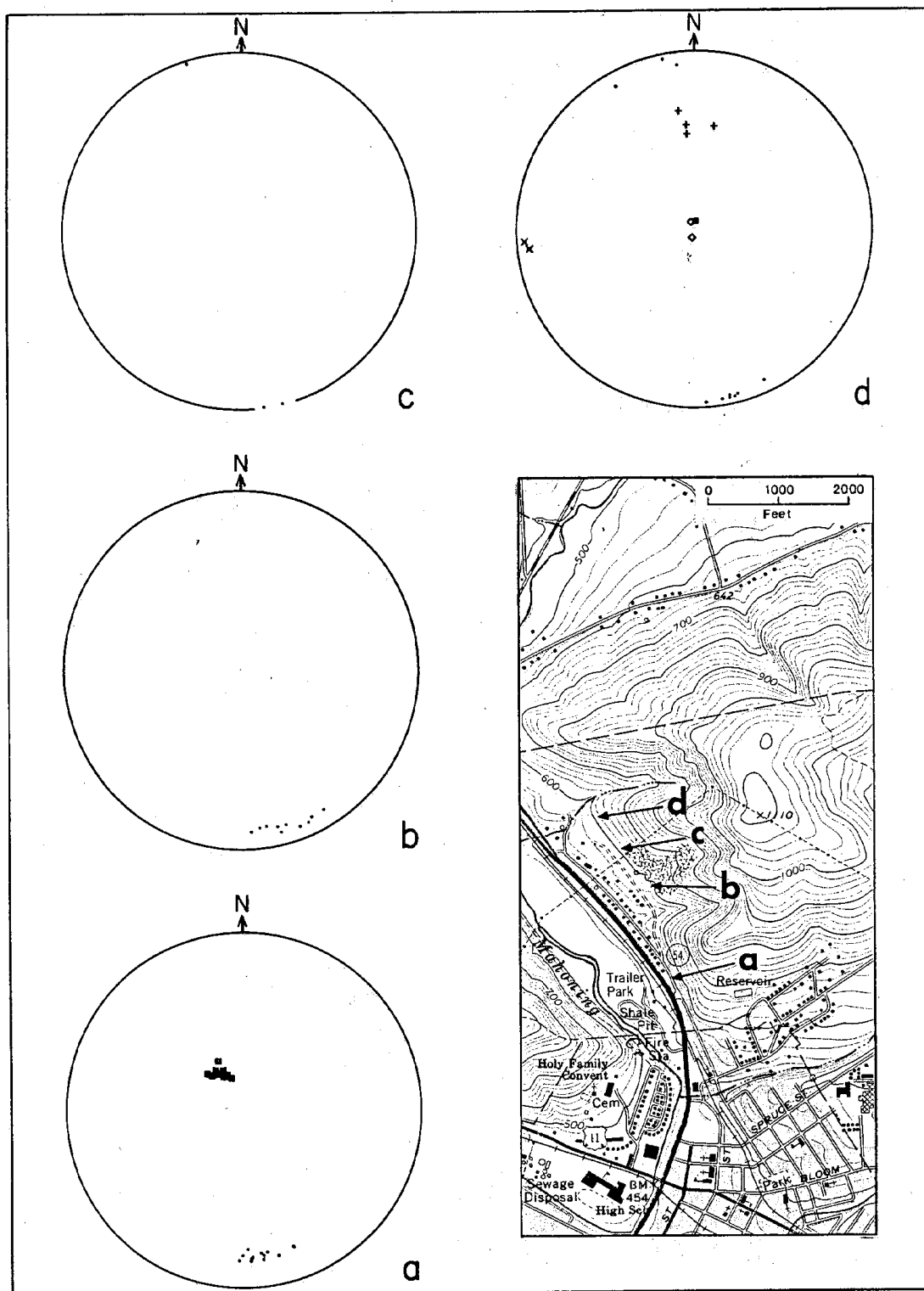


Figure 9. Location map for outcrops in the vicinity of Danville. Stereograms a through d (Schmidt net, lower hemisphere projections) are keyed to the corresponding sites. Symbols: dots = bearing and plunge of striations; x's = bearing and plunge of minor fold axes; +s = poles to cleavage in shale; diamonds = poles to bedding; squares = poles to slip surfaces.

(Figure 10, site a). Slip surfaces are present here, and the striations plunge to the north-northwest, demonstrating that the slip surfaces and striations have been folded. The transport direction in the Danville outcrops is indicated to be from approximately  $170^{\circ}$  toward  $350^{\circ}$  and in the Bloomsburg outcrops from approximately  $160^{\circ}$  toward  $340^{\circ}$ . This should approximate the orientation of sigma-one at the time of formation of the slip surfaces.

It is possible that bedding-parallel transport on these slip surfaces was considerable, because the number of slip surfaces is large. At Danville, surfaces are spaced 2-3 feet apart, although as many as eight have been found in a 4-foot stratigraphic interval. This pattern is maintained in Bloomsburg, although many multiple surfaces are encountered, with as many as 15 individual slip surfaces per inch. Displacement indicators are absent in Danville, but quartz-chlorite-(+/-)dolomite veins cut bedding in the outcrops at Bloomsburg. Some of these veins are thick (up to 8 inches wide) and are cut by the slip surfaces. In one exposure a vein in the lower plate is not repeated above a multiple slip surface. This indicates a minimum displacement greater than the scale of the outcrop ( $> 20$  feet).

Examination of thin sections shows that displacement on slip surfaces and growth of chlorite-bearing transverse tensile fractures was contemporaneous. Some veins cross slip surfaces, but are then truncated by another slip surface. Other veins partially penetrate slip surfaces and are then truncated (Figure 11a), indicating that slip was followed by locking of the fault and that movement jumped to a new, immediately adjacent, surface. The quartz and chlorite fault-surface material was presumably derived from the surrounding rock and transported toward the fault surface along the transverse veins. Quartz in the slip surfaces generally has undulatory extinction, but some layers are characterized by cataclastic texture (Figure 11b).

Thin sections of oriented specimens show examples of a penetrative cleavage formed by recrystallization of sheet silicates and pressure solution "ramping" from a lower slip surface and folding an overlying slip surface in the pattern of a passive roof duplex (Figure 11c). This indicates a genetic relationship between transport on the slip surfaces and a south-dipping cleavage which is not very prominent in outcrop, but is present on both limbs of the fold at Bloomsburg and has also been observed at Danville. Figure 11d shows the bedding-cleavage relationships more clearly.

Some small folds at site d in Danville (Figure 9d), with associated south-dipping wedge faults and south-dipping cleavage, might help to indicate how movement on the slip surfaces fits into the pattern of Alleghanian deformation. Some slip surfaces are deflected by these structures, whereas others are not. A tentative correlation of the small structures at Danville with Stage III of Nickelsen (1979, 1983) would place the episode of bedding-parallel transport and of formation of veins and cleavage in the Rose Hill Formation into Stage III or IV. Layer parallel compression in Rose Hill shales may have resulted in layer-parallel transport rather than the thrust faulting and strike-slip faulting (Stage IV of Nickelsen) that occurred in the sandstones of the Llewellyn Formation at Bear Valley (Nickelsen, 1983).

The structures that are described here may be more important than their visibility, or lack of it, might indicate. There are many slip surfaces in the Rose Hill Formation, and surfaces that appear to be single in outcrop are

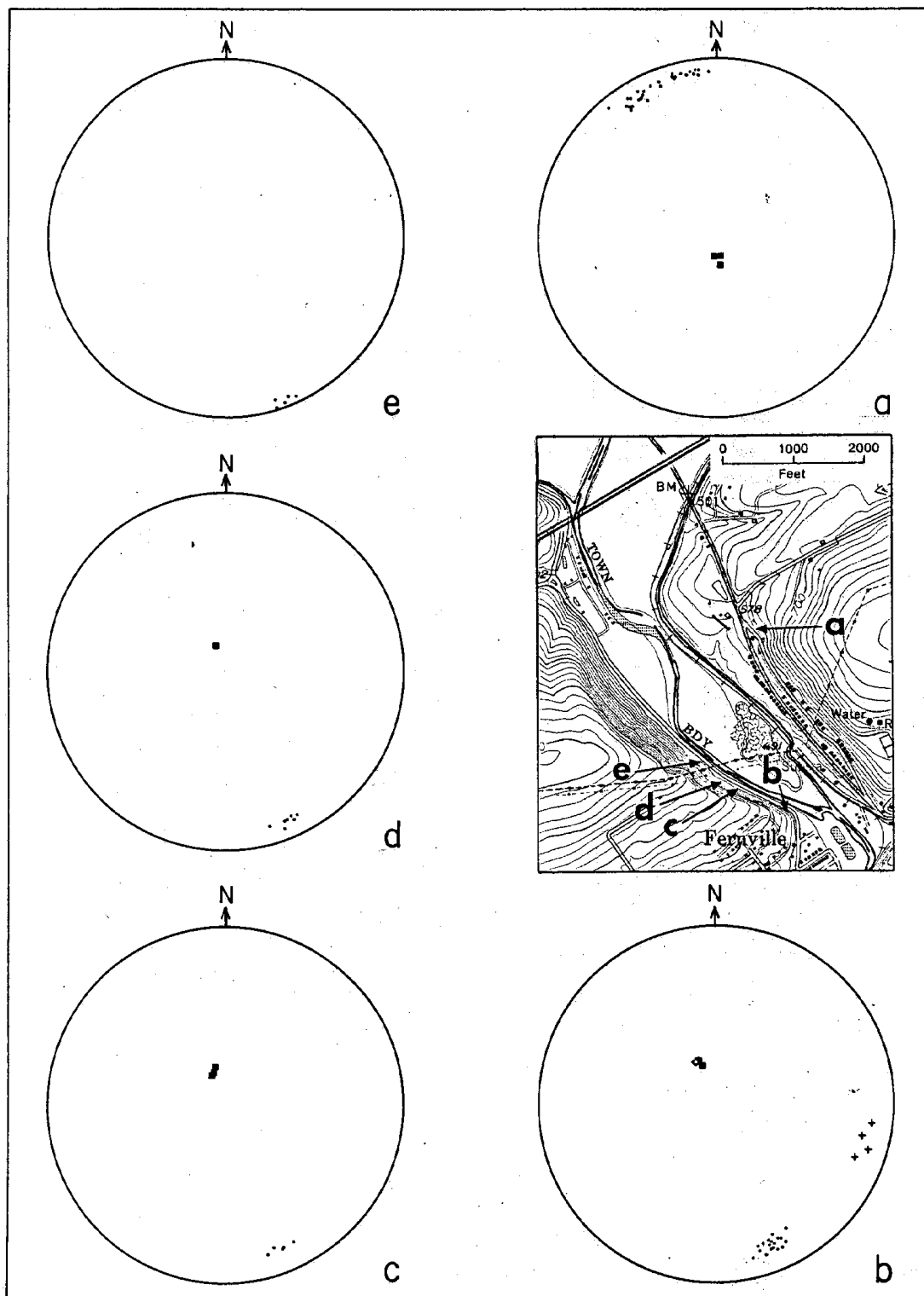
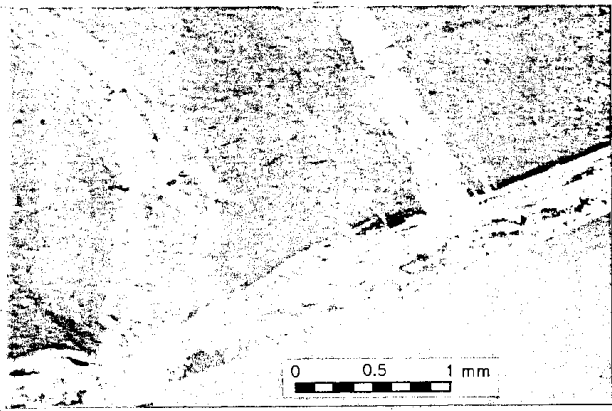
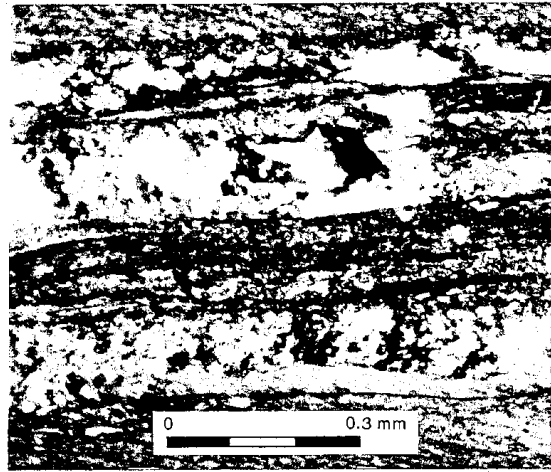


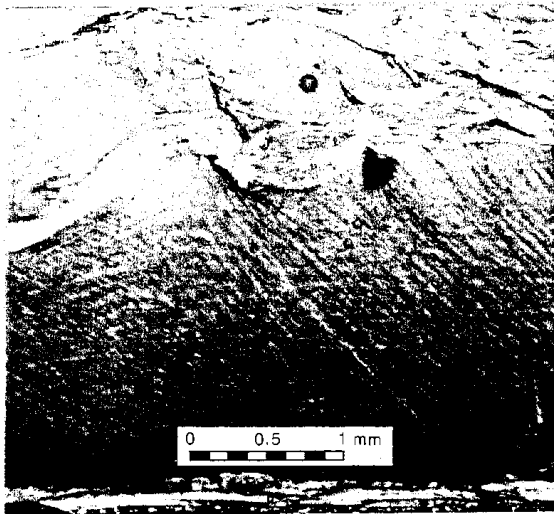
Figure 10. Location map for outcrops in the vicinity of Bloomsburg. Stereograms a through e (Schmidt net, lower hemisphere projections) are keyed to the corresponding sites. Symbols are the same as on Figure 9, except that +'s = poles to chlorite veins.



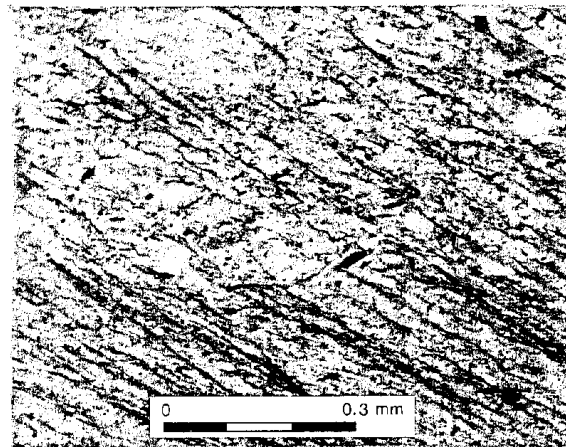
a



b



c



d

Figure 11. Photomicrographs of thin sections showing structural features in Rose Hill shales at the Danville and Bloomsburg localities.

- a. Quartz-chlorite veins penetrating to different levels of a slip surface (left to right). Vein at left is cut by margin of slip surface, whereas one to right penetrates past the edge of the slip surface. Chlorite in slip surfaces is sheared, but chlorite in transverse veins grows from margins toward interior of veins, indicating their tensional origin. Orientation: Top is up; north is left. Plane-polarized light.
- b. Quartz with undulating extinction at margins of slip surface. Cataclastic fabric at center, above stringer of shale with pronounced south-dipping cleavage. Orientation: Top is up; north is left. Crossed nicols.
- c. Abandoned slip surface (top) folded by south-dipping cleavage ramps rooted in planar slip-surfaces on bottom. Note that this structure is a micro-scale model of a passive roof duplex. Orientation: Top is up; north is left. Crossed nicols.
- d. Bedding-cleavage relations in Rose Hill silty shale from Bloomsburg. Cleavage dips to the south and is not only characterized by recrystallization of sheet silicates, but also by truncation of detrital grains and the presence of fine-grained residue along cleavage surfaces. The cleavage is formed at least in part by pressure solution. Plane-polarized light.

apparently multiple on the microscopic scale. Slip on some surfaces can be shown to be substantial. Therefore, the net slip that has been accommodated on these surfaces appears to be large. Could this be a subtle version of a décollement, spread over a large stratigraphic interval?

#### REFERENCES CITED

- Cotter, E., 1988, Hierarchy of sea-level cycles in the medial Silurian siliciclastic succession of Pennsylvania: *Geology*, v. 16, p. 242-245.
- Nickelsen, R. P., 1979, Sequence of structural stages of the Alleghany orogeny, at the Bear Valley Strip Mine, Shamokin, Pennsylvania: *American Journal of Science*, v. 279, p. 225-271.
- \_\_\_\_\_, 1983. Stop III - Bear Valley Strip Mine, structural geology, in Nickelsen, R. P., and Cotter, E., leaders, Silurian depositional history and Alleghanian deformation in the Pennsylvania Valley and Ridge: Annual Field Conference of Pennsylvania Geologists, 48th, Danville, PA, Guidebook, p. 128-139.

## THE EASTERN MIDDLE ANTHRACITE FIELD

by

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The Eastern Middle field, the smallest of the four major anthracite fields of northeastern Pennsylvania, is situated in Luzerne, Carbon, Schuylkill, and Columbia Counties. Its maximum length is 26 miles and its maximum width is 10 miles. Coal-bearing rocks underlie approximately 30 mi<sup>2</sup>. Most of the Eastern Middle field occupies a high plateau centered on the city of Hazleton (population 27,000). The highest altitudes (1,600 to 1,800 feet) occur on the steep escarpments bordering the plateau and along several northeast-southwest trending ridges that have local relief of 200 to 300 feet.

### BEDROCK STRATIGRAPHY

Bedrock units exposed within and directly adjacent to the Eastern Middle field range from the Late Mississippian Mauch Chunk Formation to the Middle to Late Pennsylvania Llewellyn Formation (see Table 1 and Figure 15). All the rocks are apparently of non-marine origin and represent terrigenous sediments shed from intermittently uplifted "southeastern" highlands during an early phase of the North American-African plate collision that culminated in the Alleghanian orogeny.

The Mauch Chunk Formation consists of at least 3,000 feet of interbedded sandstones, siltstones, mudstones and conglomerates that are characterized by a dominant red coloration. Informal members at the top and bottom of the formation are coarser grained and contain numerous non-red sandstone and conglomerate units (Schasse and others, in press; Inners, 1978). The middle member, approximately 1,500 feet thick, contains the fine-grained redbeds that are most typical of the Mauch Chunk. Most of the Mauch Chunk is composed of fining-upward alluvial cycles (conglomeratic at the base in the lower and upper members) that apparently formed on a broad upper deltaic plain (Wood and others, 1986). In the Eastern Middle field the upper half of the upper member is dominantly non-red and contains relatively few thin, discontinuous red mudstone units; these beds are clearly correlative with strata called basal Pottsville in the Southern Anthracite field (see Stop 12). The dominant red color, the paucity of plant remains, and the abundance of mudcracks and carbonate soil nodules all suggest that the Mauch Chunk was deposited under semi-arid conditions.

The Pottsville Formation in the Eastern Middle field is predominantly thick-bedded, light-gray, oligomict quartzose conglomerates that total 250 to 300 feet in thickness. While all three members recognized by U.S. Geological Survey workers in the Southern and Western Middle fields -- the Tumbling Run, Schuylkill, and Sharp Mountain (in ascending order) (Wood and others, 1969; Wood and Arndt, 1973) -- are present in the McAdoo and Sheppton areas, the darker-gray, polymict Tumbling Run Member disappears to the north and northeast (Schasse and others, in press; see Stop 12). Throughout the remainder of the Eastern Middle field, "white" quartz conglomerate typical of the Schuylkill-Sharp Mountain Members disconformably overlies the upper member of the Mauch Chunk. Inners and Lentz (Stop 12) believe that the rocks directly above this unconformity belong to the Schuylkill Member, but Edmunds (this volume) makes a compelling case for assigning them to the Sharp Mountain. The Pottsville conglomerates represent the deposits of a great system of braided rivers that

debouched from the "southeastern" highlands at a time of plate impact and subsequent uplift (Eggleston and Edmunds, 1981). One or two coalbeds (namely the Alpha and/or the Little Buck Mountain) occur in the finer-grained, upper part of the Pottsville.

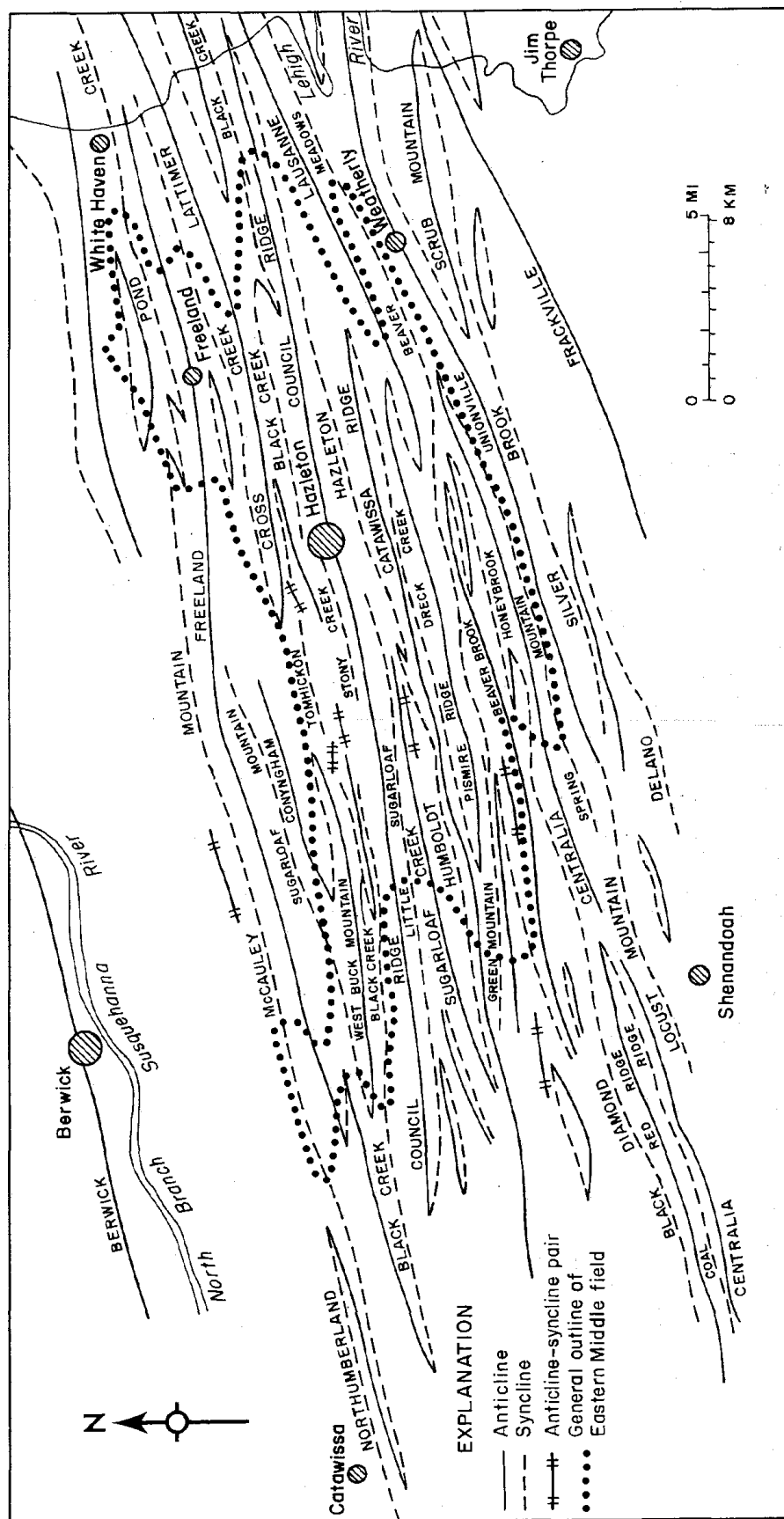
The Llewellyn Formation is about 1,500 feet thick and contains all of the major coalbeds of the Eastern Middle Field. Aside from its numerous anthracite seams, it consists predominantly of interbedded, dark-gray, carbonaceous sandstones (and some conglomerates), siltstones, claystones, and shales that are often arranged in fining-upward cycles 50 to 60 feet thick. The Llewellyn contains an abundance of pyrite and siderite, attesting to a predominance of reducing and acidic conditions during deposition and diagenesis. Pyrite occurs interstitially in many of the coarser-grained sandstones adjacent to the anthracite seams, in stringers and blebs within the coalbeds, and as large "sulfur balls" in claystone and siltstone seatrocks. Siderite concretions to several feet in diameter and commonly hollow jut out of the sandstone and claystone footwalls of many old strippings, perhaps being most common in the seatrocks of the Mammoth seam. The sediments that form the Llewellyn Formation were deposited on an alluvial plain in which short periods of high-energy fluvial deposition (10's to 100's of years) alternated with relatively longer periods of quiescent, swampy conditions (1,000's to 10,000's years). (See Wood and others, 1986, for a brief discussion of rates of coal formation.) Such a time frame suggests either climatic or tectonic influences on depositional processes.

## STRUCTURE

The Eastern Middle field lies in the east-central part of the great structural depression in the Appalachian fold belt that forms the Pennsylvania Anthracite region. Unlike the other anthracite fields which occupy deep synclinalia, the coal-bearing areas of the Eastern Middle field consist of numerous relatively shallow, elongate 2nd-order synclines that lie mainly on the crestal area of the Selinsgrove-Shade Mountain anticlinorium (Arndt and others, 1968; Figure 12). These synclines are commonly chevron-shaped and complexly faulted, whereas the intervening anticlines are more open (Eggleston and Edmunds, 1981; Schasse and others, in press).

Many of the synclines are interrupted along their lengths by localized 3rd-order anticlines, or "whalebacks," that may have amplitudes of more than 100 feet. Although none of the "whalebacks" in the Eastern Middle field are known to exhibit the wealth of structural details that characterize the great levathian at Shamokin (Nickelsen, 1979, 1987), some show a few minor structures indicating various stages in the development of the Appalachian orogen (Inners and Lentz, in press).

Aside from bedding plane displacements which are ubiquitous, the two most common types of faults are high-angle thrusts and transverse extensional faults. Most of the thrust faults are south-dipping (e.g., at mile 10.7 of Day-2 Road Log) and appear to propagate from one or two detachment horizons in the middle member of the Mauch Chunk (Schasse and others, in press). It is not known whether these detachments are widespread décollements or simply localized zones of slippage which developed during folding. If the former, one of them is probably the Pottchunk fault of Wood and others (1969). The transverse extensional faults are typically small structures that have displacements of one foot or less. They probably formed during orogenic Stage VI of Nickelsen (1979).



MacLachlan (1985) has observed a greater intensity of deformation in the Anthracite region as compared to other parts of the Valley and Ridge fold belt, as well as a possible upward increase in the number of higher order structures within the local Pennsylvanian section. He relates this to the broader concept of the "anthracite overthrust," an idea independently arrived at by Levine (1986) on other grounds (see below).

## ANTHRACITE

Anthracite in the Eastern Middle field occurs in a number of generally elongate, disconnected basins (Figure 13). Only the Hazleton and Jeansville basins exceed a depth of 1,000 feet to the bottom coal. In the other basins, the lowest minable coal lies well above sea level and could be completely mined out by open-pit methods under the proper economic conditions.

The mined coal is generally of very good quality (Socolow and others, 1980). Fixed carbon (dry, ash-free basis) increases in a roughly east-west direction from 94 percent in the McCauley Mountain basin to 98 percent at the east ends of the Hazleton and Jeansville basins. Sulfur content ranges from less than 0.5 percent to somewhat over 1.0 percent. Heating value depends on the amount of volatiles and increases from 14,400 Btu/lb in the east to 15,300 Btu/lb in the west (dry, ash-free basis).

### Coalbeds

The chief coalbeds of the Eastern Middle field are shown in Figure 14. The Mammoth and Buck Mountain, in that order, are the most important. Production from the other seams has been relatively less, both because of their usual lesser thickness and somewhat poorer quality and because of the limited extent of outcrop of the beds above the Mammoth.

The Mammoth seam in the Eastern Middle field generally consists of a single bed that averages about 30 feet in thickness. For example, in the medial part of the Hazleton basin the Mammoth ranges from 25 to 32 feet thick and contains less than 10 percent refuse. To the northwest, however, this single Mammoth apparently splits to form two 10- to 15-foot beds in the Black Creek and Roberts Run basins. Mammoth anthracite is generally shiny, jet-black, conchoidally fractured "bottle coal" that is low in ash.

The Buck Mountain (No. 5) is mined in all the basins and averages about five feet of good coal (Arndt and others, 1968). In many places, as in the Pond Creek and Big Black Creek (Stop 11) basins and at the east end of the Hazleton basin (Inners and Lentz, in press), the "Buck" consists of two splits 10 to 20 feet apart. Like the Mammoth, the Buck Mountain is typically a "bottle coal" that is relatively low in ash.

### Coal metamorphism

The "anthracite overthrust" hypothesis briefly mentioned above has grown out of recent mineralogical and coal reflectance studies. Coalification models require that anthracite probably formed at temperatures between 200 and 250°C (390 and 480°F) at a burial depth of 5 miles (Levine, 1986). Mineralogical investigations of anthracite underclays, however, indicate temperatures of between 250 and 450°C (480 and 840°F) and even deeper burial to account for the

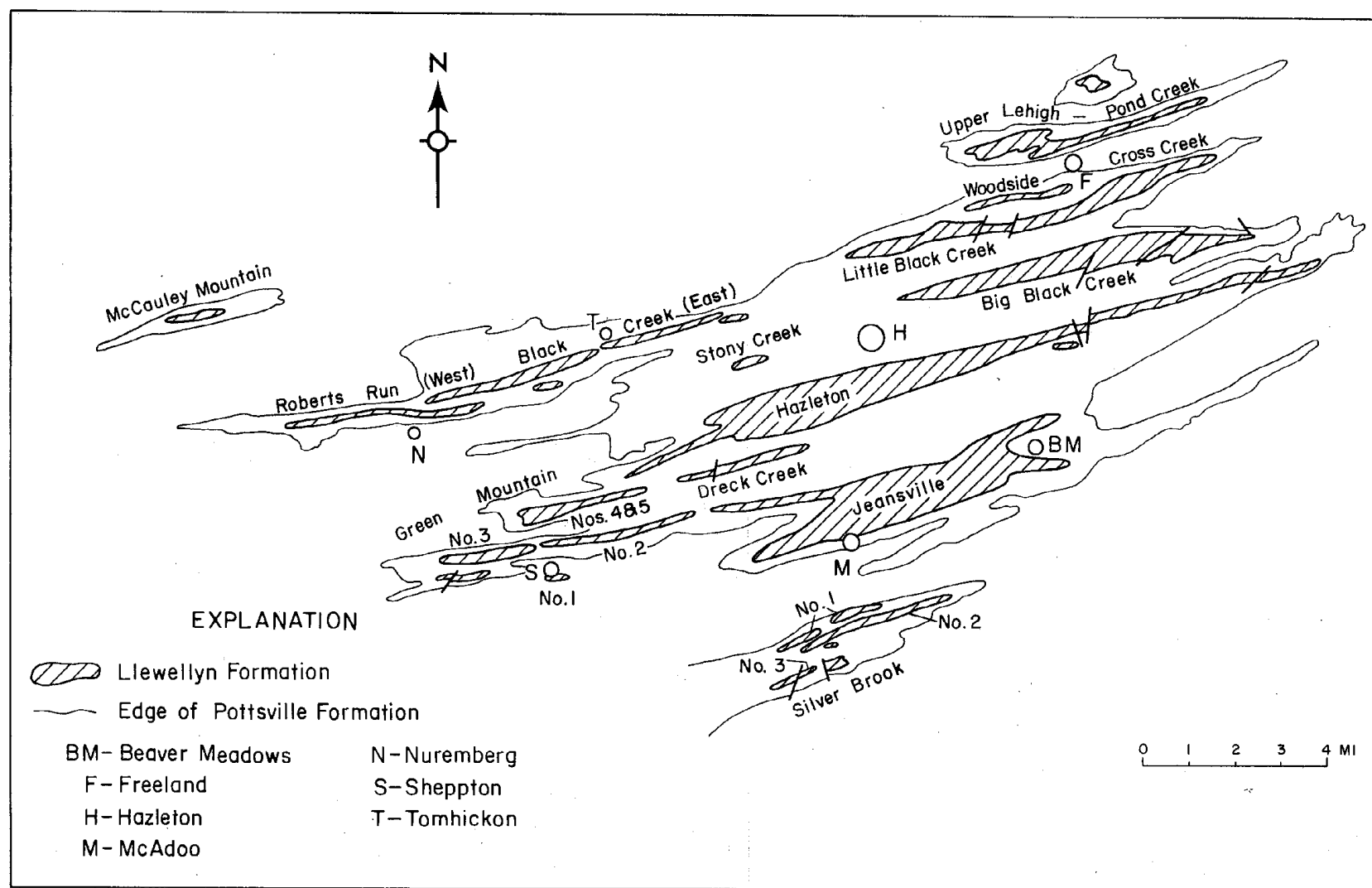


Figure 13. Anthracite basins of the Eastern Middle field. Although similar in size to basins further north, the Silver Brook basins are geologically more related to the Western Middle field.

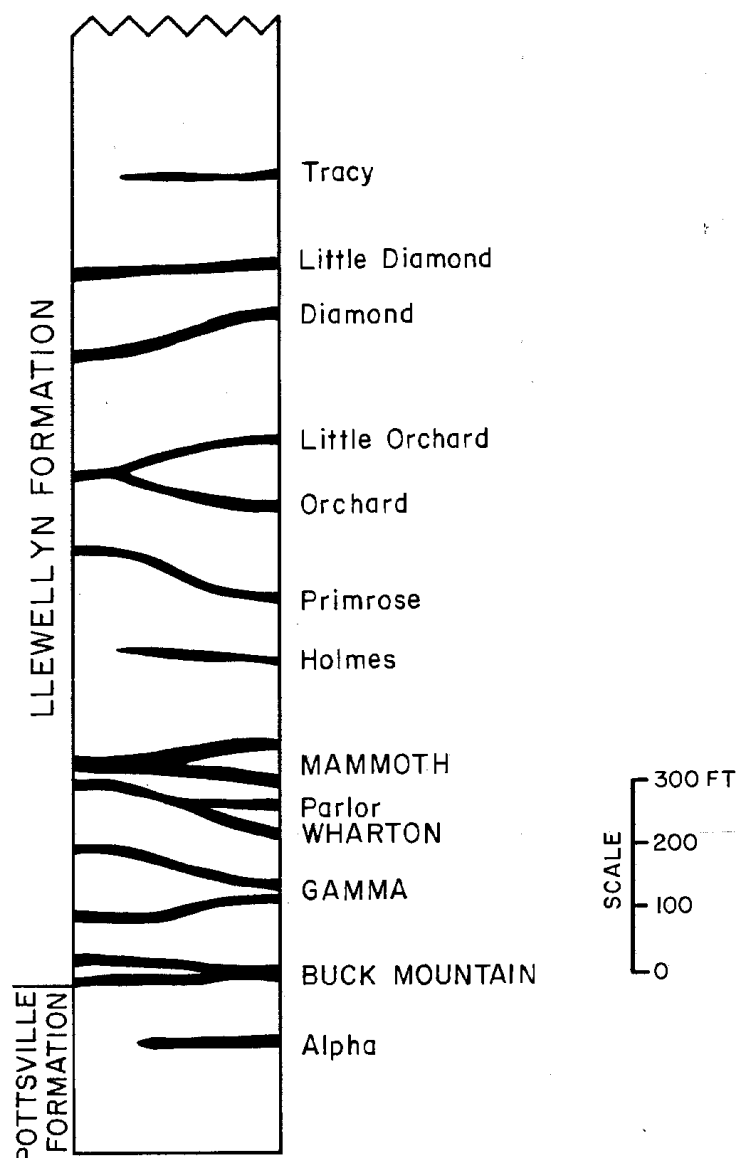


Figure 14. Coalbeds of the Eastern Middle field. The major seams are capitalized.

presence of a mineral assemblage including pyrophyllite, phlogopite, chlorite, and possibly microcline (Hosterman and others, 1970). Both MacLachlan (1985) and Levine (1983, 1985) postulate that much of the former overburden may have been emplaced tectonically within a relatively short period of time. This great overthrust block may have consisted of warm, formerly deep-seated crustal rocks rooted south of the Great Valley that buried and at the same time heated the underlying rocks to create anomalous metamorphic conditions in the Anthracite region (MacLachlan, 1985). While all trace of the rocks that made up this hypothetical body of rock have been eroded away, its former northwestern edge may now be marked by the course of the Susquehanna River from Pittston southwestward to Harrisburg (Sevon, 1986).

## Production

No longer "King" as it was seventy-five or more years ago, anthracite is now a dwindling part of the diversified economy of the Hazleton area. Production first passed a million tons per year in 1855, reached a peak of 8.9 million tons in 1914 and by 1948 had declined to 4.5 million tons (Ash and others, 1950, Fig. 1). During this approximately 100-year period, the great strikes of 1875, 1887, 1902, 1922, and 1925 caused major disruptions of the normal production curve. The sharpest decline set in after World War II, and at the present time production is only about 500,000 tons per year. Based on an original resource base of 684,000,000 tons, approximately 172,811,000 tons of anthracite remain to be mined in the Eastern Middle field; of this, 167,052,000 tons lies within 1,000 feet of the surface (Stingeln and others, 1984).

Current production in the field depends on large and small stripping operations in formerly deep-mined areas and reclamation of old breaker waste piles. Deep mining ceased entirely by 1970. The major operators include Jeddo-Highland Coal Company (open-pit mine at Ebervale [Stop 11] and strippings at Highland and Jeansville), Beltrami Enterprises (strippings at Eckley), Brook Contracting Corporation (strippings at Stockton), Coal Contractors, Inc. (open-pit mine at Gowen [Stop 9] and strippings near Fern Glen), and Amscot Coal Company (bank reprocessing at Lattimer).

## REFERENCES CITED

- Arndt, H. H., Averitt, P., Dowd, J., Frenzel, D. J., and Gallo, P. A., 1968, Coal, in Mineral resources of the Appalachian region: U.S. Geological Survey Professional Paper 580, p. 102-133.
- Ash, S. H., Kynor, H. D., Fatzinger, R. W., Davies, B. S., and Gilbert, J. C., 1950, Inundated anthracite reserves: Eastern Middle field of Pennsylvania: U.S. Bureau of Mines Bulletin 491, 28 p.
- Eggleston, J. R., and Edmunds, W. E., 1981, Field Guide to the Anthracite Coal basins of eastern Pennsylvania: Atlantic Margin Energy Symposium, Atlantic City, NJ, 90 p.
- Faill, R. T., in press, Tectonic map of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Map 65.
- Hosterman, J. W., Wood, G. H., Jr., and Bergin, M. J., 1970, Mineralogy of underclays in the Pennsylvania Anthracite region: U.S. Geological Survey Professional Paper 700-C, p. C89-C97.
- Inners, J. D., 1978, Geology and mineral resources of the Berwick quadrangle, Luzerne and Columbia Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 174c, 34 p.
- Inners, J. D., and Lentz, L. D., in press, The Eckley Whalebacks: Pennsylvania Geology.
- Levine, J. R., 1983, Tectonic history of coal-bearing sediments in eastern Pennsylvania using coal reflectance anisotropy: unpublished Ph.D. thesis, The Pennsylvania State University, 314 p.
- \_\_\_\_\_, 1985, Interpretation of Alleghanian tectonic events in the Anthracite region, Pennsylvania using aspects of coal metamorphism (abs.): Geological Society of America Abstracts with Programs, v. 17, p. 31.
- \_\_\_\_\_, 1986, Deep burial of coal-bearing strata, Anthracite region, Pennsylvania: sedimentation or tectonics?: Geology, v. 14, p. 577-580.
- MacLachlan, D. B., 1985, Pennsylvania anthracite as a foreland effect of Alleghanian thrusting (abs.): Geological Society of America Abstracts with Programs, v. 17, p. 53.
- Nickelsen, R. P., 1979, Sequence of structural stages of the Alleghany orogeny, at the Bear Valley Strip Mine, Shamokin, Pennsylvania: American Journal of Science, v. 279, p. 225-271.
- \_\_\_\_\_, 1987, Sequence of structural stages of the Alleghany orogeny at the Bear Valley Strip Mine, Shamokin, Pennsylvania, in Roy, D. C. (ed.), Northeastern Section: Geological Society of America Centennial Field Guide, v. 5, p. 55-58.

- Schasse, H. W., Inners, J. D., and MacLachlan, D. B., In press, Geology and mineral resources of the Conyngham quadrangle, Luzerne and Schuylkill Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 175b.
- Sevon, W. D., 1986, A sesquicentennial story -- Susquehanna River water gaps: many years of speculation: Pennsylvania Geology, v. 17, no. 3, p. 3-7.
- Socolow, A. A., Berg, T. M., Glover, A. D., and others, 1980, Coal resources of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Information Circular 88, 49 p.
- Stingeln, R. W., Kern, J. R., and McGrory, B. J., 1984, Defining the anthracite resources of northeastern Pennsylvania: U.S. Bureau of Mines Report No. J0333932, 228 p.
- Wood, G. H., Jr., and Arndt, H. H., 1973, Geologic map of the Delano quadrangle, Schuylkill County, Pennsylvania: U.S. Geological Survey Quadrangle Map GQ-1054.
- Wood, G. H., Jr., Kehn, T. M., and Eggleston, J. R., 1986, Depositional and structural history of the Pennsylvania region, in Lyons P. C., and others (eds.), Paleoenvironmental and tectonic controls in coal-forming basins of the United States: Geological Society of America Special Paper 210, p. 31-47.
- Wood, G. H., Jr., Trexler, J. P., and Kehn, T. M., 1969, Geology of the west-central part of the Southern Anthracite field and adjoining areas, Pennsylvania: U.S. Geological Survey Professional Paper 602, 150 p.

## THE POTTSVILLE FORMATION OF THE ANTHRACITE REGION

by

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...Point Mountain, upon which Gibbsville's earliest settlement was made, is the delight of geologists, who come from as far away as Germany to examine Gibbsville Conglomerate, a stone formation found nowhere else in the world. When that geological squeeze or whatever it was that produced veins of coal, occurred, it did not go south of Point Mountain, and coal is found on the north slope of Point Mountain, but not on the south side, and at the eastern face of Point Mountain is found Gibbsville Conglomerate.

John O'Hara, Appointment in Samara (1934)

### HISTORICAL BACKGROUND

The Pottsville Formation derives from Formation XII of Rogers (1836, 1837) who recognized the sequence as one composed dominantly of conglomerates and sandstones distinct from the underlying redbeds of Formation XI (Mauch Chunk Formation) and the overlying coal measures of Formation XIII (Llewellyn Formation). Broadly viewed, the Pottsville represents the alluvial phase of the delta system of which the Mauch Chunk Formation is the delta plain phase.

By the time of the publication of the final report of the Second Pennsylvania Geologic Survey in 1895, the current definition of the Pottsville Formation of the Anthracite region had been accepted as extending from the top of the highest Mauch Chunk redbed to the base of the Buck Mountain (Lower Red Ash) coal (Figure 15). The section of the Pottsville Formation exposed in the gap cut through Sharp Mountain by the Schuylkill River just south of Pottsville, as described by C. D. White (1900), has come to be considered the type section of the Pottsville Formation and, by extension, the type section of the base of the Pennsylvanian System. At this same site, Wood and others (1956) redescribed the formation and defined the Tumbling Run, Schuylkill, and Sharp Mountain Members. The section was most recently redescribed by Levine and Slingerland (1987).

### LITHOLOGY

In general, the Pottsville Formation is approximately 50 to 60 percent cobble and pebble conglomerate and conglomeratic sandstone, 25 to 40 percent sandstone, and 10 to 20 percent other finer clastics and coal. Most of the formation is fining-upward alluvial or alluvial to coal-swamp cycles.

The Tumbling Run Member is the basal unit of the Pottsville Formation. As far as is known, it is always conformable with the underlying upper member of the Mauch Chunk Formation. The Mauch Chunk upper member and the Tumbling Run jointly represent a long transition from the red mudstones, shales, siltstones and fine sandstones of the middle member of the Mauch Chunk to the gray conglomerates and sandstones of the post-Tumbling Run Pottsville. Other than the lack of red coloration, the lower quarter of the Tumbling Run is very similar to the uppermost Mauch Chunk.

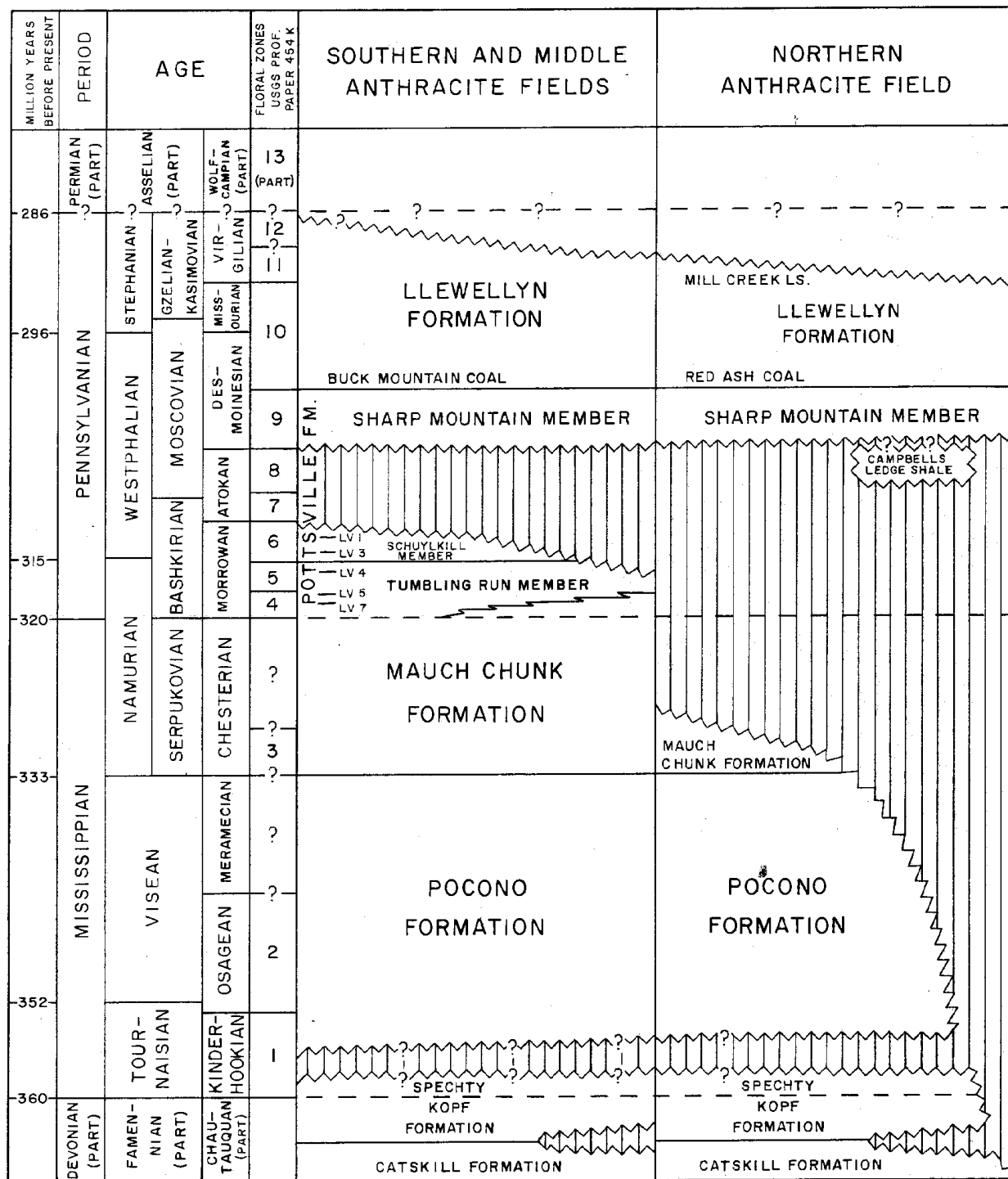


Figure 15. Correlation chart of the upper Paleozoic rocks of the Anthracite region.

The lower one-half to two-thirds of the Tumbling Run, up to the level of the lowest Lykens Valley coal, is distinct from the remainder of the overlying Pottsville Formation. This is particularly noticeable in matters of color, conglomerate clast composition, and the presence or absence of organic carbon in the system in the form of coal beds, plant fragments, and finely disseminated carbon expressed as dark coloration.

The color of pre-Lykens Valley Tumbling Run lithologies is dominated by hues in the "5GY", "10GY", "5G", and "5Y" ranges (Munsell color chart), such as olive grays, olive greens, yellow grays, and gray greens. In absolutely fresh samples, the olive and yellowish cast may be very subdued and the color will appear to be more gray. Lithologies above this level tend to fall overwhelmingly in the "N" range from light gray to black. The occurrence or, more likely, the preservation of organic carbon (including coal and plant fragments) in the sediments corresponds closely to the coloration change from green and yellow hues to gray. In many respects, the upper Tumbling Run is more similar to the Schuylkill Member than to the lower Tumbling Run.

Pottsville conglomerate pebbles and cobbles are dominantly vein quartz and quartzite throughout; however, the Tumbling Run Member commonly contains clasts of sandstone, chert, and various metamorphics in distinctly greater quantities than the other two members. Most conglomerates and conglomeratic sandstones are concentrated in the lower half of the Tumbling Run Member. The upper half of the member is mostly sandstone and contains the intermittently present Lykens Valley No. 4 through 7 coal beds.

The Schuylkill Member tends to be somewhat finer grained than the other two members, although no finer grained than the upper Tumbling Run. Shale, siltstone, and claystone are more common and conglomerate clasts are mostly in the granule to fine pebble size. Lykens Valley Nos. 1, 2, and 3 coals occur in the Schuylkill Member. The conglomerate zone which marks the base of the Schuylkill Member is not especially distinctive nor persistent, making separation of the Schuylkill from the underlying Tumbling Run difficult.

The Sharp Mountain is the coarsest of the three members. The conglomeratic sequence which marks its base is reportedly very persistent. The basal Sharp Mountain conglomerate, more than any other, is the archetype Pottsville "goose-egg conglomerate". This member contains two or three coal beds, only the uppermost of which has any great persistence.

In the Northern field, with the Tumbling Run and Schuylkill Members absent, the Sharp Mountain usually rests disconformably upon Mississippian to Devonian rocks (Figures 15 and 16). At some places in the Northern Field, the Sharp Mountain overlies up to several feet of dark, carbonaceous Campbell's Ledge Shale.

#### THICKNESS AND DISTRIBUTION

Maximum thickness of the Tumbling Run Member is about 600 feet along the south edge of the Southern field south and southwest of Tower City (Meckel, 1964, Fig. 35; Wood and others, 1969, Fig. 36). It thins to possibly as little as 100 to 150 feet along the north edge of the Eastern Middle field and is absent in the Northern field (Figure 16). Thinning in the Southern and Western Middle field is apparently the result of both general depositional thinning and

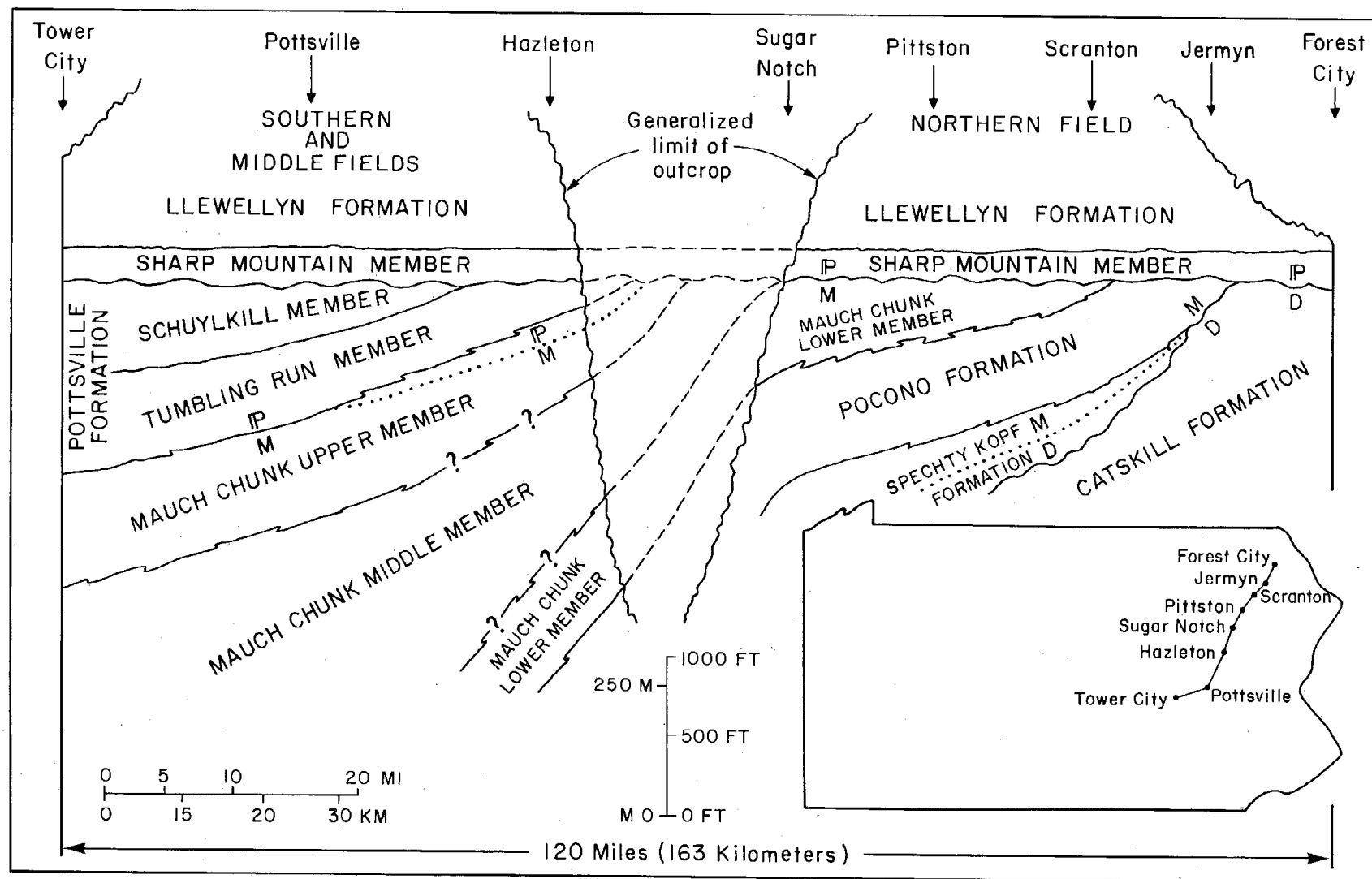


Figure 16. Diagrammatic cross section from southwest to northeast across the Southern, Eastern Middle, and Northern Anthracite fields, showing the sub-Sharp Mountain disconformity.

technical loss of section at the base by virtue of the fact that some of the finer units become red, thus by definition, transferring them and subjacent rocks to the Mauch Chunk Formation.

Maximum thickness of the Schuylkill Member is over 650 feet along the south edge of the Southern field south and southwest of Tower City. From there, it appears to thin irregularly to the northeast (Meckel, 1964, Fig. 36; Wood and others, 1969, Fig. 37). The Schuylkill Member is missing across the Northern field, and perhaps over much or all of the Eastern Middle field.

The Sharp Mountain Member is reported to reach a maximum thickness of over 400 feet at the east end of the Southern field, but thins rapidly to the north and northwest, stabilizing at between 100 and 300 feet across most of the Anthracite region (Meckel, 1964, Fig. 37). There seems little disagreement that the entire Pottsville Formation in the Northern field (aside from the thin Campbell's Ledge Shale) is Sharp Mountain Member only (White, 1904, p. 274; Meckel, 1964, p. 35-36; Wood and others, 1956, p. 2688; Read, 1944, p. 680 and Chart 6; Kehn and others, 1966). The Sharp Mountain rests disconformably upon units ranging from the Late Mississippian lower member of the Mauch Chunk Formation at the southwest end of the Northern field to the Late Devonian Catskill Formation at the northeast end. (Figures 15 and 16).

Where present, the thin Campbell's Ledge Shale is also above the disconformity. It is not clear whether the Campbell's Ledge is part of the Sharp Mountain and becomes interbedded with the basal conglomerates or if there is a relatively small, but real, general erosional hiatus between the two units. In any case, it is part of the Pottsville Formation, although possibly independent of any of the three established members.

#### BIOSTRATIGRAPHY AND CHRONOSTRATIGRAPHY

Plants are the only significant macrofossils known to occur in the Pottsville Formation of the Anthracite area and the only group upon which systematic study has been conducted (White, 1900, and Reed and Mamay, 1964). (White [1904, p. 277] mentions the occurrence of Naiadites and Spirobus in the upper Tumbling Run ["Lower Lykens"] without additional comment or reference).

The Mississippian-Pennsylvanian time boundary is defined at the Mauch Chunk-Pottsville contact at the type section at Pottsville. Additional time correlations are those linked to Read's Upper Paleozoic Floral zonation, which is the only biostratigraphic framework available to tie the Anthracite Pottsville to other areas (Figure 15). Any rise in the stratigraphic position of the highest redbed raises the position of the Mauch Chunk-Pottsville contact, requiring the Mississippian-Pennsylvanian systemic boundary to pass into the uppermost part of the Mauch Chunk Formation.

In the Southern and Middle fields, Read (1944) and Read and Mamay (1964) assigned the Tumbling Run and Schuylkill Members to their floral zones 4, 5, and 6 which are considered Morrowan age (Figure 15). The Sharp Mountain Member in all four fields was assigned to floral zone 9, which is Early Demoinesian age.

White (1900, p. 819-821) said of the Campbell's Ledge flora of the Northern field, that it cannot be older than Lykens Valley No. 1 coal (bed "L" of White's Pottsville section) of the upper Schuylkill Member and is probably about equal

in age to shales within the lower Sharp Mountain conglomerates (beds "M" and "N" of White's Pottsville section). He also notes that the Campbell's Ledge flora is equivalent to that of the Mercer coals of western Pennsylvania, which falls in the upper part of Read's floral zone 8 and are Late Atokan age. Read (1944, p. 680 and Chart 6) indicates that the Campbell's Ledge is distinctly younger than Schuylkill Member and slightly older than Sharp Mountain.

Disconformably absent in the Northern field, therefore, are rocks equivalent to all of the Morrowan and most of the Atokan Ages of the Pennsylvanian and part to all of the Mississippian Period and some of the Late Devonian Period (Figure 15).

#### WHAT'S HAPPENING TO THE POTTSVILLE FORMATION?

Between the south edge of the Southern Anthracite field and the northeast end of the Northern Anthracite field, striking changes are affecting the Pottsville Formation, both internally and in its relationship to subjacent units. Specifically, several general facts are fairly well established which raise questions requiring mutually consistent answers throughout the Anthracite area. These are:

1. In the Southern and Middle Anthracite fields, the interval from the top of the Mauch Chunk Formation to the base of the Sharp Mountain Member of the Pottsville is a maximum of about 1250 feet along the south edge of the Southern field south and southwest of Tower City (Wood and others, 1969, Figs. 36 and 37). Here, the Tumbling Run is about 600 feet and the Schuylkill is about 650 feet. This declines to 825 feet at Pottsville (Tumbling Run, 525 feet; Schuylkill, 300 feet), to 240 feet (all Tumbling Run) at West Hazleton (Stop 12) on the north edge of the Eastern Middle field, and to zero in the Northern field (Figure 16).
2. The Sharp Mountain Member thins from a reported maximum of over 400 feet at the east end of the Southern field to about 200 feet  $\pm$  100 feet elsewhere (Meckel, 1964, Fig. 37). The Sharp Mountain is present throughout all four fields (Figure 16).
3. In the Northern field, the entire Pottsville is composed of the Sharp Mountain Member plus the thin and intermittently present Campbell's Ledge shale which underlies the Sharp Mountain and may interfinger with it. The Tumbling Run and Schuylkill Members are absent in the Northern field (Figure 16). The Campbell's Ledge shale is not known to occur other than in the Northern field.
4. There is some loss of section at the base of the Tumbling Run Member by virtue of the appearance red coloration in some of the finer clastics, thus technically raising the Mauch Chunk-Pottsville contact in the stratigraphic sequence. The equivalent rocks, however, are otherwise more or less similar (Figure 16).
5. There is some depositional thinning of the Tumbling Run Member northward or northwestward away from the southeastern source area and the axis of maximum sediment accumulation and subsidence in the geosynclinal trough (Meckel, 1964, Figs. 35 and 37; Wood and others, 1969, Figs. 36 and 38).

6. The main direction of thinning of the Schuylkill Member is southwest to northeast (Meckel, 1964, Fig. 36 and Wood and others, 1969, Fig. 37). Between the area a few miles south of Tower City and Pottsville, it declines from over 650 feet to 300 feet. This thinning direction is almost 90 degrees to the direction of sediment transport and nearly parallel to the axis of the depositional basin. As pointed out by Meckel (1964, p. 103), "... the lithofacies trends of the Schuylkill bear no systematic relation to isopach contours." These facts are contrary to what would be expected if thinning were principally due to the effects of distance from source and reduced subsidence northward from the main axis of the geosynclinal basin.
7. As far as is known, there is no significant disconformity or time hiatus anywhere within the stratigraphic interval including the Mauch Chunk upper member, Tumbling Run Member, and Schuylkill Member.
8. In the Northern field, the Sharp Mountain and, where present, the Campbell's Ledge shale overlie a large disconformity. The rocks subjacent to the disconformity range downward from the lower member of the Mauch Chunk Formation at the southwest end of the Northern field to Catskill Formation at the northeast end (Figure 16). The time represented by this hiatus extends from at least late Atokan, based upon the Campbell's Ledge flora, to a generally accepted Late Mississippian (Chesterian) age for the Mauch Chunk lower member and to Late Devonian (Chataquan) age for the Catskill (Figure 15).
9. In the Southern field, with all members of the Pottsville Formation present, the Lower to Middle Pennsylvanian floral succession (Read floral zones 4 through 10) is also present except for zones 7 and 8, which are missing near the contact between the Schuylkill and Sharp Mountain Members (Figure 15).
10. The Campbell's Ledge flora (Figure 15) is as old or older than any known flora of the Sharp Mountain Member and is younger than any flora of the Schuylkill Member (Read, 1944, p. 680 and Chart 6).
11. Since both the Mauch Chunk lower member and the Sharp Mountain Member are present in the Northern field, the south-tilted uplift and extensive erosion of that area had to take place sometime within the period between deposition of these two units, i.e. sometime during the period that the middle and upper Mauch Chunk members and Tumbling Run and Schuylkill Members of the Pottsville Formation were being deposited in the basin a few tens of miles to the south.

Five major questions concerning the Pottsville Formation in the Anthracite area which require answers are:

1. What is causing the decline in thickness of the combined Tumbling Run and Schuylkill Formations from 1250 feet south and southwest of Tower City to 825 feet at Pottsville to 240 feet at West Hazleton and to zero in the Northern field?
2. What can best explain the southwest to northeast thinning trend of the Schuylkill Member?

3. What becomes of the large disconformity below the Sharp Mountain Member in passing southward from the Northern field to the other fields?
4. What became of the large mass of sediments eroded from the area of the Northern field, if at the same time the Mauch Chunk upper and middle members, Tumbling Run Member, and Schuylkill Member were being deposited a short distance to the south?
5. How can the absence of floral zone 7 and most or all of floral zone 8 from the biostratigraphic succession be explained?

#### THE CASE FOR A REGIONAL SUB-SHARP MOUNTAIN DISCONFORMITY

The first to address these questions was Read (1944, p. 680-681 and Chart 6, columns 6 and 7. Note: The "Pottsville congl." of column 6 and "Goose egg congl." of column 7 are the Sharp Mountain Member of present usage, and the section containing "Lykens no. 2 coal" through "Lykens no. 7 coal" of column 7 is the combined Tumbling Run and Schuylkill Members of present usage). Based mostly upon the absence of his floral zones 7 and 8 in the Southern and Middle Fields, Read projected a major disconformity between the Sharp Mountain and underlying Schuylkill and Tumbling Run. From this, it can be reasonably be inferred that the loss of Schuylkill and Tumbling Run Members was principally erosional.

Read's concept of a major regional disconformity below the Sharp Mountain, extending to all Anthracite fields, does explain all five questions posed previously. The thinning of the Tumbling Run and Schuylkill Members can be explained as being, in part, the result of disconformable erosion, although depositional thinning and facies loss to the Mauch Chunk are not excluded. It does require that the Schuylkill Member be eroded away first before the Tumbling Run is affected in sequential order from north to south. In this regard, White (1900, p. 810ff) remarked that all floral specimens collected from Lykens Valley coals in the Western Middle field came from his "lower Lykens Division" (Tumbling Run) and none from his "Upper Lykens Division" (Schuylkill). The thinning trend direction of the Schuylkill Member is also compatible with a disconformity.

A widespread hiatus can account for the absence of the material eroded from the Northern field area by allowing it to be swept entirely out of the Anthracite area. It also explains the absence of floral zones 7 and 8, which was actually Read's main interest.

Wood and others (1969, p. 73-79) specifically reject the presence of a major disconformity below the Sharp Mountain Member, at least in the Southern field, stating (p. 74), "The upper contact of the Schuylkill is at the bottom of the basal conglomerate of the Sharp Mountain Member, which rests conformably on the finer grained rocks in the upper part of the Schuylkill." They further state (p. 74) that, "The constant stratigraphic position of the [Lykens Valley] No. 1 [coal] bed [of the Schuylkill Member] at 5 to 50 feet below the basal conglomerate of the Sharp Mountain Member supports the concept that the Schuylkill and Sharp Mountain are conformable."

In an earlier paper, Wood and others (1962, Fig. 74.2) show a correlation between the Pottsville type section and a section measured near the village of

Upper Lehigh on the north edge of the Eastern Middle field (about 8 miles north-east of Stop 12 at West Hazleton). They indicate that the Tumbling Run Member thins from 535 feet at Pottsville to 45 feet at Upper Lehigh, mostly through facies loss to the underlying Mauch Chunk upper member. At the same time the Schuylkill and Sharp Mountain decline from 300 feet to about 100 feet and from 275 feet to about 150 feet respectively, apparently by general depositional thinning.

Wood and others (1969, p. 79) conclude that the missing floral zones 7 and 8 may be present in the coarse basal conglomerates of the Sharp Mountain Member, presumably implying that the depositional environment was too hostile to permit preservation.

It seems reasonably clear that Wood and others (1962 and 1969) believe that all Pottsville stratigraphic thickness changes are the result of depositional thinning and loss of section at the base of the Tumbling Run to the Mauch Chunk Formation.

Meckel (1964, p. 36) recognizes that the Sharp Mountain Member rests unconformably on Mississippian rocks in the Northern field. At the same time, he explains the lack of Tumbling Run and Schuylkill in the Northern field as "thinning" (see p. 36 and footnote on p. 101) which presumably is to be interpreted to mean "depositional thinning." Meckel (p. 40) mentions Read's major hiatus briefly, but does not pursue the idea, apparently concluding that, if it exists at all, it is of little significance. He describes the Tumbling Run and Schuylkill Members as depositional wedges (p. 101), the thickness and distribution of which are controlled by relative rates of subsidence between the rapidly sinking trough to the south and the stable shelf to the north.

The interpretations given by Wood and others and Meckel provide an explanation for the thinning of the Tumbling Run and Schuylkill Members as loss of section at the base to the Mauch Chunk Formation combined with mass thinning of the units away from the source area and the effect of passing from the rapidly subsiding geosynclinal trough to the more stable cratonic margin. They do not deal with the fact that the Schuylkill Member actually thins in a direction normal to the direction of transport and parallel to the geosynclinal trend. It could be argued, however, that the Schuylkill Member is actually a depositional lobe and that the observed direction of thinning represents declining sedimentation lateral to the main input axis.

Their reason for the absence of floral zones 7 and 8, while possible, is difficult to accept upon close examination. Early Desmoinesian floral zone 9 forms (White's bed "M", 1900, p. 765) lie directly above the basal conglomerate of the Sharp Mountain Member and Late Atokan upper zone 8 forms lie directly below the conglomerate in the Campbell's Ledge Shale, leaving no room for zone 7 and most of zone 8 in the Sharp Mountain. As the Lykens Valley No. 1 coal of the Schuylkill Member contains a Late Morrowan zone 6 flora, the only other possible interval which might contain the missing floral zones is the sandstone and conglomerates of the uppermost Schuylkill Member between Lykens Valley No. 1 and the base of the Sharp Mountain Member. This interval ranges from 5 feet (Wood and others, 1969, p. 74) and 70 feet (Wood and others, 1956, p. 2071). This short, coarse-clastic, high-energy sequence is required to represent at least 5 million years, while the total Pottsville (up to 1500 to 1600 feet) spans only about 20 million years (Figure 15). This allows a maximum sedimen-

tation rate of 14 feet per million years, in sediments of a type that could put that much down in one flood.

Wood and others and Meckel do not directly deal with the problems of what becomes of the major disconformity below the Sharp Mountain in the Northern field nor the question of where the large volume of eroded sediment went. Although they do not clearly specify it to be the case, it can only be assumed that in their model the major disconformity of the Northern field disappears into a completely conformable Upper Mississippian-Pennsylvanian section to the south.

Across the Northern field from south to north, increasingly older rocks are beveled almost flat (judging from the way the Sharp Mountain is sheeted across the entire area). Therefore, it appears that the rocks were not only epeirogenically upwarped, but tilted toward the south in the direction of the nearby geosynclinal trough (Figure 16). It seems reasonable to assume that at least a very substantial part of the material eroded would be carried directly south and southwest into that trough -- the very trough which at the same time Wood and others and Meckel consider to be receiving an unbroken influx of Mauch Chunk, Tumbling Run and Schuylkill sediments from the south and southeast. Considering only the area of the Northern field (175 mi<sup>2</sup>) and just the 1,700 feet of Mauch Chunk, Pocono, and Spechty Kopf rocks which exist at the southwest end of the Northern field but are eroded away at the northeastern end (an average of 850 feet eroded), 28 cubic miles of sediment had to go somewhere. Undoubtedly, the area affected actually extended considerably beyond the limits of the present Northern Anthracite field. Clearly, this large volume of sediments issuing from a positive area less than 25 miles to the north should be intercalated with the sediments arriving from the south and southeast. There is no known instance of this occurring.

It may be that some complex structural obstacle operated to divert all the eroded material away from its logical southward course, but, if so, it is unknown and it subsequently failed to interfere, even slightly, with the northward building of the Sharp Mountain clastic sheet or the later Llewellyn Formation. At this point, it seems impossible to explain the total absence of any trace of the sediments eroded from the area of the Northern field, except by a regional uplift and disconformity involving the entire Anthracite area. Unless there is such a disconformity, unrecognized, somewhere in the thick middle member of the Mauch Chunk Formation, the best prospect is a regional continuation of the known disconformity below the Sharp Mountain of the Northern field as originally proposed by Read.

#### REFERENCES CITED

- Kehn, T. M., Glick, E. E., and Culbertson, W. C., 1966, Geology of the Ransom quadrangle, Lackawanna, Luzerne, and Wyoming Counties, Pennsylvania: U.S. Geological Survey Bulletin 1213, 81 p.
- Levine, J. R., and Slingerland, R., 1987, Upper Mississippian to Middle Pennsylvanian stratigraphic section, Pottsville, Pennsylvania, in Roy, D. C. (ed.), Northeast Section: Geological Society of America Centennial Field Guide, v. 5, p. 59-63.
- Meckel, L. W., Jr., 1964, Pottsville sedimentology, central Appalachians, unpublished Ph.D. dissertation, Johns Hopkins University, 412 p.
- Read, C. B., in Moore, R. C., and others, 1944, Correlation of Pennsylvanian formations of North America: Geological Society of America Bulletin, v. 55, p. 657-706.

- Read, C. B., and Mamay, S. H., 1964, Upper Paleozoic floral zones and floral provinces of the United States: U.S. Geological Survey, Professional Paper 454-K, 35 p.
- Rogers, H. D., 1836, First annual report of the State Geologist: Harrisburg, PA, 22 p.
- \_\_\_\_\_, 1838, Second annual report on the geological survey of the State of Pennsylvania: Harrisburg, PA, 93 p.
- White, C. D., 1900, The stratigraphic succession of the fossil floras of the Pottsville Formation in the Southern Anthracite Coal Field, Pennsylvania: U.S. Geological Survey, 20th Annual Report, p. 743-953.
- \_\_\_\_\_, 1904, Deposition of the Appalachian Pottsville: Geological Society of America Bulletin, v. 15, p. 267-282.
- Wood, G. H., Jr., Trexler, J. P., Arndt, H. H., Yelenosky, A., and Soren, J., 1956, Subdivision of the Pottsville Formation in Southern Anthracite Field, Pennsylvania: American Association of Petroleum Geologists Bulletin, v. 40, p. 2669-2688.
- Wood, G. H., Jr., Trexler, J. P., and Arndt, H. H., 1962, Pennsylvanian rocks of the southern part of the Anthracite region of eastern Pennsylvania: U.S. Geological Survey Professional Paper 450-C, p. C39-C42.
- Wood, G. H., Jr., Trexler, J. P., and Kehn, T. M., 1969, Geology of the west-central part of the Southern Anthracite field and adjoining areas: U.S. Geological Survey Professional Paper 602, 150 p.

TOSUDITE: Déjà Vu  
INTERMITTENT BLUE

by

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During the fall of 1979, a soft bluish mineral from the interstices of a quartz pebble conglomerate was brought to the Mineral Resources Division for identification. It was collected by Henry W. Schasse, then of the Geologic Mapping Division, who assumed that he had found a copper carbonate mineral in the Sharp Mountain [?] Member of the Pennsylvanian Pottsville Formation in Luzerne County. As collected and bagged by Schasse, the mineral was a medium blue. As he pulled it from the bag to show us, he was astonished to find that it was an extremely pale greenish blue, about the shade of his face. After some false starts and Schasse's finding another locality with less weathered material, the mineral was identified as tosudite, a regularly stratified mixed-layer clay mineral.

During the summer of 1987 an identical-appearing soft bluish mineral was found in a similar lithology of the Schuylkill Member of the Pottsville Formation in Schuylkill County by Jon D. Inners and Leonard J. Lentz of the Geologic Mapping Division, who tentatively assumed that they had found a copper carbonate mineral. Like Schasse, Inners and Lentz were a bit perplexed that their blue-in-the-field mineral was pale-greenish gray in the laboratory. Preliminary X-ray diffractometer data suggest that the mineral from the Schuylkill Member is also tosudite.

Tosudite is a dioctahedral chlorite-dioctahedral smectite, regularly interstratified clay mineral (G. W. Brindley, personal communication, 1980). It was named after the first scientist to study it, Professor Dr. Toshio "To" Sudo, who worked with material from the Kurata mine, Yamaguchi Prefecture, Japan (Shimoda, 1969; Nishiyama and others, 1975; and Ichikawa and Shimoda, 1976). Unlike the Pennsylvania tosudite localities, the Japanese localities are reported to be in Cretaceous-to-Tertiary rhyolites and altered tuffaceous wall rocks adjacent to gold-silver-quartz veins. Did the Anthracite region tosudite form from volcanic feldspars ground to oblivion during formation of the quartz pebble conglomerate? Or, is its formation a very late retrograde metamorphic phenomenon related genetically to pyrophyllite, dickite, and rectorite elsewhere in the region? Or, should we be looking for hydrothermal ore?

Schasse's two tosudite localities and the location of Inners' and Lentz's more recent discovery are shown in Figure 17. Schasse locality No. 1 is a jeep trail 0.95 mile (1.50 km) north of Humboldt Fire Tower on Little Sugarloaf Mountain, Hazle Township, Luzerne County, (40°57'09"N, 76°05'07"W). Schasse locality No. 2 was a pipeline excavation at 1790' elevation, 0.88 mile (1.40 km) south-southeast of Tomhicken, Hazle Township (40°57'23"N, 76°05'29"W) or about 2,300 feet (700 m) northwest of the first locality, within the same, faulted outcrop belt (H. W. Schasse, personal communication, 1980). Inners and Lentz No. 1 is from an outcrop between the northbound and southbound lanes of I-81, 0.7 mile (1.1 km) northeast of Delano and 0.5 mile (0.8 km) north-northeast Interchange 38 (40°50'32"N, 76°03'34"W). Inners and Lentz No. 1 is about 7.7 miles (12.4 km) south-southeast of Schasse No. 1.

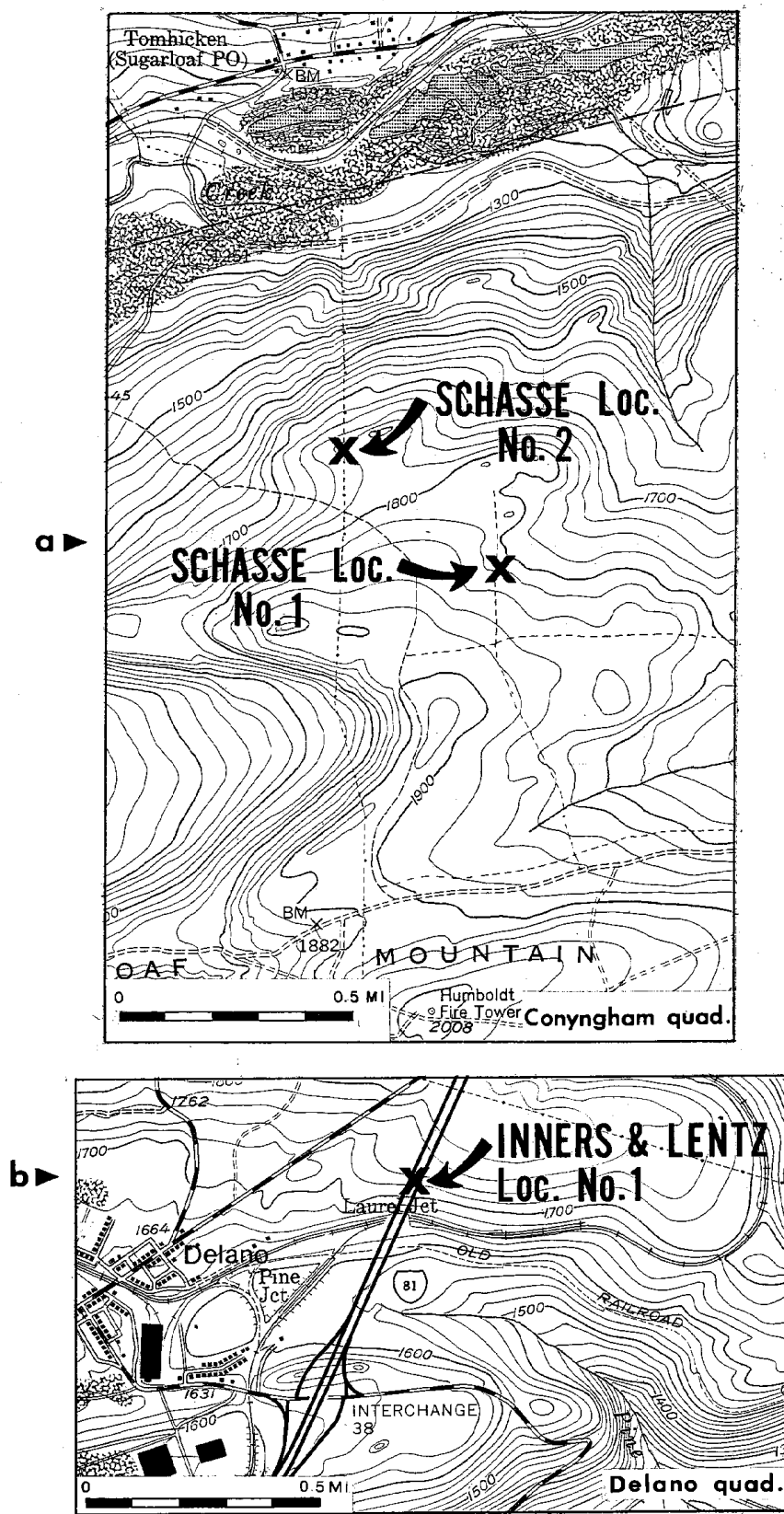


Figure 17. Locations of known tosudite localities in Pennsylvania. a. Schasse localities No. 1 and No. 2, Luzerne County. b. Inners and Lentz locality No. 1, Schuylkill County.

X-ray diffraction data for samples from each of the three Pennsylvania localities and the Takatama mine are given in Table 3. With the oriented amyl acetate-collodian technique used for the samples from Pennsylvania, each appears to be well-crystallized and to exhibit at least ten higher orders of the basal spacing.

Table 3. X-ray diffractometer data for tosudite from three localities in Pennsylvania and one locality from the Takatama mine, Fukushima Prefecture, Japan (Shimado, 1969) for comparison. Data for samples from Pennsylvania was obtained using collodian-amyl acetate smears.

|      | D79-298          |                    | D80-39           |                    | D88-29                  |                    | Takatama Mine<br>Fukushima Pref.<br>Japan |                    |
|------|------------------|--------------------|------------------|--------------------|-------------------------|--------------------|-------------------------------------------|--------------------|
|      | Schasse<br>No. 1 |                    | Schasse<br>No. 2 |                    | Inners & Lentz<br>No. 1 |                    |                                           |                    |
| hkl  | d, Å             | I/I <sub>100</sub> | d, Å             | I/I <sub>100</sub> | d, Å                    | I/I <sub>100</sub> | d, Å                                      | I/I <sub>100</sub> |
| 001  | 27.9             | 40                 | 30.7             | 60                 | 29.0                    | 36                 | 30.4                                      | 100                |
|      |                  |                    | 24.4             | 10*                |                         |                    |                                           |                    |
| 002  | 13.9             | 100                | 15.3             | 100                | 14.6                    | 100                | 15.2                                      | 75                 |
|      | 10.41            | 1                  | 14.55            | 15                 |                         |                    |                                           |                    |
|      |                  |                    | 12.24            | 8*                 |                         |                    |                                           |                    |
| 003  | 9.22             | 22                 | 9.20             | 33                 | 9.75                    | 10                 | 10.0                                      | 6                  |
|      |                  |                    | 7.68             | 24*                | 9.17                    | 71                 |                                           |                    |
| 004  | 7.00             | 4                  | 7.19             | 12                 | 7.33                    | 10                 | 7.56                                      | 6                  |
| 005  | 5.56             | 4                  |                  |                    | 5.86                    | 5                  | 5.98                                      | 1                  |
|      | 4.89             | 1                  |                  |                    |                         |                    |                                           |                    |
| 006  | 4.64             | 19                 | 5.12             | 15                 | 4.90                    | 25                 |                                           |                    |
|      |                  |                    | 4.85             | 5*                 |                         |                    |                                           |                    |
|      |                  |                    | 4.74             | 3                  |                         |                    | 5.01                                      | 22                 |
|      |                  |                    | 4.66             | 3                  | 4.60                    | 39                 |                                           |                    |
|      |                  |                    | 4.60             | 16                 |                         |                    | 4.48                                      | 30                 |
| 007  | 4.47             | 2                  | 4.47             | 15                 | 4.20                    | 3                  | 4.25                                      | 5                  |
| 008  | 3.48             | 12                 |                  |                    | 3.67                    | 8                  | 3.70                                      | 6                  |
|      |                  |                    | 3.58             | 5                  |                         |                    |                                           |                    |
| 009  | 3.06             | 10                 | 3.42             | 8,B                | 3.26                    | 7                  | 3.30                                      | 8                  |
|      | 2.83             | 1                  |                  |                    | 3.06                    | 90                 |                                           |                    |
|      | 2.81             | 1                  |                  |                    |                         |                    |                                           |                    |
|      | 2.80             | 2                  |                  |                    |                         |                    |                                           |                    |
| 0010 | 2.77             | 4,B                | 3.07             | 35                 |                         |                    | 2.95                                      | 6                  |
| 0011 |                  |                    |                  |                    | 2.67                    | <1                 |                                           |                    |
|      |                  |                    | 2.80             | 2,B                |                         |                    |                                           |                    |
| 0012 |                  |                    | 2.57             | 3                  | 2.42                    | <1                 | 2.56                                      | 12                 |
|      |                  |                    |                  |                    | 2.30                    | 4                  |                                           |                    |
|      |                  |                    | 1.836            | 1                  |                         |                    |                                           |                    |
| 060  | 1.494±0.001      |                    | 1.493±0.001      |                    | 1.532±0.002**           |                    | 1.493                                     |                    |

\*Probable impurity of rectorite, a smectite-illite mixed layer mineral.

\*\*Unreliable estimate of 060 for D88-29 because of a quartz impurity. hkl indices given are only tentative assumptions. Spacings for D79-298 verified with XRD scan D79-299 run on double stick tape to avoid possibility of solvate expansion of D79-298 with collodian-amyl acetate.

The higher orders of basal spacings are not always in exact agreement with the 001 spacing. Several explanations are possible. One is that there might be interference between the high-order basal spacings and non-basal hkl spacings for the individual chlorite or smectite components. Another is that the hydration state of the expandable component might change during the course of a diffractometer run, while exposed to radiation in the warm confines of the sample chamber. It is also possible that not all of the sample X-rayed might have been at the same initial state of hydration.

Schasse No. 2 (XRD scan D80-39) yielded unidentified spacings at 24.4Å, 12.24Å, and 7.68Å, etc. (having the ratios 1, 1/2, and 1/3). Assuming that they are not the 005, 0010, and 0016 orders of "super tosudite" with a 123Å basal spacing, then the sample probably contains a trace impurity of rectorite (formerly called "allevardite"). Rectorite is a regularly interlayered smectite-illite with basal spacings of about 25Å. It has been identified from elsewhere in the Anthracite fields and is known to occur with tosudite, dickite and pyrophyllite from the Toshio deposit, Japan (Nishiyama et al., 1975).

Quantitative major and minor oxide analyses for tosudite from Schasse locality No. 2 and the Takatama mine are presented in Table 4. Not surprisingly, analyses for tosudite reported in the literature are quite variable. Compared to chemical analyses for tosudite from the Takatama mine, Schasse No. 2 is very low in interlayer cations such as K<sub>2</sub>O, Na<sub>2</sub>O, and CaO, suggesting that much H<sub>2</sub>O is present in this position. The presence of rectorite, suspected from the X-ray power diffraction data, suggests that much of even these low amounts of K<sub>2</sub>O, Na<sub>2</sub>O, and CaO is present in intermixed rectorite. This essentially water-supported layer may account for the unstable, intermittent properties of the Pennsylvania tosudite.

Table 4. Major and minor oxide data for tosudite from Schasse No. 2 locality, Luzerne County, Pa.

|                                | Schasse<br>No. 2* | Probable Error | Takatama Mine<br>Fukushima Prefecture |
|--------------------------------|-------------------|----------------|---------------------------------------|
| SiO <sub>2</sub>               | 42.8              | ±1             | 42.14                                 |
| Al <sub>2</sub> O <sub>3</sub> | 39.7              | .5             | 37.38                                 |
| Total Fe as FeO                | 1.81              | .05            | 0.27                                  |
| MgO                            | 1.61              | .05            | .08                                   |
| CaO                            | .03               | .01            | 1.65                                  |
| Na <sub>2</sub> O              | .18               | .02            | .15                                   |
| K <sub>2</sub> O               | .22               | .02            | 1.40                                  |
| TiO <sub>2</sub>               | .03               | .02            |                                       |
| MnO                            | .003              | .001           |                                       |
| Total                          | <u>86.383</u>     |                |                                       |

\*Atomic absorption and flame emission analyses by the authors. Li, reported in some analyses, was not determined because of the lithium metaborate dissolution procedure used. Sample purified by gentle grinding in an agate mortar and pestle and removal of hard impurities recognized by "feel."

In conclusion, until such time as more definitive data become available, the blue-today, gray-tomorrow mineral from Luzerne and Schuylkill Counties is being described as tosudite. Further research by others of this well-

crystallized clay mineral and the genetic significance of tosudite, rectorite, dickite, and pyrophyllite in the Anthracite region is encouraged.

#### REFERENCES CITED

- Ichikawa, A., and Shimoda, S., 1976, Tosudite from the Hokuno Mine Hokuno Gifu Prefecture, Japan: Clays and Clay Minerals, v. 24, p. 142-148.
- Nishiyama, T., Shimoda, S., Shimosaka, K., and Kanacka, S., 1975, Lithium-bearing tosudite: Clays and Clay Minerals, v. 23, p. 337-342.
- Shimoda, S., 1969, New data for tosudite: Clays and Clay Minerals, v. 17, p. 179-184.

# CARBONIFEROUS SEAT-EARTH FLORAS IN THE ANTHRACITE FIELDS

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## INTRODUCTION

Carboniferous seat-earth floras have not been studied intensively, yet these fossil assemblages are critical indicators of the environmental and edaphic characteristics of swamps and the paleoecology of swamp plant communities. In the following discussion, the origin and biological and paleoecological significance of seat-earth floras will be considered; in the final section, the paleobiological, paleoecological, and sedimentological characteristics of a particular seat-earth flora in an abandoned strip mine in the Hazleton quadrangle, Pennsylvania, will be discussed.

## OCCURRENCE AND CHARACTERISTICS OF CARBONACEOUS SHALES AND FLORAS

Black, carbonaceous, fossiliferous, rooted, shale seat-earth is common below many Pennsylvanian coal beds in the Appalachian basin, but, because the beds are flat lying, the seat earths are covered after mining. In the Anthracite region, the coal beds dip steeply as a result of the intense structural deformation, and long, continuous seat-earth bedding-plane surfaces are typically exposed in the strip-mine highwalls. These surfaces are ideally suited for studies of seat-earth floras.

The floras in seat-earths hold important clues to the sedimentology, paleobotany, paleoecology, and paleoclimate of the coal region. The origin and significance of carbonaceous seat-earth shale and its flora are discussed in detail in Wnuk (1985a, 1986) and Wnuk and Pfefferkorn (1987) and are summarized in the discussion that follows.

Seat-earth floras have distinctive plant-part compositions, consisting mainly of the fossilized remains of large trunks and branches. Trunks as long as 21.5 m have been measured, and even longer trunks may be present in some inaccessible strip mine highwalls. Seat-earth floras differ from most preserved fossil assemblages in that foliage and small branch remains are rare or non-existent in seat earths, although, under certain conditions (Wnuk and Pfefferkorn, 1987), these remains are common and even dominant.

The carbonaceous shales containing the distinctive trunk fossil floras are associated with medium- to light-gray, massive, rooted, but otherwise unfossiliferous shale or siltstone beds. The carbonaceous shales range from 2 to 30 cm in thickness and typically grade upward into the overlying coal.

## ORIGIN AND SIGNIFICANCE OF CARBONACEOUS SEAT-EARTHS AND ASSOCIATED FLORAS

Wnuk (1986) and Wnuk and Pfefferkorn (1987) proposed that the floras in the carbonaceous seat-earths are in situ and that they flourished in paleoenvironments transitional between clastic- and peat-swamp conditions. In order to explain the origin of the carbonaceous shales, it is fundamental to demonstrate the in situ accumulation of these floras. Wnuk and Pfefferkorn (1987) studied a

carbonaceous shale unit in the Bernice basin in the Western Northern Anthracite field (Sullivan County, Pennsylvania) and presented several arguments that support an in situ genesis. Because most rooted carbonaceous shale deposits in the Anthracite fields are similar to the Bernice basin deposit in lithology and floral content, the origins of all of these shale units are presumed to have been similar.

Trunk accumulations are widespread in many stratigraphic units. For example, trunk assemblages have been found at the base of all of the Mammoth coalbed splits in the Western Middle Anthracite field and in parts of the Southern Anthracite field. If these assemblages were allochthonous, their widespread distribution implies that the trunks were transported into the swamp during a major flood event. In modern sediments, flood-transported trunks are deposited in association with coarse clastic sediments. Trunk assemblages tend not to be associated with rooted horizons and are never drifted into areas occupied by a standing forest because the standing vegetation filters the floating debris from the water column before it enters the forest (McQueen, 1969; Wnuk and Pfefferkorn, 1987). The trunks in the carbonaceous shales occur in very fine silt and in clay-sized sediments, show no evidence of mechanical abrasion or biological degradation which is an expected consequence of transport, and are always associated with rooted sediments. Also the root bases of upright trees are often found in the upper parts of the carbonaceous shale units. Preservation of these root bases indicates that the bases were occupied by standing lycophytes; otherwise, they would have been destroyed by erosion and/or rooturbation from subsequent floras. Since trunks and root bases occur on the same surface, the preferred interpretation for the origin of the trunks is the in situ collapse of the standing swamp forest. Wnuk and Pfefferkorn (1987) presented evidence from Bernice that many stems break above the root base, so the most basal part of the trunk remains standing long after the stems collapse and continues to protect the rooted hummock from erosion and bioturbation while the accumulation is being buried.

Wnuk (1986) suggested that swamp environments can be classified on the basis of the amount of clastic sediment input. Clastic swamps and peat swamps are regarded as end members in this classification. The clastic swamps form on inorganic mineral substrates, and the system accumulates little or no organic material. Peat swamps are depositional systems that are dominated by the accumulation of organic materials and have little or no clastic sediment input. Carbonaceous shales form in environments intermediate between these end members. The edaphic conditions in carbonaceous-shale environments favor the accumulation of organic materials during clastic deposition in the swamp. The amount of organic matter in these carbonaceous shales can range from isolated coalified trunk compressions in units that are predominantly gray to such high proportions that the unit resembles impure coal. Through time, the amount of clastic sedimentation usually decreases, and many carbonaceous shales grade into thick coalbeds. Renewed sediment influx may arrest the transition from carbonaceous shale to coal at any stage, and, at many places, the seat-earth is characterized by multiple carbonaceous shale beds.

Carbonaceous shale is associated with coal beds at most places in the Anthracite fields, but individual shale occurrences are laterally discontinuous and lenticular. The carbonaceous shales grade laterally into gray, rooted, unfossiliferous seat-earths. Wnuk (1985a, 1986) postulated that carbonaceous shales accumulate in those parts of the swamp where the water tables are

highest. The interpretation of some of the foliage-bearing trunk accumulations as lacustrine deposits supports this conclusion (Wnuk and Pfefferkorn, 1987).

Until the origin of carbonaceous shale floras was recognized, in situ floras were not commonly noted in clastic sediments. Most fossil assemblages in clastic strata are transported and typically represent mixtures of components derived from more than one plant community. Environmental and ecological reconstructions based on transported assemblages must be interpreted cautiously, because the information derived from these intermixed assemblages can distort interpretations of the ecological and environmental relationships (Spicer, 1981; Scheiing and Pfefferkorn, 1984; Ferguson, 1985).

Composition, ecology, and structure of the plant communities outside of the peat swamp are poorly understood even though clastic environments represent the majority of the vegetated terrestrial surface. In situ plant fossil occurrences have been reported in clastic strata characterized by high sedimentation rates (Gastaldo, 1986), but these occurrences represent specialized plant communities that usually colonize unstable shifting substrates. These plant communities are not a representative sampling of the plant community types that would be expected in a typical Pennsylvanian tropical-forest system.

Carbonaceous shale floras grew in widely distributed, clastic, lowland environments and are commonly preserved in the fossil record. Studies of these floras provide several unique benefits to paleobotany. Plant growth and development are responsive to external stimuli caused by climatic, environmental, and edaphic conditions and by biotic interactions with other plants and animals. In most cases, these external stimuli produce specific and identifiable effects on the morphological and/or anatomical characteristics of the plant. The same external stimuli also have a pronounced effect on the organization, structure, and composition of entire plant communities. Careful studies of plant anatomy and morphology and of the composition of plant fossil assemblages can be used to reconstruct plant community composition, architecture and organization, niche partitioning among species, and the effects of edaphic and climatic conditions on plant growth and development (DiMichele and others, 1985; Phillips and others, 1985; Wnuk, 1985b; Wnuk and Pfefferkorn, 1984).

Because the fossilized plant remains in the carbonaceous shales are large, they are ideally suited for the kinds of morphometric analysis used to reconstruct the growth and development history of individual species (Wnuk and Pfefferkorn, 1984; Wnuk, 1985b). The preservational dynamics of the floras suggest that the plant remains belong to relatively intact community associations (although certain floral elements probably experience selective degradation). Studies of natural community assemblages that provide insights into community organization and ecology enable the reconstruction of local and regional environmental, climatic, and edaphic variation (Wnuk and Pfefferkorn, 1987) and permit the reconstruction of biogeographic variation in community structure and composition.

#### CARBONACEOUS SHALE IN THE EASTERN MIDDLE ANTHRACITE FIELD

Most studies of the carbonaceous shale floras have been in the Western Middle and Western Northern Anthracite fields. Preliminary investigations in the Hazleton quadrangle in the Eastern Middle field have identified several small carbonaceous shale outcrops where paleobotanical and lithological com-

positions resemble those of typical Western Middle field carbonaceous shale. However, the large highwall exposures of strip mines in the extensive Mammoth coalbed contain floral assemblages compositionally distinct from those farther to the west. It has not been determined if the compositional differences between floras beneath the Mammoth coal bed in the Western Middle and the Eastern Middle Anthracite fields represent broad regional variations in floral patterns or are localized phenomena.

The seat-earth strata that have been investigated in the strip mines in the Hazleton quadrangle (Figure 18, locations 59-64) are coarser grained than units farther west, and at many places the shales are intensely rooted but contain no trunk fossils. Fossil trunk floras have been identified on highwalls at two strip mines in the Hazleton quadrangle; the Amscot mine in the Wharton (?) coalbed (J. D. Inners, oral communication, 1987), approximately 0.7 km northeast of Milnesville (Figure 18, location 62), and a mine in the Mammoth coalbed west of US Route 309, 0.5 km north of Milnesville (Figure 18, location 63). Floras are compositionally similar at both sites. They consist of Calamites trunk fragments as much as 22 cm in diameter (but less than 1 m long), smaller Calamites axes, and some Calamites foliage (Asterophyllites equisetiformis). Abundant Stigmaria (lycopod roots) are also present.

These locations contain the first reported occurrences of a Calamites-dominated carbonaceous shale flora in the Anthracite region, although calamitean and lycopod-Calamites-dominated floras are known beyond the Anthracite basin (Gastaldo, 1986). In the Western Middle field, Calamites is a common constituent of the flora in the basal part of carbonaceous shale units at many places, but Calamites is succeeded everywhere by a lycopod- or lycopod-pteridosperm-dominated vegetation.

Several interpretations for the origin of this calamite assemblage are possible. Its stratigraphic position as a seat-earth flora indicates an in situ genesis. However, known characteristics of calamitean ecology suggest several alternatives. Scott (1978) stated that Calamites was associated with a lacustrine facies at many places and that the plant commonly grew along lake margins. The strata underlying the Mammoth coalbed (Figure 19) contain large amounts of laminated and wavy-bedded siltstone and shale that have been interpreted to be lake deposits. The sequence between the unnamed coalbed and the Mammoth coalbed (Figure 19) is interpreted to represent a cycle of rising and falling water levels. Rising water drowned the peat bed, creating a lake basin that later filled with sediments (or was drained) and was then colonized by land plants. The first colonizers are presumed to have been the lake-margin Calamites.

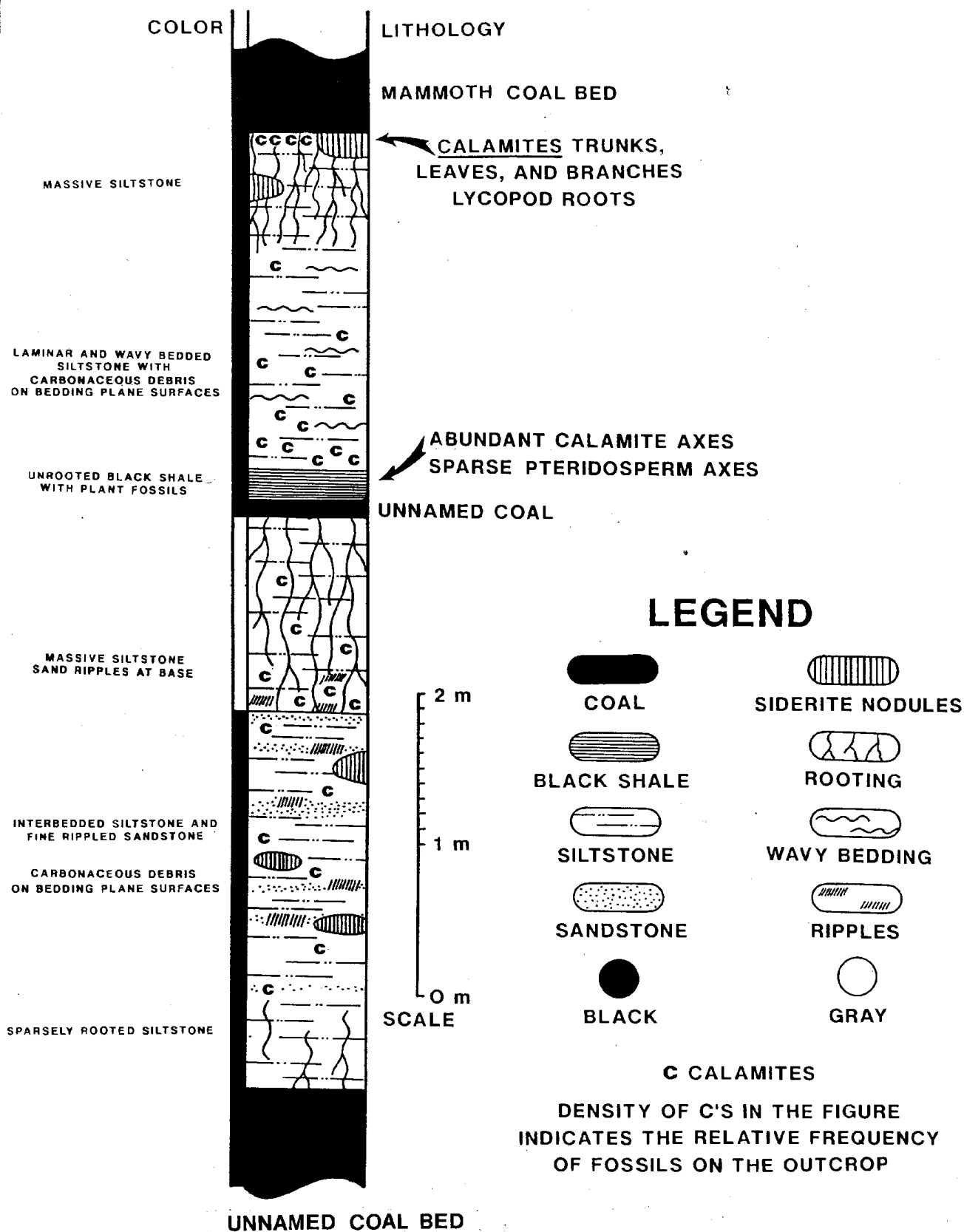
Since lycopod trunks are not associated with the Calamites stems, the two plant groups may not have co-existed at this site. Rather, the Calamites may have been displaced by a lycopod-dominated, peat-forming vegetation. Pfefferkorn and Zodrow (1982) described a similar lycopod-calamitean succession.

A third alternative explanation is that the calamitean component was a transported assemblage incorporated into the lake deposits before the sediments were colonized by the lycopods. According to this interpretation, the Calamites flora has no successional affinities with the subsequent lycopod community.



Figure 18. Seat-earth localities in the Hazleton quadrangle.

# FIGURE 19. STRATIGRAPHY OF SITE 63



## CONCLUDING REMARKS

The perceived differences in floral assemblages between the Eastern and Western Middle fields suggests two questions. Are there indeed broad regional differences in plant communities from east to west across the Anthracite region, and, if so, what environmental, edaphic, and climatic factors are responsible for these differences? Very likely, collections from the few sites that have been investigated in the Eastern Middle field do not represent the majority of the carbonaceous-shale floras, but, instead, probably represent particular plant community types. Only with continued study across the basins can these questions be resolved.

## REFERENCES CITED

- DIMichele, W. A., Phillips, T. L., and Peppers, R. A., 1985, The influence of climate on the distribution and evolution of Pennsylvanian coal-swamp plants, In Tiffney, B. H. (ed.), *Geological factors and the evolution of plants*: New Haven, Yale University Press, p. 223-256.
- Ferguson, D. K., 1985, The origin of leaf assemblages - new light on an old problem: *Review of Palaeobotany and Palynology*, v. 46, p. 117-188.
- Gastaldo, R. A., 1986, Implications on the paleoecology of autochthonous lycopods in clastic sedimentary environments of the Early Pennsylvanian of Alabama: *Palaeogeography, Palaeoclimatology, and Palaeoecology*, v. 53, p. 191-212.
- McQueen, D. R., 1969, Macroscopic plant remains in recent lake sediments: *Tuatara*, v. 17, p. 13-19.
- Phillips, T. L., Peppers, R. A., and DIMichele, W. A., 1985, Stratigraphic and inter-regional changes in Pennsylvanian coal swamp vegetation: environmental inferences: *International Journal of Coal Geology*, v. 5, p. 43-109.
- Pfefferkorn, H. W., and Zodrow, E. L., 1982, A comparison of standing forests from the Pennsylvanian of Nova Scotia with modern tropical forests (abs.): *Botanical Society of America Abstracts for 1982 Annual Meeting*, p. 62-63.
- Scheilng, M. H., and Pfefferkorn, H. W., 1984, The taphonomy of land plants in the Orinoco Delta: a model for the incorporation of plant parts in clastic sediments of late Carboniferous age of Euramerica: *Review of Palaeobotany and Palynology*, v. 41, p. 205-240.
- Scott, A. C., 1978, Sedimentological and ecological control of Westphalian B plant assemblages from West Yorkshire: *Yorkshire Geological Society Proceedings*, v. 41, p. 461-508.
- Spicer, R. A., 1981, The sorting and deposition of allochthonous plant material in a modern environment at Silwood Lake, Silwood Park, Berkshire, England: *U.S. Geological Survey Professional Paper 1143*, 77 p.
- Wnuk, C., 1985a, Transition from clastic to peat swamp sedimentation in the Appalachian basin Pennsylvanian swamps in West Virginia and Pennsylvania (abs.): *American Association of Petroleum Geologists Bulletin*, v. 69, p. 1452.
- \_\_\_\_\_, 1985b, The ontogeny and paleoecology of Lepidodendron rimosum and Lepidodendron bretonense trees from the Middle Pennsylvanian of the Bernice Basin (Sullivan County, Pennsylvania): *Palaeontographica*, v. 195B, p. 153-181.
- \_\_\_\_\_, 1986, Preliminary observations on the paleoecological significance and taphonomic history of underclay floras, In *Proceedings of the New River Symposium* (Wytheville, VA): Oak Hill, Eastern National Park and Monument Association, p. 89-98.
- Wnuk, C., and Pfefferkorn, H. W., 1984, The life habits and paleoecology of Middle Pennsylvanian medullosan pteridosperms based on an in situ assemblage from the Bernice Basin (Sullivan County, Pennsylvania, U.S.A.): *Review of Palaeobotany and Palynology*, v. 41, p. 329-351.
- \_\_\_\_\_, 1987, A Pennsylvanian age terrestrial storm deposit: using plant fossils to characterize the history of sediment accumulation: *Journal of Sedimentary Petrology*, v. 57, p. 212-221.

# THE MINE DRAINAGE TUNNELS OF THE EASTERN MIDDLE ANTHRACITE FIELD

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## INTRODUCTION

It was the morning of February 4, 1891 when two miners were preparing to fire a shot in the No. 10 slope of the J. C. Hayden and Company mine. Their mine map indicated that they were 60 feet from the No. 8 slope which was abandoned several years before and was flooded. In reality, they were only 5 feet away from the old slope. When the shot was fired, it opened up the old workings and the water poured in. The two miners were swept to a point where they could swim to safety. Seventeen other miners were not as fortunate and were trapped by the flood (Tyson, 1977). Miraculously, four men survived to be rescued twenty days later.

This incident, known as the Jeansville Disaster, occurred in the Eastern Middle Anthracite field. It illustrates the problem, and one serious consequence of, ground water in the early anthracite mines. One method which was widely used to dewater the deep mines was the mine drainage tunnel. This article presents a geological, historical and environmental overview of the mine drainage tunnels in the Eastern Middle field.

## BEFORE THE TUNNELS

The early mining companies used several techniques to minimize the amount of water entering the mines. Sidehill ditches were dug on the flanks of the ridges surrounding the mine basin in order to collect and divert surface water runoff around the coal outcrops where it could easily enter the mine. Wooden flumes (raised wooden channels) were built to carry the creeks that crossed the mine basin thus minimizing stream bed leakage into the mine. Some creeks were purposely seeded with silt in an attempt to make the stream bed impervious. These techniques only served to minimize the amount of water entering the mine. Direct precipitation and groundwater infiltration from adjacent areas necessitated the use of steam driven pumps to bring the mine water to the surface.

As the mines continued to meet the demand of a rapidly industrializing country for more coal, the miners followed the coal deeper into the ground. Strip mining, first introduced in the 1870's, saw greater use. The increased depth of the mines coupled with increased infiltration due to strip mining resulted in the need for greater pumping capabilities. Sudden influxes of water from storm events, snow melt or subsidence near a creek channel often required shutting down the mine until the water could be pumped out. Pump maintenance was another concern due to the corrosive nature of mine drainage. All these factors contributed to an increase in operating costs.

The solution of this problem was the mine drainage tunnel. There are 11 drainage tunnels in the Eastern Middle field; more than in any other anthracite field in Pennsylvania (Figure 20). These tunnels are not to be confused with mine workings (gangways and breasts) which were driven in coal as part of the mining process. Mine drainage tunnels are rock tunnels generally driven cross-

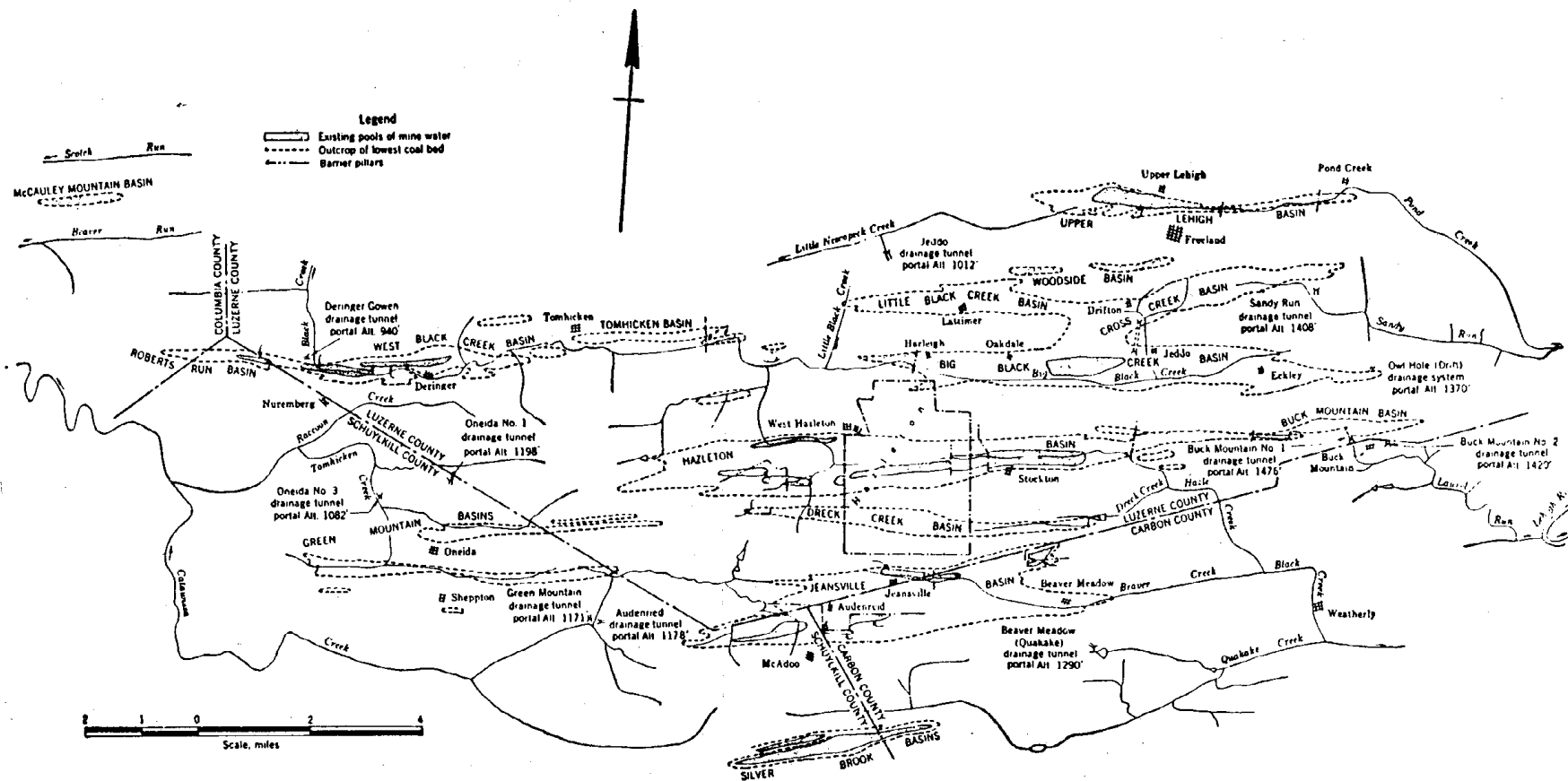


Figure 20. Mine drainage tunnels of the Eastern Middle field (slightly modified from Ash and others, 1950).

strike for the purpose of conveying mine drainage to a surface stream outside of the coal measures. In some instances, if the geometry of the basin was favorable, the tunnels tapped the lowest point in the mine and provided gravity drainage that allowed the mine to be dewatered without pumping. Other tunnels, coupled with pumping systems, operated as drainage levels. A drainage level is a horizontal tunnel which intersects the surfaces and serves as a conduit for a pump discharge. These tunnels reduced the head against which a pump had to work to reach the surface.

## GEOLOGY

The discontinuous coal measures in the vicinity of the City of Hazleton together comprise the Eastern Middle field, the smallest of the four anthracite fields in Pennsylvania. The field is 23 miles in length (east-west), 7 miles wide (north-south) and contains 33 square miles underlain by coal (Ash and others, 1950). Topographically the area can be described as an undulating plateau of moderate relief at an average elevation of approximately 1,600 feet Mean Sea Level (ft MSL). This plateau is surrounded by broad, deep non-coal valleys at an average elevation of approximately 1,000 feet MSL.

The geologic structure consists of a series of anticlines with broad flat crests and shallow intervening synclinal basins. Anthracite is found mostly in the Llewellyn Formation which occupies the basins. Up to 20 coals are found in the Llewellyn Formation in the Eastern Middle field, of which 10 were principally mined. The underlying Pottsville Formation consists predominantly of white to light-gray quartzose conglomerate and sandstone. It contains a few locally mineable coalbeds, but the Lykens Valley seams that are well developed in the Southern field are virtually absent in the Eastern Middle.

The red and green sandstones, siltstones and shales of the Mauch Chunk Formation underlie the Pottsville Formation. These beds outcrop on the crests of many of the anticlinal ridges and floor the deep valleys that surround the plateau (e.g., the Conyngham and Quakake Valleys).

As an example of the lithologies and structure found in the Eastern Middle field, the following excerpt describes the conditions encountered during the construction of the Oneida No. 3 Drainage Tunnel in 1913 (Reed, 1914):

The tunnel is 7 x 9 ft. in cross-section, and is driven its entire length (7,040 ft et.) through solid rock. This ranges from hard, close-grained, dark conglomerate, pitching at an angle of 45 deg., at the inside end, successively to coarse-grained conglomerate bluerock of a close grain, and finally red shale, at the surface end of the tunnel. The pitch of the rock flattens out, from the inside end, until it is practically horizontal when the surface is reached.

To understand why mine drainage tunnels were commonly used in the Eastern Middle field, two of its characteristics must be discussed. First, most of the coal basins (the larger ones, such as the Hazleton basin, being exceptions) are perched above or nearly above the elevation of the surface drainage networks in the surrounding non-coal valleys. Thus, it was feasible in many cases to drive a tunnel with a sufficient gradient to drain most, if not all, of each individual mine by gravity. In the three other Anthracite fields, the coal measures extend well below the elevation of the local surface drainage networks. For

example, the Northern field is essentially a single basin which underlies the Wyoming-Lackawanna Valley. A large part of the coal basin is below the elevation of the North Branch Susquehanna River or nearly 1,500 feet below sea level at its deepest point (Ash and others, 1949). Similar conditions also exist in the Western Middle and Southern fields as well, such that pumping of the mines below the elevation of the local drainage network was required.

Secondly, the discontinuous nature of the basins in the Eastern Middle field has in effect hydrologically isolated each basin. Thus, individual tunnels were constructed to dewater the individual basins.

### TUNNEL CONSTRUCTION

The driving of a rock tunnel is unlike the mining of coal. A different class of miner and equipment is required (Donaldson, 1910). While many mining companies had the equipment and skills to drive rock tunnels, they contracted this work, particularly a project as large as a drainage tunnel, to private contractors. The workmen themselves were considered "hard rock miners" rather than coal miners. It is interesting to note that many "hard rock miners" came from the Tyrol region of Northern Italy and Austria. These men were well suited since they had experience in the quarries, roads and railroad tunnels of the Alps. Typically, work on a tunnel was conducted around the clock. During the construction of the Oneida No. 3 drainage tunnel, boarding houses were set up on each end of the tunnel to provide food and beds to the men as they came off each shift. The labor force required to construct this tunnel include 1 superintendent, 2 foremen, 6 chargemen, 18 drill runners, 18 helpers, 6 muckbosses, 24 muckers, 4 drivers, 3 dumpmen, 1 stableman, 2 compressor runners, 4-8 blacksmiths and helpers, 1 timekeeper and 1 clerk (Reed, 1914).

The tunnels were generally driven from two headings. One heading advanced from the discharge end of the creek, upgrade towards the mine. Groundwater that was encountered could easily drain from the working face and out the tunnel. The second heading advanced from the mine end in the downgrade direction. Groundwater that accumulated in this heading had to be pumped back to the mine to be handled by the existing mine pumping system.

When surveying the route of a drainage tunnel, the length of the tunnel and the fact that both portals could not be seen from a single point on the surface necessitated that an accurate surface survey be conducted to insure that both tunnel headings would eventually meet. Whether it was the skill of the contractor or the imagination of the author, all published accounts of the construction of the tunnels indicated that when the two headings met, they were either within one inch of each other or joined imperceptibly. Early rock tunnel surveying methods utilized control monuments established at each tunnel portal to provide reference points on which to sight the surveying instrument and maintain a correct bearing. To prevent the tunnel from meandering along this bearing as it was being driven, two weighted cords were suspended from the roof of the tunnel. The cords were set equi-distant on each side of the bearing to establish the working face (Durham, 1913). Thus, only the minimum amount of rock was removed to keep the tunnel on line.

The drainage tunnels were driven using steam or compressed air rock drills up to 2.5 inches in diameter (Cumming, 1951). Once drilled, the holes were packed with explosives and fired. The explosives that were used included dyna-

mite and forcite. Forcite was a milder form of dynamite which produced less smoke. Using these methods, the average rate of advance was on the order of 10 feet per day (Reed, 1914).

A cross-section of a typical tunnel is shown in Figure 21.

### TUNNEL HISTORY

The first drainage tunnel in the Eastern Middle field was the Buck Mountain No. 1 Tunnel completed in 1847. The Buck Mountain Coal Company began mining in the No. 1 basin south of Eckley in 1839 through surface slopes at the top of Buck Mountain. In order to provide drainage for the mine as well as to improve coal handling abilities, the No. 1 Tunnel was driven from the southern flank of Buck Mountain 1,570 feet northward to intercept the No. 1 basin at its lowest point, 1,489 ft MSL, thus providing gravity drainage.

In 1855 this property was sold to Eckley B. Coxe who continued to develop the No. 1 basin as well as the adjacent No. 2 basin which was larger and deeper. In 1895, Coxe Brothers and Company drove to the Buck Mountain No. 2 Drainage Tunnel 1,650 feet northward to intercept the eastern end of the No. 2 basin. At this point, the tunnel was at elevation 1,426 ft MSL and 140 feet above and 1,400 feet east of the deepest point of the No. 2 basin. A pumping plant was

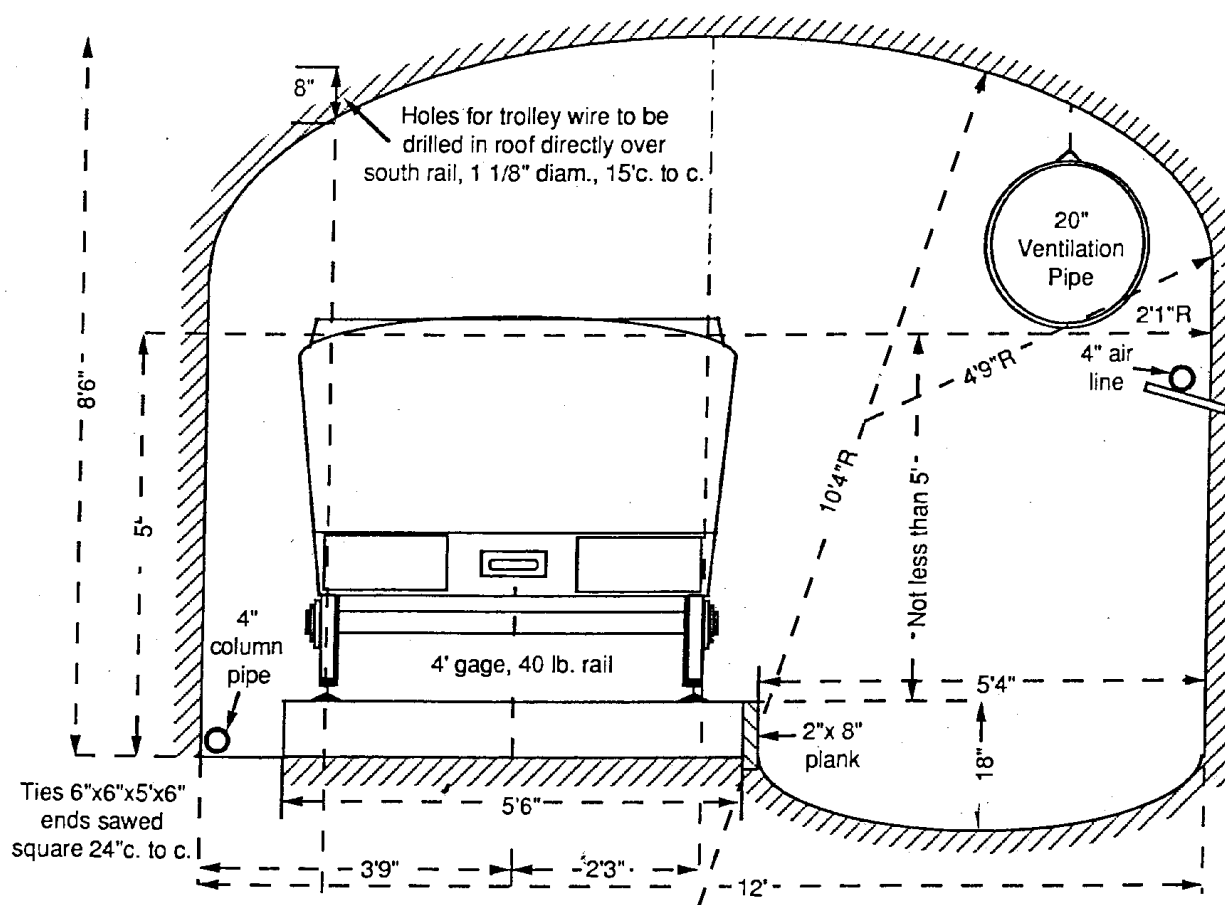


Figure 21. Cross section of the Audenried Tunnel (adapted from Huber, 1932).

set up at the lowest point of the mine to pump the mine water to the No. 2 Tunnel. This tunnel served as a drainage level which reduced the pumping head by nearly 200 feet.

A third tunnel exists in the Eckley area and is known as the Owl Hole Tunnel. This drainage way is technically a drift rather than a rock tunnel. It was driven in the Buck Mountain seam in the Eckley North basin and served as a portal for the removal of coal. It is now collapsed and serves as a groundwater overflow point for the basin.

The measures north of Eckley at the village of Sandy Run are drained by the Sandy Run Tunnel. This tunnel was driven for M. S. Kemerer Company, operators (owners?) of the Sandy Run mine. The total length of this tunnel is 1,900 feet. All tunnels draining from the Eckley area discharge acid mine drainage to tributaries of the Lehigh River.

Coxe Brothers, apparently having seen the advantages and long-term economics of the drainage tunnel, constructed three additional tunnels at other mines in the area. The Quakake Drainage Tunnel was started in 1899 and completed in 1902, twenty years after the Coxes acquired the property. It drained the No. 3 and No. 4 slopes of the Coxe operation in the east end of the Jeansville basin at Beaver Meadows. Its total length is 5,487 feet and discharges to a tributary of the Lehigh River in the adjacent Quakake Valley. The contract for the work was awarded to John Lloyd, a former mine foreman for McNair & Company, a mine operating firm.

The Oneida No. 1 Tunnel was completed in 1910 to drain the Oneida (Green Mountain) North basin. The tunnel was driven to provide gravity drainage from the Buck Mountain seam. Its total length is 5,150 feet. In 1930, approximately 200 feet of the discharge end was excavated to correct a recurring subsidence problem. Despite this work, the discharge portal is now collapsed.

The Oneida No. 3 Tunnel was constructed between April 1912 and June 1913 by the Portland Contracting Company of Pottsville. The tunnel is 7,040 feet long and intersected the western end of the Oneida South basin at the foot of the No. 5 slope in the Buck Mountain seam. It provided gravity drainage and eliminated the need for 20 mine pumps, the largest of which pumped against a 500 foot head. Both Oneida Tunnels discharge to Tomhickon Creek in the Susquehanna River watershed.

The Eastern half of the Oneida South basin was owned and operated by the Glen Alden Coal Company, who constructed the Green Mountain Tunnel. This tunnel provided gravity drainage from the lowest point in the "Lykens" coal seam at elevation 1,190 ft MSL (Green Mountain Colliery mine map, undated, in possession of G. Gatti, Sr.). Its total length is 4,153 feet; and it discharges to Catawissa Creek, a tributary of the North Branch Susquehanna River.

One-half mile upstream of the Green Mountain Tunnel is the Audenried Drainage Tunnel. This tunnel was constructed by the Glen Alden Coal Company between 1928 and 1931. With a length of 16,150 feet, it is the longest single tunnel in the Eastern Middle field. Its drainage area includes the Audenried, Springbrook and Tresckow mines near McAdoo. The tunnel was driven from two headings. Work was begun at the mine end in March, 1928, and penetrated 5,265 feet of conglomerate and 2,386 feet of green sandstone. The rock work at the

discharge end was begun in July, 1928, and penetrated 8,470 feet of alternating red and green shale and 29 feet of conglomerate. In February, 1930, the two ends of the tunnel were 3,000 feet apart when a fracture was encountered in the mine heading which resulted in the groundwater-inflow of nearly 800 gallons per minute, a quantity greater than the capacity of the pumps used to keep the heading dewatered. It was decided that rather than invest in new pumps and piping to dewater the heading, work would continue in the creek heading only. The work continued and in December, 1930, the working face of the creek heading was 50 feet from the flooded mine heading. During this time, the area was experiencing a drought. The Honey Brook Water Company (a Glen Alden subsidiary) which supplied the Audenried area was compelled to start up its wells to supply water to the community and the Glen Alden Colliery. Rather than rationing water to the community, pumps were installed in the mine heading to supply the colliery. The well water was then supplied unrestricted to the community. This continued until April, 1931, when the drought eased and work resumed on the tunnel. In early April, 2 six-inch diameter diamond drill holes were bored through the 50 feet of rock separating the two tunnels in order to release the estimated 4.5 million gallons of water in the mine heading. The water was drained in late April and work continued until June, 1931, when the tunnel was completed (Huber, 1932).

The Gowen or Haddock Tunnel drains the former Gowen mine at Fern Glen (Gowen Mine mine map, undated, in the possession of Coal Contractors, Inc.). The tunnel was constructed prior to 1929 and is 1,740 feet long. It was driven on a southwesterly heading and intercepted the north limb of the Buck Mountain seam at elevation 956 ft MSL. At this point, the tunnel joined with the No. 10 rock tunnel which proceeded cross-strike through the south limb of the Buck Mountain seam ending at a dam in the Buck Mountain Overlap (Underlap) seam. The Creek Tunnel Gangway then proceeded westward from the dam in the overlap eventually joining the south limb of the Buck Mountain seam. Mine drainage from the Buck Mountain workings below 956 ft MSL was then pumped up to the Creek Tunnel Gangway. The discharge from the tunnel is to Black Creek in the Susquehanna River watershed.

### JEDDO TUNNEL SYSTEM

The largest and probably best known drainage tunnel in the Eastern Middle field is the Jeddo Tunnel system. Its two main tunnels, Tunnel A and Tunnel B, were completed in 1895 and were heralded by New York and Philadelphia newspapers as a "remarkable feat of engineering" (McNair, 1951). Over the years, additional tunnels were added which increased the length of the system to nearly six miles. The tunnel system drains the mines in the area of Harleigh, Ebervale, Jeddo, Lattimer, Drifton, Eckley, Hazleton, Stockton, Cranberry, and Harwood for a total of nearly 25 square miles of coal measures (Figure 22).

The Jeddo Tunnel was born out of an act of God and the ingenuity of John Markle, son of G. B. Markle and a renowned mining engineer. The Black Creek Basin, named after the creek of the same name, was among the largest and richest coal reserves in the Eastern Middle field. During the 1850's and 1860's, several companies began extensive development of the mines in the vicinity of Jeddo, Ebervale, and Harleigh. With the advent of strip mining and the need to reduce stream bed leakage, Black Creek was relocated to a new channel on the southern edge of the basin. In January, 1886, during a period of heavy runoff, the creek broke through its banks and flowed into the Harleigh Mine operated by

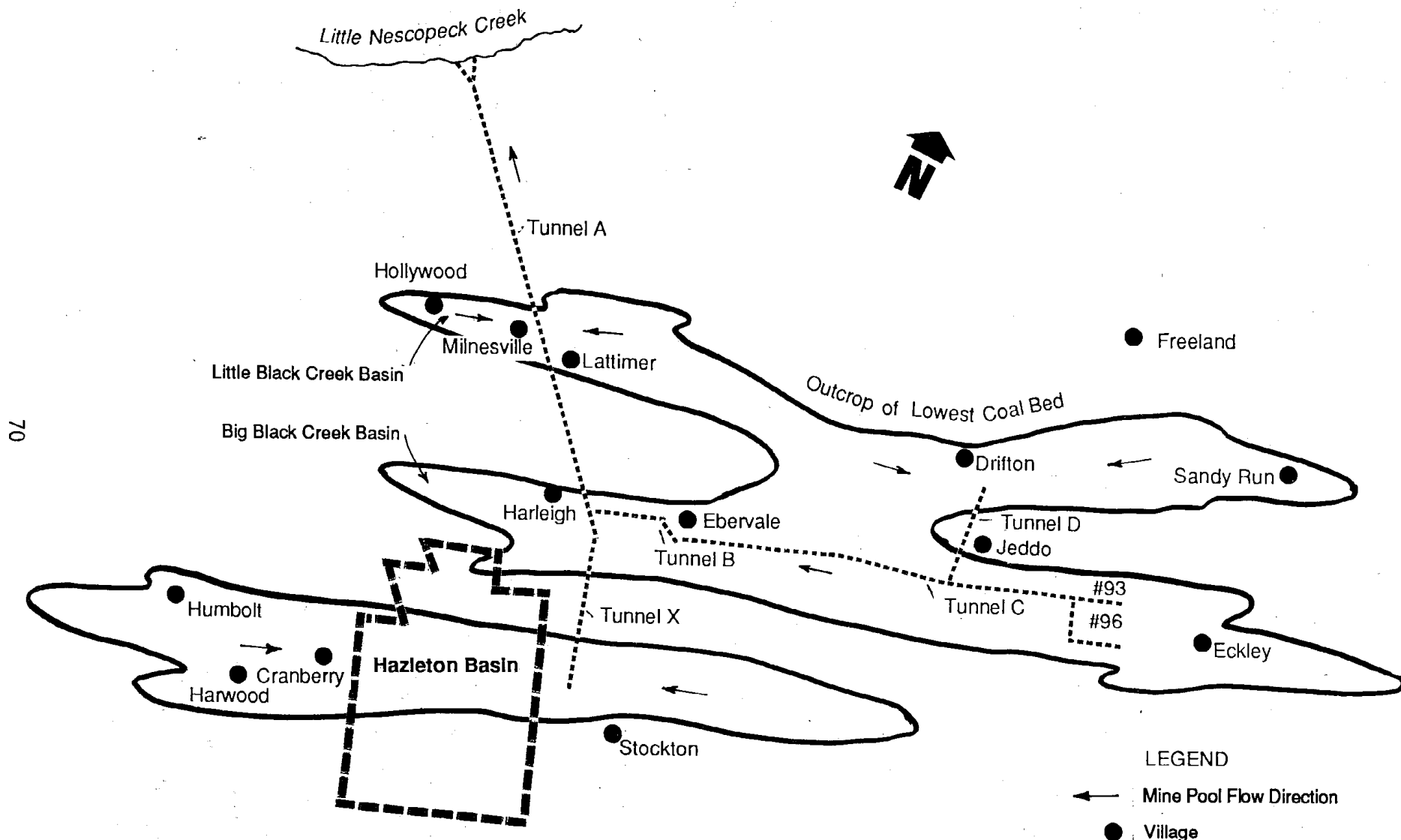


Figure 22. The Jeddo Tunnel system. Scale 1" = approx. 3300'.

M. S. Kemerer & Company. The level rose in the mine until it overflowed into the Ebervale Mine, operated by A. S. Van Wickle & Company, effectively flooding both mines beyond pump capacity. The mines remained flooded for several years. During this time, John Markle, president of G. B. Markle and Company and operator of the Jeddo Mine, became interested in dewatering the flooded mines. With the assistance of Thomas McNair, resident engineer of the Lehigh Valley Railroad Company and Lehigh Valley Coal Company, Markle prepared a plan for dewatering the basin with a drainage tunnel. The plan was presented to the mine owners and coal operators and it was decided that a drainage tunnel was feasible. In December, 1890, the Jeddo Tunnel Company, Ltd., was formed to oversee the construction of the tunnel.

The contract for the actual tunnel construction was awarded to Charles F. King & Company. George Scott of Ebervale was superintendent for the project which required 250 hard rock miners and laborers. The tunnel was originally designed with an 8 foot by 8 foot opening but the contractor realized they could make faster progress with a 7 foot by 9 foot opening. Three hundred and forty thousand pounds of forcite were used to complete the tunnel sections A and B. Seven pumps totaling 799 horsepower were required to remove the ground water which accumulated in the headings during their construction.

Tunnel A was completed in June, 1895, after four years of construction and is 15,100 feet long. It begins at the bottom of the Ebervale Mammoth Vein slope No. 2 at elevation 1,058 ft MSL and discharges to Little Nescopeck Creek (Figure 23).

Tunnel B extends at nearly a right angle from Tunnel A and proceeds east for 9,800 feet to the Jeddo Mammoth Vein slope No. 9. At this point the tunnel

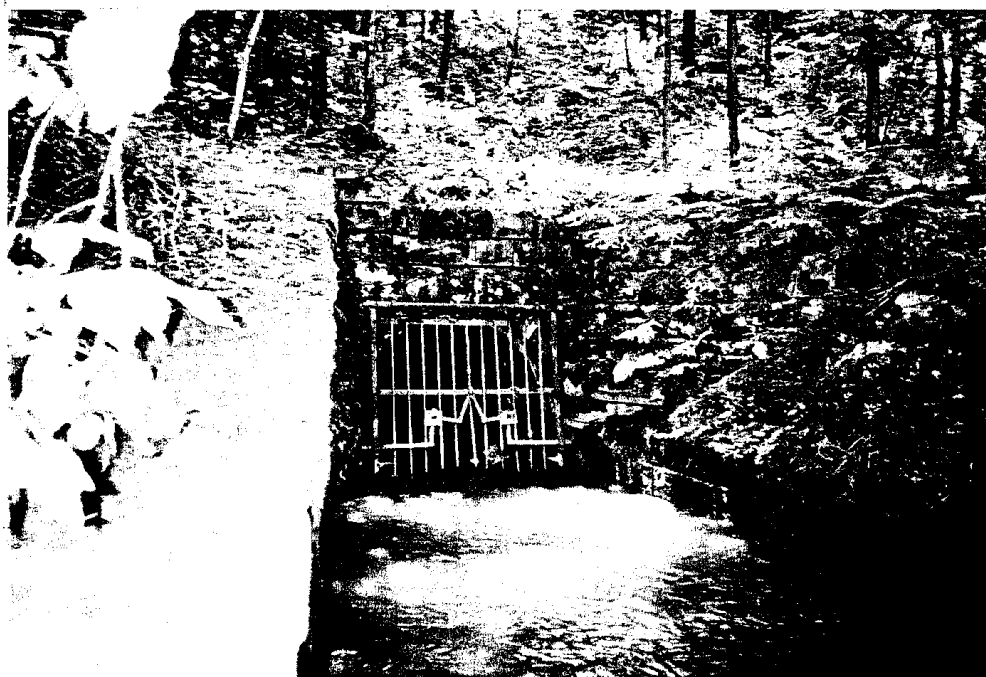


Figure 23. The mouth of the Jeddo Tunnel near Drums, about 3.5 miles east-northeast of Conyngham.

is approximately 380 feet above the deepest point in the basin. Due to the length of each tunnel it was felt that better progress could be achieved if the tunnels were each driven in two directions from intermediate construction slopes. The first slope was opened to the line of Tunnel A about 5,000 feet from the creek portal.

Five work crews of 50 men each were used to drive the tunnel segments in the various directions. Crew No. 1 drove from the discharge end up-grade to the Lattimer slope. Crew No. 2 drove from the foot of the Lattimer slope down-grade to crew No. 1. Crew No. 3 drove from the Lattimer slope up-grade toward Tunnel B. Crew No. 4 drove from the foot of the Ebervale slope west toward Tunnel A. Crew No. 5 drove from Ebervale east toward the end of Tunnel B at the Jeddo No. 4 slope. Once Tunnel B was completed and intercepted Tunnel A, the crews were put to work in Tunnel A. One crew drove down-grade toward crew No. 3, the other drove upgrade toward the terminus of Tunnel A. In order to avoid serious damage and flooding of the receiving stream when the mine was tapped, a bore hole was advanced from the surface at the village of Ebervale to provide controlled drainage of the flooded workings into the tunnel. With this method it was estimated the 8,000 gallons per minute would discharge into the tunnel and take nearly two months to drain the workings. The bore hole was drilled with a cable tool drill rig to a depth of 440 feet and sealed with temporary steel casing to case off the flooded workings. When the tunnel was reached, a hickory wood plug was placed to hold back the water during the removal of the temporary casing prior to draining the mine.

In the years that followed, additional tunnels were constructed which extended the drainage area of the Jeddo Tunnel. Tunnel C was completed in 1926 for total length of 4,268 feet. It drains the Highland No. 5 mine to Tunnel B.

Coxe Brothers and Company (by then a subsidiary of the Lehigh Valley Coal Company) entered into an agreement with the Jeddo Tunnel Company in 1929 to drain their operations at Drifton and Eckley. Tunnel D was driven 4,038 feet to drain the Drifton No. 2 mine into Tunnel C. Water which had collected in the western end of the Eckley mine was drained by two drill holes through a barrier pillar into the Highland No. 5 mine. Once drained, tunnels 93 and 96 were driven under the barrier pillar in solid rock. The length of each tunnel is 340 and 250 feet respectively. The last addition to the Jeddo Tunnel system was Tunnel X completed in 1934. This tunnel, an extension of Tunnel A, drains the Hazleton Shaft Colliery of the Lehigh Valley Coal Company. Its total length is 9,601 feet and was driven from three headings. The first heading proceeded northward from a construction slope at Ebervale.

#### CONOWINGO TUNNEL

With the decline of the anthracite industry following World War II, those mines still in operation were looking into ways of maintaining production by cutting costs. As mines shut down, pumping ceased and the mine water accumulated in the abandoned workings became the problem of the adjacent active mine. The industry, already failing, was looking towards the government for help in dealing with the problem. The matter was studied and several alternatives were developed to dewater the basins in the Eastern Middle field. One plan included the construction of an 8.6 mile tunnel to drain the Gowen and Derringer mines in the West Black Creek basin (Ash and others, 1950).

The most ambitious plan, however, was the proposed Conowingo Tunnel (Anonymous, 1940). This 102 mile long rock tunnel would have been driven from Glen Lyon at the southern tip of the Northern field through the Eastern Middle, Western Middle and Southern fields to discharge into the Susquehanna River below the Conowingo Dam in Maryland (Ash and others, 1952). This was quite an ambitious project despite the advances in surveying and tunnelling technologies by the 1950's. The project, however, proceeded no further than the collection of 15 core borings along the route of the proposed tunnel.

### ENVIRONMENTAL EFFECTS

Today the tunnels continue to discharge acid mine drainage. It has been estimated that the maximum flow for all the tunnels combined may exceed 300,000 gallons per minute during wet weather (Ash and others, 1950). Average monthly flows from the Jeddo Tunnel as recorded by the PA DER Bureau of Abandoned Mine Reclamation for the water year October 1974 to September 1975 are as follows:

| Month     | Flow (MGD)       |
|-----------|------------------|
| Oct. 1974 | 37.09            |
| Nov.      | 27.92            |
| Dec.      | 51.91            |
| Jan. 1975 | 53.99            |
| Feb.      | * (gauge frozen) |
| Mar.      | * ( " )          |
| Apr.      | 65.13            |
| May       | 42.26            |
| June      | 30.59            |
| July      | 29.81            |
| Aug.      | 39.38            |
| Sept.     | 59.36            |

In the early 1970's the Hazleton City Authority investigated the feasibility of using the Jeddo Tunnel as a water supply source. A typical inorganic analysis of the Tunnel's water quality is given below (Growitz and others, 1985):

|                      |                             |
|----------------------|-----------------------------|
| Temperature          | 10°C                        |
| Specific Conductance | 875 $\mu$ mhos              |
| pH                   | 3.6 std. units              |
| Sulfate              | 430 mg/l                    |
| Dissolved iron       | 6 mg/l                      |
| Alkalinity to pH 4.3 | 0 mg/l as $\text{CaCO}_3$   |
| Acidity to pH 7.0    | 150 mg/l as $\text{CaCO}_3$ |

With the exception of the Buck Mountain No. 2 Tunnel and Owl Hole drift, the discharge from the tunnels is untreated and unmonitored. At the two tunnels with treatment facilities, the discharges are neutralized with powdered lime from a self-feeding lime silo situated atop the drainage channel. The silos are maintained by the PA DER Bureau of Abandoned Mine Reclamation and function to reduce the acid loading to the Lehigh River.

In the late 1970's, three alternate passive methods were tested at the Quakake Tunnel to determine their effectiveness in neutralizing pH (Hoover, 1978):

1. Static barriers consisting of beds of crushed limestone were placed in the discharge to allow the mine drainage to flow over and through them, thus neutralizing the acid water.
2. To prevent the buildup of chemical coatings on the limestone in a static barrier, the pulsating fluid-bed was devised. In this method the limestone is loosely packed and allowed to abrade against itself as the mine drainage cascades over and through it.
3. A final method utilizes rotating drums of crushed limestone. The drums are suspended in the discharge channel and driven by the force of the water. The rotational movement abrades the limestone and the resulting dust particles are more readily available to neutralize the mine drainage.

All of the Quakake treatment facilities are currently inoperable.

#### REFERENCES CITED

- Anonymous, 1940, Government aid to drive tunnels for drainage advocated in Anthracite region: *Coal Age*, v. 30, no. 12.
- Ash, S. H., Eaton, W. L., Hughes, K., Romischer, W. M., and Westfield, J., 1949, Water Pools in Pennsylvania anthracite mines: U.S. Bureau of Mines Technical Paper 727, p. 22.
- Ash, S. H., Kynor, H. D., Fatzinger, R. W., Daves, B. S., and Gilbert, J. C., 1950, Inundated anthracite reserves: Eastern Middle field of Pennsylvania: U.S. Bureau of Mines Bulletin 491, p. 4, 24.
- Ash, S. H., Doherty, R. E., Miller, P. S., Romischer, W. M., and Smith, J. D., 1952, Core drilling at shaft sites of proposed mine-water drainage tunnel: U.S. Bureau of Mines Bulletin 513, p. 3.
- Cumming, J. D., 1951, Diamond drill handbook: Toronto, J. K. Smith & Sons, Ltd., p. 293.
- Donaldson, F., 1910, Practical shaft sinking: New York, McGraw-Hill, p. 4.
- Durham, E. B., 1913, Mine Surveying: New York, McGraw-Hill, p. 238-241.
- Growitz, D. J., Reed, L. A., and Beard, M. M., 1985, Reconnaissance of mine drainage in the coal fields of Eastern Pennsylvania, U.S. Geological Survey Water Resources Investigations Report 83-4274, 54 p.
- Hoover, K. V., 1978, Anthracite coal region, northeastern Pennsylvania, in Annual Meeting of the Association of Engineering Geologists, Hershey, PA, Guidebook, p. 227-269.
- Huber, C. F., 1932, Drainage tunnel cuts costs at Honey Brook: *Coal Age*, v. 37, no. 1, p. 2-4.
- Hudson Coal Co., 1932, The Story of Anthracite: New York, Hudson Coal Co., p. 16.
- McNair, J. B., 1951, With rod and transit, the engineering career of Thomas S. McNair: Fox Printing and Publishing Co., p. 149.
- Reed, M. C., 1914, The Oneida No. 2 Anthracite Drainage Tunnel, *Coal Age*, v. 5, No. 8, p. 324-325.
- Tyson, M. S., 1977, The miners: Pine Grove, PA, Sweet Arrow Lake Press, p. 136-137.

## MINE DEWATERING PUMPS, THE EARLY YEARS

by  
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Water and the mining of coal have always been closely inter-related, especially in the Anthracite region of Pennsylvania. Steeply dipping coal seams in the synclinal basins necessitated various methods of removing water from the working faces of the mine as the miners progressed downward through the seam. Commonly used methods were the mine drainage tunnel, driven to the mine workings from adjacent valley floors, water hoists, and finally, pumps, both steam and electrically driven. With the mine tunnels gravity could do the work on all the water coming from above, but as the mines dropped below the levels of these drainage tunnels and in areas where tunnels were not economically feasible, pumps and water hoists had to take over the job of removing water from the workings.

We intend to look at the development of mechanical mine dewatering equipment in the Anthracite fields, concentrating on the centrifugal pumps that came into common use in the first part of the twentieth century but starting with a quick review of their predecessors.

### THE BEGINNINGS: STEAM PUMPS AND WATER HOISTS

The principle of moving water with a pumping mechanism dates back to the second century, B.C., but did not find widespread practical application until the late seventeenth and early eighteenth centuries when the addition of a piston to the steam pumps and separation of the pump and steam engine by a "walking beam" allowed safer operation of the pump. This design, the "Newcomen engine," held sway until the work of James Watt in the 1770's and Richard Trevithick in the early 1800's with double acting steam pistons. From Trevithick's high-pressure single-cylinder design came the "Cornish engine" that was installed throughout the United States; some were still in operation as late as 1923 at the Pennsylvania Coal Company's Central and Old Forge Collieries (Anonymous, 1936).

Further development in the United States of simple, non-condensing direct-acting pumps to duplex and triplex versions provided quite a mix of pumping equipment draining the coal measures. Companies that produced these steam-driven pumps included the Goyne Steam Pump Company of Ashland, Pennsylvania, the Jeansville Iron Works of Hazleton, and the Epping-Carpenter Company of Pittsburgh.

Most of these units were considered "low-duty" installations that were rated under 2,000,000 gallons per day. There were, however, several "high-duty" installations, the most notable according to Norris (1904) being the high-duty plant at the Lehigh Valley Coal Company's Hazleton Shaft. This station consisted of two compound-condensing flywheel pumping engines that were each rated at 5,141,247 gallons per day.

Concurrent with the "Cornish" and multiple expansion steam pumping systems were the water hoists, which are documented to have been regularly operating at the Nanticoke Collieries of the Susquehanna Coal Company and the Coaldale and Lansford Collieries of the Lehigh Navigation Coal Company in 1880. Other anthracite companies using water hoists during the same period were the Philadelphia and Reading Coal and Iron Company and the Lehigh Valley Coal Company. All of these early water hoists used tanks suspended under the regular hoisting cages. The first documented use of a separate vertical shaft for a water hoist was at the Luke Fidler Colliery of the Mineral Railroad and Mining Company in Shamokin (Perkins, 1903; Norris, 1904; Springer, 1921; Anonymous, 1936).

Norris (1904) described the operation of a water hoist at the Lytle Coal Company's operation as follows:

The hoisting is done by very large first-motion engines, hoisting at very high speeds. The 1,500-foot hoist at the Lytle shaft has frequently been made at an average of 50 seconds per trip, including filling and dumping. The duty of the 36 by 60 inch first-motion water-hoisting engines at the Lytle shaft was found to be approximately 33,250,000 foot pounds per 1,000 pounds of dry steam, and the cost of the installation, complete for 2,300,000 gallons daily capacity, including shaft sinking, machinery and steam plant, was \$80,777.96

Water hoists remained competitive with the existing steam driven pumping systems, especially in deep mine installations, and were not displaced until the common usage of centrifugal pumps during the second decade of the twentieth century. They did so due to their inherent simplicity and the advantage of the motive force remaining on the surface protected from flooding and readily available for any maintenance.

#### EARLY CENTRIFUGAL PUMP INSTALLATIONS

The next movement forward in the dewatering of the mine workings came with the advent of the centrifugal pump. These units were first driven by steam turbines, but became more indispensable with the use of electric motors, due primarily to their size advantages. The centrifugal pumps were not common in the mines until after 1911. Possible the first centrifugal pump placed into operation in an anthracite mine was by the Coal Department of the Delaware, Lackawanna and Western Railroad (DL&W) (later the Glen Alden Coal Company) at their Dodge Colliery (Northern field) in late 1901 (Anonymous, 1936). The first unit was a 6-inch Morris single-stage cast-bronze unit generating 90 feet of head. The flow volume is unknown. In 1905 the DL&W added a 6-stage Worthington at the Hampton Water Shaft, and in 1908, a 6-stage Allis-Chalmers at the same location. Both of these pumps were direct connected to 1,000-hp, 2,300-volt induction motors. They were each rated at 2,000 gpm at 500 feet Total Dynamic Head (TDH). The DL&W also installed a 2-stage centrifugal at their Truesdale breaker in 1907.

These early centrifugal installations made the Delaware, Lackawanna and Western the leader in centrifugal dewatering. It was not until October of 1908 that the Kingston Coal Company became the second firm to take this route by installing a 4-stage, 125-hp centrifugal from the Jeansville Iron Works. It was rated at 800 gpm at 375 feet TDH.

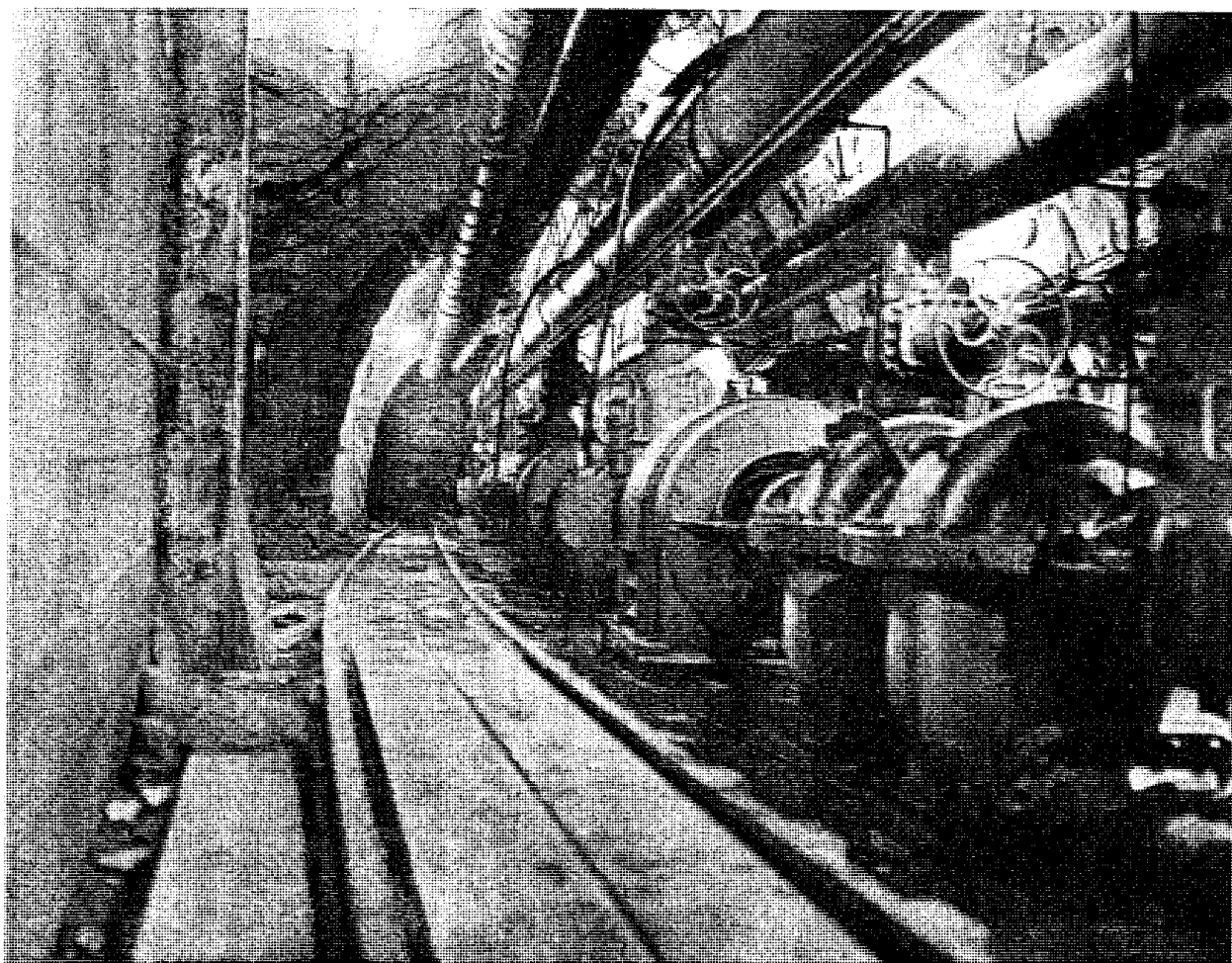


Figure 24. Bulkheaded pump station. (This and all subsequent photos courtesy of Barrett, Haentjens and Company, Hazleton, Pennsylvania).

#### THE HEYDAY OF CENTRIFUGAL MINE DEWATERING

After 1911, the dewatering of the mines was primarily performed by centrifugal pumps, even though some steam pumps and water hoists continued to operate through the 1920's. The major developments that aided in the emergence of the centrifugal pump was the development of a sump system throughout the face of the mine that then fed to the "new" submersible pumproom. A bulkheaded station design could remain in operation with a head of water over it and provide needed protection against inundation of the mine workings. Such flooding, unfortunately, was a common occurrence in the Anthracite region, especially in the Northern field where many mines extended under the Susquehanna and Lackawanna Rivers. It has been noted that these stations could remain submerged with as much as 117 feet of water overlying them.

Figure 24 shows two multi-stage pumps located within a submersible pump station circa 1925. Note the discharge piping passing through the bulkhead at the back of the station. Additional bulkheading can be seen on the left-hand side of the photo.

While many of these stations were independently hewn from solid rock with the approaches driven directly from the surface and not intersecting the mine workings, numerous pump stations could only be reached through the mine shafts and tunnels. It was in these stations that brick and tile covering of the walls aided in preventing water entry into the pump room. An example of this type of pump station can be seen in Figure 25, while Figure 24 is an example of a separate rock tunnel.

Not all the water in the mine was able to flow directly to the main dewatering sumps, so other low-head, low-volume pumps were placed within the mine workings, especially near the face to keep the water from accumulating in the work area. Goulds', LaBour, and Allis-Chalmers' horizontal pumps and Barrett-Haentjen's HAZLETON horizontal and vertical sump pumps were used to convey the accumulated water to the main, high-head dewatering pumps. The pumps ranged in size from the small portable vertical shown in Figure 26 to units capable of pumping several hundred gallons per minute.

As all pump stations could not be assured of a positive head at all times, automation of the mine dewatering pump stations did not come into being until the early 1920's with the advent of an automatic pump priming system developed and patented by Otto Haentjens of Barrett, Haentjens and Company. The first completely automatic pump station came in 1923 as a collaboration between Mr. Haentjens, J. T. Jennings, an electrical engineer with the Philadelphia and Reading Coal Company (P&R), and B. M. Horter and G. V. Woody at P&R's Draper Colliery (Haentjens, unpublished; Anonymous, 1936).

#### CENTRIFUGAL MINE DEWATERING PUMP DESIGN

The types of centrifugal pumps used in high-head, high-flow mine dewatering applications are generally of either the multi-stage volute or double-suction volute styles.

The materials of construction generally used in both types of pumps were a bronze alloy, lead, or wood for corrosion resistance to acid. Early on the wetted ends were just lined with wood, bronze, or lead; but eventually the

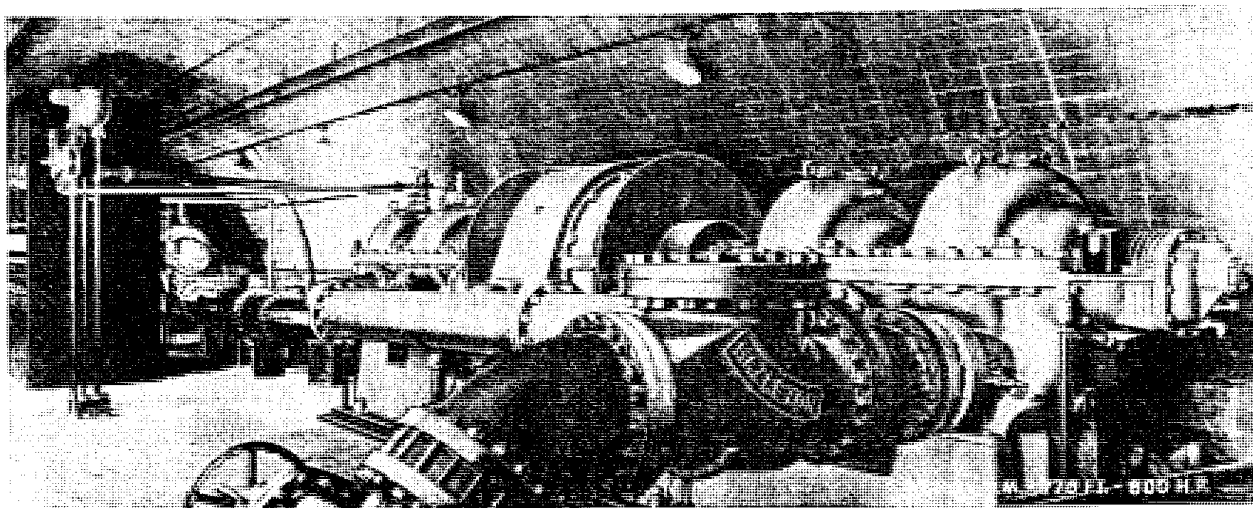


Figure 25. Tiled pump station wall aids in preventing water incursion.

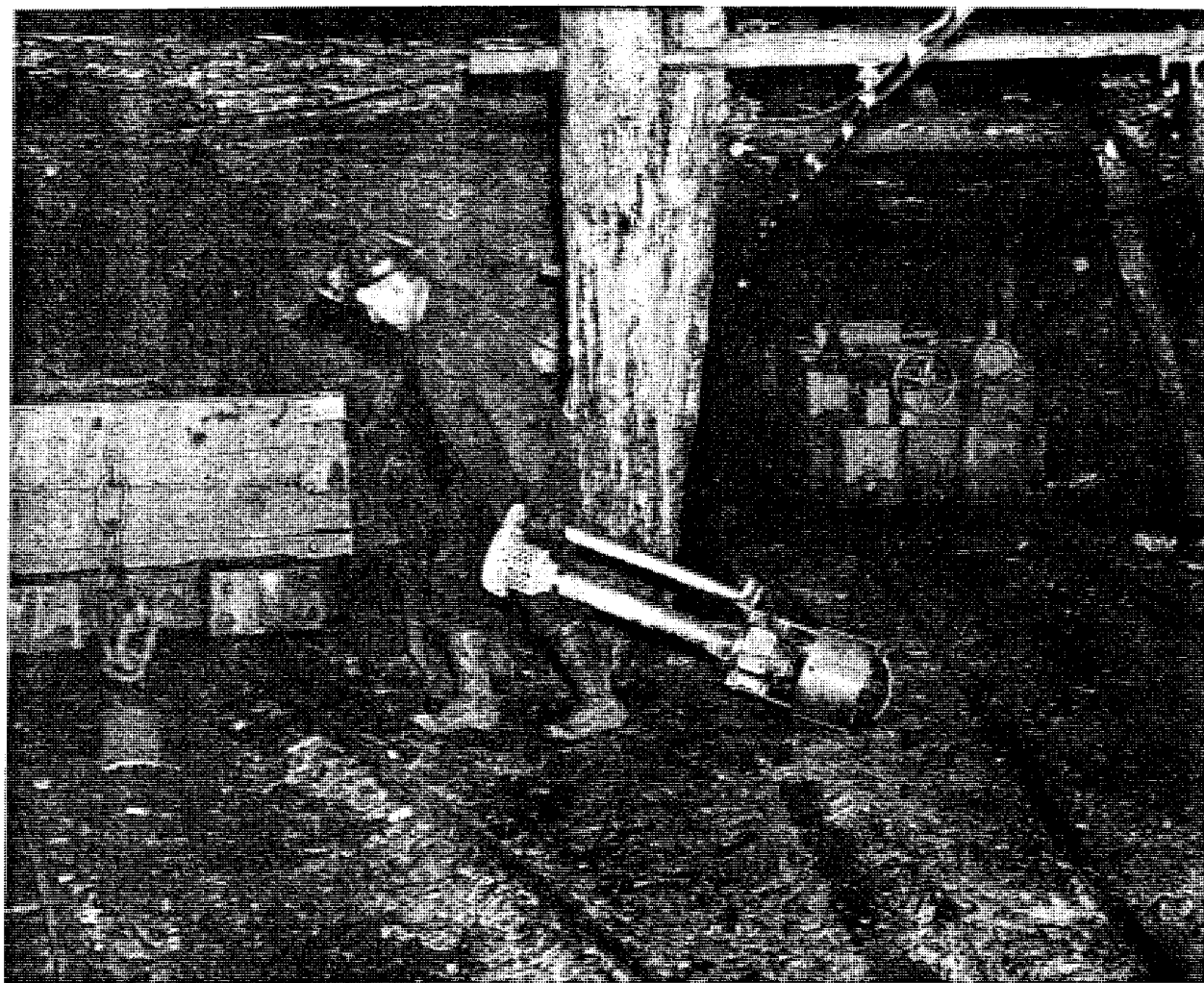


Figure 26. Portable sump pump being carried to work face.

entire wetted end of all of these pumps were constructed of bronze or were wood lined. Figure 27 shows a single-stage centrifugal pump with a wood lining, vintage 1920. Rough sawn hardwoods were fitted closely together by coopers at the manufacturing plant and were then soaked in fresh water at the mine site prior to being placed into operation. As long as the swelled wood remained wet, it provided protection from passage of acid water to the metal surfaces of the pump. Since the mid-1920's, stainless steel alloys have been used for mine pumps that required acid resistance (Norris, 1904; Anonymous, 1936; Haentjens, unpublished).

#### Multi-stage volute pumps

The principle behind the multi-stage pump is to reduce the needed operating speed to attain the heads and flows required. Pumping at the high flow rates and heads normally associated with mine dewatering would require a single stage impeller to be operated at speeds in excess of 12,000 rpm. As these speeds are not feasible for the "real world" pumping of acid and water that contain solids, single-stage centrifugal pumps could not operate in the mine environment. With

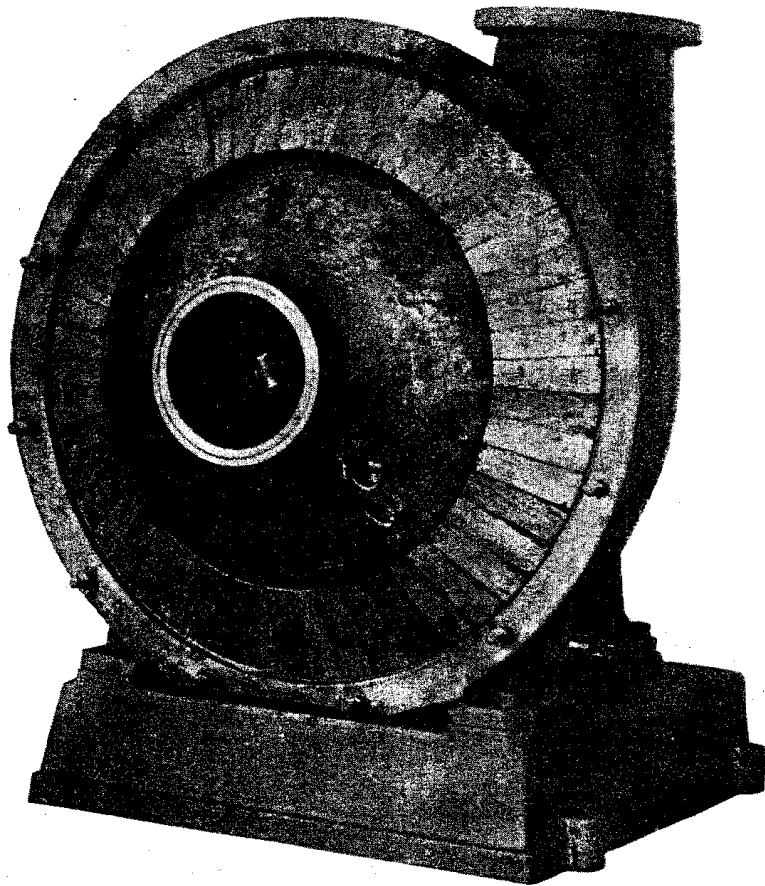


Figure 27. Wood-lined casing on a single-stage centrifugal pump. This view shows the impeller and suction head removed.

the development of the multi-stage volute design, centrifugal pumps overcame the space limitations presented by needing several single-stage pumps to attain the needed head. These compact multi-stage units, by dividing the head generating capacity between multiple impellers, all running on the same driven shaft, allowed the head derived from the pump to be obtained in stages. This resulted in the operating speeds of the units being reduced to below 3600 rpm and in most cases below 1800 rpm; yet they could reach the heads ( $>1,000$  feet TDH) and flows (2,000 to 5,000 gpm) necessary to dewater the mines.

A simple two-stage pump design featured two impellers mounted back-to-back in separate chambers. Ideally, one-half of the needed head was obtained in the first stage impeller and the remainder in the second stage impeller. This type of design produced equal and opposite thrust loads and allowed for a much more compact pump as the shaft and bearings were only sized for the expected thrust and radial loads. A typical pump used a bronze sleeve-type bearing to handle the radial loading to the shaft and a duplex set of radial ball bearings for the thrust load. A single-row radial bearing could also replace the sleeve bearing in some designs. The bearings in this type of pump were generally oil lubricated as they could lie in an oil bath, although several types did use grease lubrication. Packed stuffing boxes were used to seal the casings along the shaft. In most cases, the mine water being pumped provided the lubricating water to the stuffing boxes.

Because of the operating speeds, materials of construction, and close mechanical tolerances required in these pumps, they could not pump solids-laden water. A maximum solids concentration of 1 percent solids/weight (10,000 ppm) was allowed for operation of these pumps; otherwise, there was very rapid wear of the wetted ends.

Multi-stage centrifugal pumps used for mine dewatering ranged from two to eight stages. The more stages (i.e., impellers) the higher the heads that could be attained by a single pump. Complex interconnection piping between the stages allowed pairs of stages to be separated. This made manufacture of the casings easier, even though the individual casings still remained complex.

### Double suction volute pumps

Another style of pump used for mine dewatering was the double suction volute. While these designs were generally used to feed the high-head, multi-stage pumps, many locations only needed a lift between 200 and 450 feet. The double suction style pumps were used in these instances as the main dewatering pumps.

These pumps used a double-suction casing feeding a single impeller that had two inlet eyes. High flow volumes could be attained with these pumps because of the increased inlet area and wide impeller. The materials of construction of the double suction pump were similar to that of the multi-stage pumps and as such they could not handle any concentrations of solids above 1 percent without significant wear of the wetted end.

### AFTERWORD

The use of underground mine dewatering pump stations essentially came to an end with the intensification of strip mining and the subsequent decline of deep mining. Today's dewatering is generally accomplished through vertical turbine pump installations dropped down a shaft. Their main purpose is to keep the mine pool below the bottom of the stripping operations.

During the era of deep mining in the Anthracite region, the horizontal centrifugal mine-dewatering pump provided the means of relatively inexpensive removal of water from the mines. These styles of pumps still live on in coal-fired power plants, moving the vast volumes of water needed to transport the bottom ash away from the boilers.

### REFERENCES CITED

- Anonymous, 1936, Pumping and drainage: Coal Age, v. 41, no. 10, p.471-474.
- Haentjens, R. P., Sr., unpublished, History of Barrett, Haentjens and Company, 1916-1985.
- Norris, R. V., 1904, Unwatering of mines in the Anthracite region: The Engineering Magazine.
- Perkins, F. C., 1903, Electricity in modern mining drainage installations: Scientific American, v. 58, no. 3, p. 223-224.
- Springer, J. F., 1921, A problem in levels. How the shafts and workings of coal mines are kept free of water: Scientific American, v. 77, no. 5, p. 198-199.

## THE FOUNDERS OF ECKLEY: MEN WITH ENTREPRENEURIAL SPIRIT

by Mary Ann Landis  
Pennsylvania Historical and Museum Commission

On November 26, 1853 Richard Sharpe of Summit Hill, Pennsylvania, recorded in his diary that a cost of \$23.78 was incurred by him on an "Exploring Expedition by A. L. Foster, J. Leisenring, F. Weiss & R. Sharpe." The following March he noted that \$14.56 was "Exp. A.L.F. [Asa Lansford Foster], R.S. [Richard Sharpe], J.L. [John Leisenring], & G.B. [George Belford] to Council Ridge." It was Sharpe, along with Leisenring, Foster, Weiss (Figure 28), and silent partners George Belford and William Reed, who formed Sharpe, Leisenring and Company in 1854 and began the establishment of the Council Ridge Colliery and its adjacent village (originally Fillmore, but later renamed Eckley) on land leased from the Tench Coxe Estate of Philadelphia.

The four primary partners in the Company were not new to the business of mining anthracite in the Lehigh region. Each began his association with mining through contracts with the Lehigh Coal and Navigation Company (LCNC) and over the years gained prominence in various aspects of the industrial development of the region.

The impetus for beginning operations at Council Ridge were due in large part to the efforts of Asa Lansford Foster (Figure 28a) nearly twenty years before the colliery's founding. Foster was born in Rowe, Massachusetts, in 1799, a direct descendant of Captain Myles Standish. While still in his teens, he moved to Berwick, Pennsylvania, with his brother Thomas, and opened a general merchandise store; at that time Berwick was a rapidly developing lumbering community on the Susquehanna River. Two years later he moved to Bloomsburg to open a similar business and while there married Louisa Chapman, niece of Isaac Chapman, an engineer for the LCNC. Seeing the opportunity for expanding his mercantile business, Foster travelled to Philadelphia in 1826 to attempt to begin a wholesale business dealing in products from the Susquehanna Valley. While in Philadelphia he met, probably through Isaac Chapman, Erskine Hazard and Josiah White, owners of the LCNC. They convinced Foster to move to Mauch Chunk to operate their company's store. He did so very successfully.

Isaac Chapman, who during his travels through the region as engineer for the LCNC, was convinced that there were rich coal deposits in the land along the Lehigh River, north of Mauch Chunk on Buck Mountain and the upland beyond. Foster believed the theory and worked somewhat secretly with Chapman to discover the fuel. Unfortunately, Chapman died in 1827 before any large deposits were discovered.

After Chapman's death Foster temporarily suspended his search and concentrated on the mercantile business in Mauch Chunk. In 1829, he established the town's first newspaper, "The Lehigh Pioneer and Mauch Chunk Courier," later known simply as the "Mauch Chunk Courier."

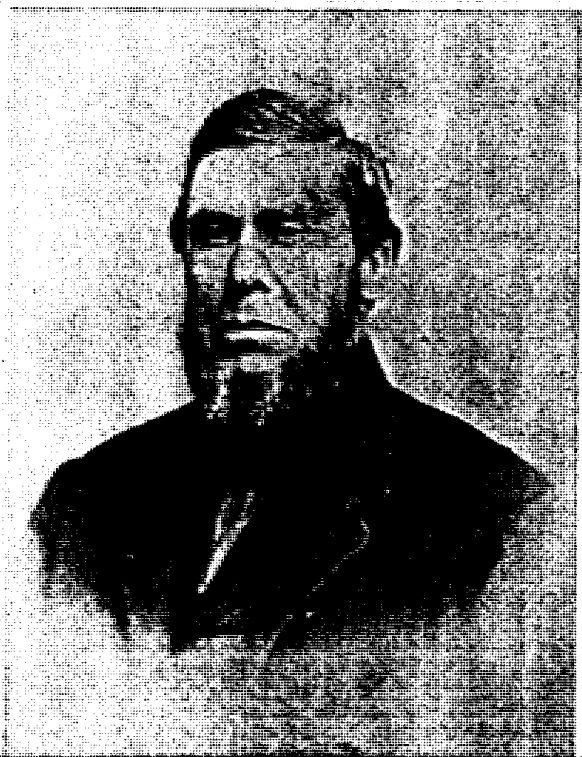
In 1831 the LCNC began to sell some of its properties in Mauch Chunk and closed its company store. Foster, in partnership with James Broderick and Benjamin McConnell, purchased land in town near the Lehigh River, where the



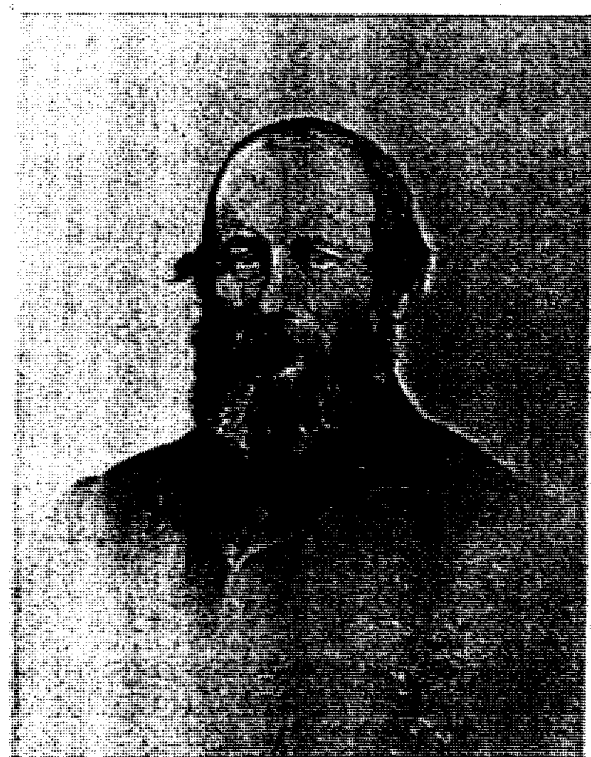
a



b



c



d

Figure 28. The founders of Eckley: a. Asa Lansford Foster (1799-1868).  
b. John Leisenring (1819-1884). c. Francis Weiss (1819-1888).  
d. Richard Sharpe (1813-1895).

Navigation Building now stands, and constructed their own store, known then as the "corner store." It became the largest store between the Susquehanna and Delaware Rivers and was constructed so that canal boats could be floated underneath the building and be loaded and unloaded.

In 1836, the LCNC completed the "Upper Grand" section of the Lehigh Canal between White Haven and Mauch Chunk, near the area Chapman and Foster suspected contained anthracite deposits. Wasting no time, Foster, along with four Philadelphia businessmen, chartered the Buck Mountain Coal Company on June 16, 1836 and within the year had purchased land four miles from the Lehigh Canal. The following year Foster uncovered the Big Black Creek Coal basin and caused a stir in the region over the new discovery.

After his find, in 1837, Foster sold his store in Mauch Chunk to Asa Packer and concentrated on developing the Buck Mountain Colliery. He engineered a gravity railroad system that consisted of two planes and a tunnel, driven 200 feet through solid rock, to transport the mined coal from Buck Mountain to the outlet on the Lehigh Canal at Rockport, a distance of about five miles. After three years of labor, in November of 1840, the first shipment of Buck Mountain anthracite was shipped to Philadelphia. Then, in January 1841, the Lehigh Canal above Mauch Chunk was destroyed by a disastrous flood which eliminated Foster's outlet to market. At great financial loss, Foster sold the company to Carey and Long, businessmen from Philadelphia. He remained as an employee for three years.

In 1844 Foster returned to Mauch Chunk and assumed the editorship of the "Carbon County Transit," which was owned by William Reed, Foster's nephew; Foster sold the "Courier" to Joseph Siewers in 1842, who changed the name. A few years later he left the newspaper business and joined with Robert Butler, a former salesman from the "corner store," and obtained a contract to drive a water level mine tunnel, "Foster's Tunnel," in the Panther Creek Valley near Summit Hill. He then became financial manager for Daniel Bertsch, a former canal and mine construction contractor who, in 1845, contracted with the LCNC to mine coal in Summit Hill; Bertsch was father-in-law to John Leisenring.

It was probably through Asa Foster's association with Daniel Bertsch and his work at Summit Hill that he became acquainted with Leisenring, Weiss, and Sharpe. Early newspaper accounts of the establishment of the Council Ridge Colliery and Eckley credit Foster with determining the location of the coal beds and the ensuing success of the mining operation. Sharpe's diary entries indicate that Foster was involved in the initial exploration of the site, which is approximately two miles from Foster's original Buck Mountain workings. Asa Foster moved to Eckley in 1855 and resided in the village until his death in 1869. Following his demise, several mining communities around Mauch Chunk incorporated into a borough called Lansford, named in his honor. The township in which Eckley is located, Foster Township, was also named for him. Asa Foster is buried in Mauch Chunk cemetery adjacent to the plots of Asa Packer and John Leisenring, a most prominent location.

John Leisenring (Figure 28b), like Asa Foster, had close associations with the LCNC and Mauch Chunk. He was born in Philadelphia on February 5, 1819, and in 1828 moved with his family to Mauch Chunk. His father, proprietor of the Mansion House, the LCNC's hotel, arranged to have him work with the company's engineering corps under the direction of the chief engineer of the LCNC, Edwin

A. Douglas. Between 1835 and 1837 he served as sub-assistant engineer on the effort to develop the "Upper Grand" section of the Lehigh Canal. The job entailed working on a survey crew and monitoring the work of contractors hired to build the works. In 1837 he was promoted to the position of assistant engineer, and he and Francis Weiss were placed in charge of the construction of the eastern division of the Lehigh and Susquehanna Railroad. The railroad connected the North Branch Canal at Wilkes-Barre with the Lehigh Canal at White Haven.

In 1838 Leisenring assisted E. A. Douglas in the surveying of the proposed Belvidere Delaware Railroad. And in 1840 he was loaned to the Morris Canal Company to assist in the enlarging of that canal between Easton and Jersey City. He was made assistant engineer and placed in charge of the canal reach between Dover, New Jersey, and Jersey City.

In 1843 Leisenring moved to Ashton (now Lansford) to be close to the LCNC's expansion and construction of a new gravity railroad system west of Mauch Chunk on Sharp Mountain. Leisenring and Robert Sayre, son of a LCNC official, are credited with the design and construction of the "Switchback," although the crucial design decisions were made by White, Hazard and Douglas. At the completion of the project Sayre was promoted to resident engineer, ahead of Leisenring. Apparently disillusioned, Leisenring left the company.

In 1844 he married Caroline Bertsch, daughter of Daniel Bertsch, the coal contractor for whom Asa Foster was working. Bertsch, along with Francis Weiss, had leased a portion of land from the LCNC in Summit Hill and was mining it; Leisenring went into business with his father-in-law shortly after the marriage.

In 1854 he joined with several other coal contractors at Summit Hill to form the firm that was to begin the workings at Council Ridge -- Sharpe, Leisenring and Company. In that year he moved to Eckley and resided there until the spring of 1860 when he returned to Mauch Chunk. E. A. Douglas, the LCNC's chief engineer died in 1859 and the company offered his position to Leisenring. Leisenring accepted, sold his interest in the Eckley operation to his partners, and moved into Josiah White's mansion in Mauch Chunk.

While engineer for the LCNC, Leisenring was involved in the rebuilding of the canal and railroad destroyed by the 1862 freshet, and the construction of an extension of the Lehigh and Susquehanna Railroad to Easton. In addition, Leisenring expanded his private investments by developing the Upper Lehigh Coal Company just north of Eckley and establishing the Lehigh Luzerne Coal Company just southwest of Wilkes-Barre. In 1871 he was made a director of the Central Railroad of New Jersey and helped the corporation to assemble a mining subsidiary, the Lehigh and Wilkes-Barre Coal Company.

In 1874, the year the original lease on the Eckley land ran out, Leisenring renegotiated with the Coxe Estate and operated the Council Ridge Colliery under the name J. Leisenring and Company. His son-in-law, Dr. John Wentz, acted as the superintendent until 1886 when the Coxe Estate refused to extend the lease and took over the operation itself.

Other investments by Leisenring included the Loiseau Pressed Fuel Corporation (1874) which combined culm with a binding agent to form a combustible block of fuel. By the late 1870's he realized that the steel industry was turning increasingly to the use of coke produced from bituminous coal in the mills of

western Pennsylvania. Consequently, in 1880, he established the Connellsville Coke and Iron Company, southeast of Pittsburgh in Fayette County. In addition he purchased coking coal lands in southwestern Virginia and formed the Virginia Coal and Iron Company and the Holston Iron and Steel Company. At the time of his death from Bright's disease on August 22, 1884, John Leisenring's wealth was estimated to be over a million dollars.

Like Foster and Leisenring, Francis Weiss (Figure 28c) had a close association with the mining industry through his contacts with the LCNC and through his family's history. Weiss was born August 23, 1819, in Weissport, Pennsylvania, to Thomas Weiss, son of Colonel Jacob Weiss. Jacob Weiss was a partner in the Lehigh Coal Mine Company of Summit Hill which was formed in 1792 after the discovery of anthracite by Philip Ginter; the Lehigh Coal Mine Company sold its operation to White and Hazard in 1818 who then formed the LCNC.

Weiss first attended school in Leighton and then went to school in Lexington in Bucks County. After completion of his schooling he was apprenticed to his uncle, Francis Weiss, who was a surveyor. He was employed in the engineer corps of the LCNC and was involved, along with John Leisenring, in the supervision of the construction of the Lehigh and Susquehanna Railroad in 1837 and the expansion of the Morris Canal in 1840. He also worked for private concerns preparing drafts and surveys in the region. In 1843 he was appointed deputy surveyor of Carbon County and served in that capacity until 1845 when he moved to Summit Hill to take advantage of the contract mining operations there with Daniel Bertsch and John Leisenring. In 1849, he, John Leisenring, Ira Courtright, George Belford, and Richard Sharpe, formed Belford, Sharpe and Company and continued to do contract work for the LCNC, each contributing \$6,000 to the organization.

In 1854 he moved to Council Ridge as a partner in the reorganized firm of Sharpe, Leisenring and Company. In 1860 the company's name was changed to Sharpe, Weiss and Company as a result of Leisenring's move to Mauch Chunk and his selling of his share of the company.

Francis Weiss and his family lived in Eckley for sixteen years. After the departure of Leisenring and Foster, he and Richard Sharpe were the only two mine owners left in the village. Weiss took an active interest in the company and the community. Of special interest to him was the study of geology; he delivered evening lectures on the subject to some of the young men in the village who were members of the Eckley Young Men's Improvement Society.

Weiss remained in Eckley until October 1, 1870, when he and his family moved to Bethlehem. While in Eckley, the company had made investments in the iron and steel industry of the Lehigh Valley, and Weiss, knowing that the Eckley lease would end in 1874, moved to be near the operation.

Although he left the Anthracite region, he remained interested in the mining industry through his ownership of the Alden Coal Company near Wilkes-Barre; he and Richard Sharpe were partners in this venture. In addition to mining interests he was a proprietor of the Lehigh Shovel Works of South Bethlehem, director of the Old Bangor Slate Company, vice-president of the Lehigh Valley National Bank, and a large stockholder in the Bethlehem Iron Company and the Pioneer Iron Works in Birmingham, Alabama. Francis Weiss died on February 14, 1888.

Richard Sharpe (Figure 28d) was the fourth visible partner in the mining concern at Eckley and apparently the center pin. He was born in England on April 10, 1813, and immigrated with his family to America in 1826. His father, also Richard Sharpe, brought the family to the Wyoming Valley where he bought a farm. In 1836 the elder Mr. Sharpe died. The younger Richard moved the family to Summit Hill in 1838 where he became involved in the contract mining business of the LCNC. In 1847 he married Sally Patterson, sister of Nathan Patterson, chief cashier of the LCNC.

In 1845 Sharpe formed a contracting partnership with Ira Courtwright, George Belford, and John Leisenring. Four years later the firm reorganized to include Francis Weiss. Finally, in 1854 the company moved from Summit Hill to Eckley.

Sharpe lived in Eckley until the lease expired in 1874, the last partner to leave. He moved his family to Wilkes-Barre where he took an active interest in the management of the Alden Coal Company. He became president of the Alden Company and of the Wyoming Valley Manufacturing Company, and a director of the First National Bank of Wilkes-Barre. He died in Wilkes-Barre on April 21, 1895.

As seen in the brief biographies of the four founders of Eckley, the Lehigh Coal and Navigation Company played a central role in the business and social associations of the men. In many ways it was the LCNC which provided them with the opportunity to test the entrepreneurial waters and to succeed. The biographies of the founders of Eckley are typical of those of most of the successful businessmen of the Anthracite region in the nineteenth century. They were men with little formal education but with the drive and willingness to compete and to risk investing in the expanding, and fluctuating, American industrial economy of the last half of the nineteenth century.

#### REFERENCES

- Anonymous, 1855, A visit to Fillmore: Mauch Chunk Gazette, November 8.
- Hayden, H. E., Hand, A., and Jordan, J. W., 1906, Genealogical and family history of the Wyoming and Lackawanna Valleys, Pennsylvania, v. 2: New York, The Lewis Publishing Co., p. 54-58.
- Jordan, J. W., Green, E. M., and Ettinger, G. T., 1905, Historic homes and institutions and Genealogical and personal memoirs of the Lehigh Valley, Pennsylvania, v. 2: New York, The Lewis Publishing Co., p. 371-372.
- Mathews, A., and Hungerford, A. N., 1884, History of the Counties of Lehigh and Carbon in the Commonwealth of Pennsylvania: Philadelphia, Everts and Richards, p. 700-704; 706-708.
- Sharpe, R., 1853, unpublished diary (November): Sharpe papers, Wyoming Historical and Geological Society, Wilkes-Barre, PA.
- \_\_\_\_\_, 1854, unpublished diary (March): Sharpe papers, Wyoming Historical and Geological Society, Wilkes-Barre, PA.

# THE SECOND GEOLOGICAL SURVEY OF THE ANTHRACITE REGION OF EASTERN PENNSYLVANIA -- AN EARLY ENDEAVOR OF QUANTITATIVE GEOLOGIC MAPPING

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## INTRODUCTION

Nineteenth-century America thrived on Pennsylvania anthracite. As an energy resource, anthracite coal contributed greatly to the growth of industry, transportation, and home comfort. Increasing awareness of the importance of this fuel and other mineral resources within the Commonwealth led to public demand for more comprehensive geologic information. With the eventual establishment of the Second Geological Survey of Pennsylvania (1874-1889), detailed geologic investigations and mapping were undertaken in the anthracite coal fields. The Second Survey devoted more time and money to the study of the Anthracite region than to any other part of the State. Because of its need and ability to obtain accurate or quantitative geologic and topographic information, the Anthracite Survey produced some of the most superb geologic maps and cross sections of the nineteenth century. More than anything else, the contributions and achievements of the Anthracite Survey were the result of its unique character.

Owing to the success of the Second Survey, many later geologists considered the geology of the Anthracite region to be known (Wood and others, 1969). Consequently, Darton's (1940) work in the Northern Anthracite field was one of the few detailed geologic studies published on the region in this century until the U.S. Geological Survey (USGS) initiated systematic investigations in 1948. Though not diminishing the importance of the Anthracite Survey, the USGS has since demonstrated that the Second Survey reports do not adequately describe the structural and stratigraphic complexities of the anthracite coal fields.

Although beyond the scope of this paper, the work of the First Geological Survey of Pennsylvania (1836-1842, 1851-1854) in the Anthracite region should not be overlooked. The First Survey conducted the earliest detailed investigations on anthracite geology and utilized surveying instruments "for the purpose of imparting increased accuracy" in the preparation of its measured sections, cross sections, and maps (Rogers, 1838, p. 12). It established "the rule of the steep north dip," which stated that, particularly for the Southern Anthracite field, most folds are asymmetrical and have more steeply inclined northern limbs. Its geologic map of the anthracite fields is one of the finest and most accurate that was made in antebellum America. The First Survey provided training on the geology of the Anthracite region to a number of individuals. Most notable is J. Peter Lesley, later to become State Geologist of the Second Geological Survey, who received his first indoctrination in geology in the Southern Anthracite field. Having been discontinued in 1842, the First Geological Survey may never have received the funds it needed to publish its "Final Report" if the Pennsylvania Legislature had not approved its reorganization in 1851, largely as the result of demands to resurvey the anthracite fields.

The Anthracite region of Pennsylvania is located in the eastern part of the State within a parallelogram-shaped area of about 5,500 square miles. The region consists of four principal coal fields and one minor coal field that

cover about 500 square miles in parts of 12 counties (Figure 29). The five coal fields are named for their relative geographic positions and include the Western Northern (Bernice), Northern, Eastern Middle, Western Middle, and Southern Anthracite fields. The anthracite coal trade, however, has traditionally divided the coal fields into three regions: the Wyoming, which is synonymous with the Northern field but which sometimes includes the Western Northern field; the Lehigh, which includes the Eastern Middle field and all of the Southern field east of Tamaqua; and the Schuylkill, which includes the Western Middle field and all of the Southern field west of Tamaqua. The coal-bearing rocks of the Anthracite region are of Pennsylvanian age. Coal rank within the five fields is anthracite and semianthracite. The semianthracite occurs throughout the Western Northern field, but of the four large fields is restricted to western parts of the Southern field. The structural configuration of the Anthracite region is characterized by increasing complexity from north to south. The Northern, Western Middle, and Southern Anthracite fields consist of intricately folded and faulted synclinalorium. The Eastern Middle field is somewhat shallower, complexly folded and faulted, and situated on the crestal area of an anticlinorium (Arndt and others, 1968). Compared to the other four fields, the

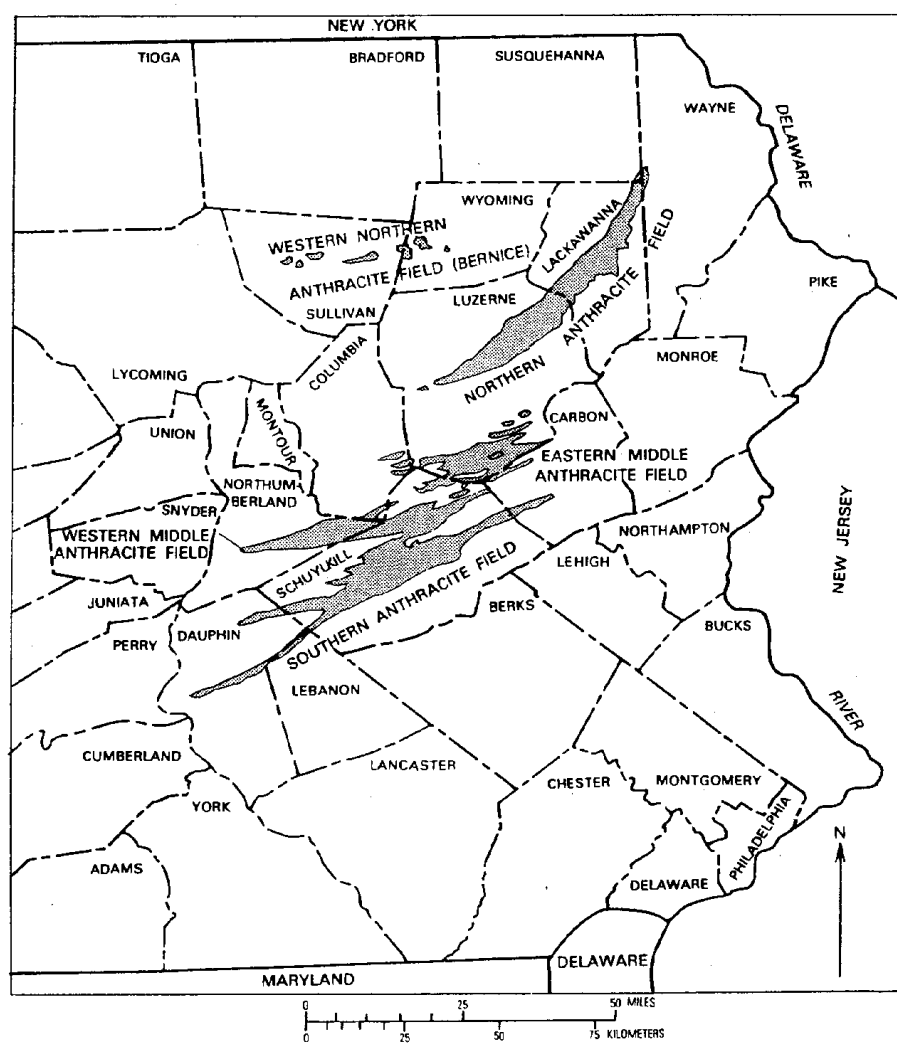


Figure 29. Map showing location of the Anthracite region, eastern Pennsylvania (from Wood and others, 1986, p. 32).

Western Middle field is only mildly deformed. The coal geology of the Anthracite region has been reviewed by Wood and others (1986) and by Arndt and others (1968). The detailed geology of the west-central part of the Southern Anthracite region has been discussed by Wood and others (1969).

Much has been written about the history of the Anthracite region and the consequences of anthracite mining. Several of the important and informative publications are by the Hudson Coal Company (1932), Eavenson (1942), Binder (1974), and Wallace (1987).

## BACKGROUND

In response to increasing public demand for more geologic information on petroleum, coal, and other mineral resources, the Legislature of the Commonwealth reluctantly approved the establishment of the Second Geological Survey of Pennsylvania (1874-1889). Highly respected and extremely well qualified, J. Peter Lesley was soon appointed State Geologist (Figure 30). Lesley's organization and management of the Second Survey were largely responsible for its success. (See Jordan and Pierce, 1981; and Dodge, 1987.)

Surprising as it may seem, the main impetus by Pennsylvania business to support a new geological survey came not from the anthracite operators or other mining concerns but rather from the oil interests. Anthracite coal was certainly the most important mineral industry in the State, but it was the very size and strength of the industry that contributed to its disinterest. The anthracite operators, with all of their mining engineers, believed that they adequately understood the coal geology of the region. Furthermore, as Lesley (1920, p. 436) noted: "[the anthracite industry] had special business reasons for not pressing its claims to a resurvey; for the railroad companies were acquiring and consolidating the collieries, and desired no interference." The petroleum industry, on the other hand, was much less organized and still suffering from the effects of recent overproduction. It knew little of its geology and wanted assistance. Nevertheless, the Second Geological Survey ultimately contributed as much or more to the understanding of the geology of anthracite as it did to any other mineral resource. Moreover, the reputation of the Second Survey helped to change attitudes that had been against public disclosure of privately obtained geologic information.

Field work by the Second Geological Survey began in July 1874 and was initially limited to "five specially important and hitherto little studied districts of the State, requiring immediate attention" (Lesley, 1878, p. i, appendix). The investigations of these districts dealt mainly with fossil (hematite) iron ore, petroleum, and bituminous coal. Work in the best known anthracite and bituminous coal fields was postponed because of limited appropriations and higher priorities. During the next several years, however, many other parts of the Commonwealth were studied and mapped, including much of the western Pennsylvania bituminous coal fields, but no organized work was accomplished in the Anthracite region. In this regard, Ashburner (1881a, p. 109-110) explained:

I am informed that the delay in commencing the survey of the anthracite coal fields was due to no want of interest in it on the part of the Board of Commissioners [the oversight committee of the Survey], but to the large extent of country in other parts of the State about which little was

known; the thorough manner in which these parts had to be surveyed; the impossibility of keeping more than a certain number of geologists at one time in the field; the difficult, slow and costly instrumental work imperatively called for in certain districts, before their geological structure could be studied, much less described; -- and lastly, the fact that an immense mass of civil and mining engineering work was being done in the anthracite basins which was all promised to the survey as soon as it was got in a condition for geological use.

Ashburner went on to suggest that this approach was wise and efficient, both in terms of time and money, owing to the modest appropriations that the Geological Survey received. Nevertheless, concern or perhaps impatience on the part of the Legislature in 1879 led to a resolution requesting that the Second Survey undertake

a survey and examination of the anthracite coal fields..., paying special attention to the question of the rapid exhaustion of this most valuable deposit, more economy in the methods of mining, the avoidance of the great waste and overproduction now threatening ruin to all interested in the trade, and to make a special report with reference to these subjects, and suggesting if possible a remedy for the evils above recited (Pennsylvania General Assembly, 1879, p. 204).

#### ORGANIZATION AND IMPLEMENTATION

Responding to this resolution, the Second Survey initiated its anthracite studies the following year. In May 1880, Franklin Platt, one of the best known and most experienced coal geologists on the staff, received instructions to prepare a special report (Platt, 1881) for the Legislature on the causes, kinds, and amount of waste produced by anthracite mining. Furthermore, Platt was to be the "accredited" -- actually titular -- head of the Anthracite Survey in order to gain the respect and confidence of the coal operators (Board of Commissioners of the Second Geological Survey of Pennsylvania, 1880). Platt completed his report at the end of the year, and soon thereafter resigned to accept more lucrative work primarily in western Pennsylvania. In August 1880, H. Martyn Chance, another experienced Survey geologist, was assigned the task of making a comprehensive, now classic, study (Chance, 1883) of the mining methods and equipment used in the anthracite fields. The geologist truly responsible for the Anthracite Survey was Charles A. Ashburner (Figure 31). A brilliant young man and protégé of Lesley, he was well suited for the work ahead (Dodge, 1981). Ashburner was instructed in August 1880 to devise a plan by which to map the detailed geology of the anthracite coal fields in a manner that would be of greatest benefit and practical use to mining engineers. This, in turn, would provide the public with the most complete information possible. Ashburner and Chance worked independently and were required to report to Platt only out of courtesy to prevent overlap in their endeavors.

Ashburner's ability to plan, organize, and manage the Anthracite Survey (1880-1889) was outstanding and led to international acclaim for the Second Geological Survey. During the latter part of 1880, Ashburner made a reconnaissance of the anthracite fields and met with mining engineers and company officials in order to help him formulate his plan for the upcoming Survey. He was particularly interested in examining and analyzing the methods employed by mining engineers to represent the results of their surveys on maps and cross



Figure 30. J. Peter Lesley,  
State Geologist



Figure 31. Charles A. Ashburner,  
Geologist in Charge

sections. It became clear to Ashburner that the Anthracite Survey would serve no useful purpose to industry unless much of the Survey's work was new or innovative and pertinent to the practical solution of problems related to coal extraction. After several months of investigation, during which he and an assistant prepared a specimen mine sheet (geologic map) incorporating many of his ideas, Ashburner presented his plan to Lesley and the Board of Commissioners in November 1880, and it was enthusiastically approved. Ashburner's most remarkable proposal to the Board of Commissioners was the unprecedented use of structure contours on all mine maps to portray the fold geometry of the coal measures. Ashburner credited Lesley with developing the concept of structure contours in America in the 1850's and acknowledged the prior use of structure contours in a general way in several private reports prepared by J. Peter Lesley, Benjamin S. Lyman, and a few other individuals. (See Ashburner, 1881b, 1883a.) Owen (1975, p. 80) attributed the first published structure contour maps to Lyman, who, as Lesley's nephew, was once employed by Lesley and undoubtedly learned the concept from him. Nevertheless, Ashburner's systematic application of this concept to a large area was unparalleled.

Ashburner started the Anthracite Survey in late 1880 on a small scale but promptly opened a field office in Pottsville. His specimen mine sheet, which covered part of the Western Middle field near Mahanoy City, was published the following January, in the back of Platt's (1881) report on anthracite mine waste, in order to solicit comments and criticism as soon as possible. (Owing to the subsequent availability of new information, the map was later revised and reissued.) With the approval of a new biennial appropriation by the Legislature in May 1881, Ashburner was appointed Geologist in Charge at the age of 27, and the Second Geological Survey's study of the anthracite fields proceeded in earnest. Ashburner continued in the same position until July 1885, at which time Lesley promoted him to First Assistant Geologist in charge of general supervision over all office and field work of the Second Survey. Lesley reassigned these duties so he would have time to begin writing a comprehensive "Final

Summary Report" on Pennsylvania geology. Ashburner was still Geologist in Charge of the Anthracite Survey, but he entrusted his Assistant Geologist, Frank A. Hill, with the detailed supervision of the work. In the autumn of 1886, Ashburner reluctantly resigned from the Second Survey to accept a more lucrative position with George Westinghouse, Jr., in Pittsburgh. Hill succeeded Ashburner as Geologist in Charge and completed the Anthracite Survey on June 1, 1889, when, by an act of the Legislature, the work of that Survey ceased and the entire corps of assistants was disbanded.

The Anthracite Survey was an ambitious enterprise and a thoroughly modern organization. Competent staff were hired, consisting of geologists, topographers, civil engineers, and various aides. Field offices were set up in Pottsville, Hazleton, and Scranton (after moving from Wilkes-Barre), and the headquarters was located at 907 Walnut Street, Philadelphia. All of the operating railroad and coal companies in the region were approached, and the Anthracite Survey made numerous friends and contacts with civil and mining engineers, mine bosses, and company management. (Several members of the Second Survey's Board of Commissioners had strong interests in anthracite mining and provided the Anthracite Survey with whatever assistance they could. These commissioners were Ario Pardee of Hazleton, Eckley B. Coxe of Drifton, and Charles A. Miner of Wilkes-Barre.) An organized system for mapping the coal fields was established, and all Survey maps and sections were submitted to the appropriate companies for colleague review prior to publication. Great care was taken during the printing of maps to minimize distortion and maximize registration.

The Anthracite Survey recognized its position of leadership at the forefront of a new era in geology, that of truly quantitative mapping. The Survey combined the products of its own detailed surface and subsurface investigations with the abundant, accurate information -- mine maps, diamond drill-hole records, and sections -- acquired from the mining companies. Numerous inconsistencies, ambiguities, errors, and miscorrelations had to be resolved. Each coal field had its own set of problems, requiring differences in time and technique for solution. In all aspects of its work, the Survey continually demonstrated its strict adherence to scientific principles and standards (and made certain that the public was aware that it did so).

### CONTRIBUTIONS

The results of the Anthracite Survey were published in several reports and as a remarkable series of sheets in a total of 20 atlases, two Grand Atlases, and one general map. Consistent with Lesley's policy, all members of the Survey staff received due credit for their contributions. "Reports of Progress," which contain detailed descriptive information, were intended to accompany each atlas, but owing to far greater public demand for the atlases and a reduction in staff brought on by declining appropriations, these reports were released only occasionally. Nevertheless, they cover many important topics such as the status of the work accomplished in the several fields, stratigraphy and structural geology of the coal measures, topical studies undertaken, coal-quality, statistics, and more. In addition to these reports, much information was first published in the "Final Summary Report."

The atlases of the Anthracite Survey contain up to five different series of sheets, consisting of mine maps (Figure 32), cross sections (Figure 33), columnar sections, topographic maps, and miscellaneous maps and graphs. The mine maps

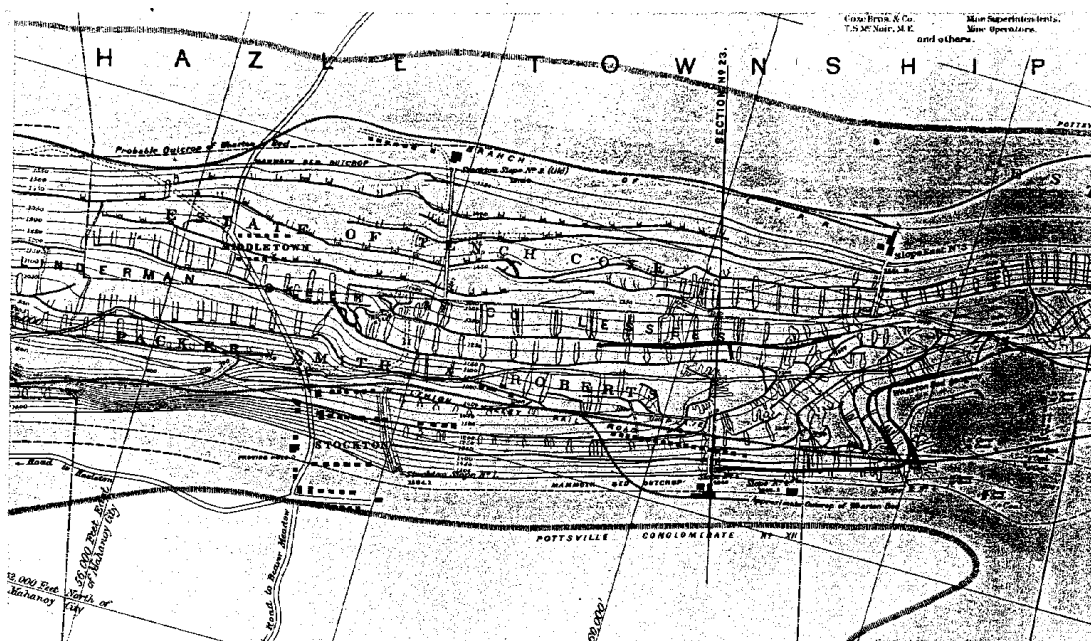


Figure 32. Portion of mine sheet 1, east of Hazleton, Eastern Middle Anthracite field, showing structure contours, extend of deep mining, and other features. Parallel lines are 2,000 feet apart. From Ashburner and others (1885).

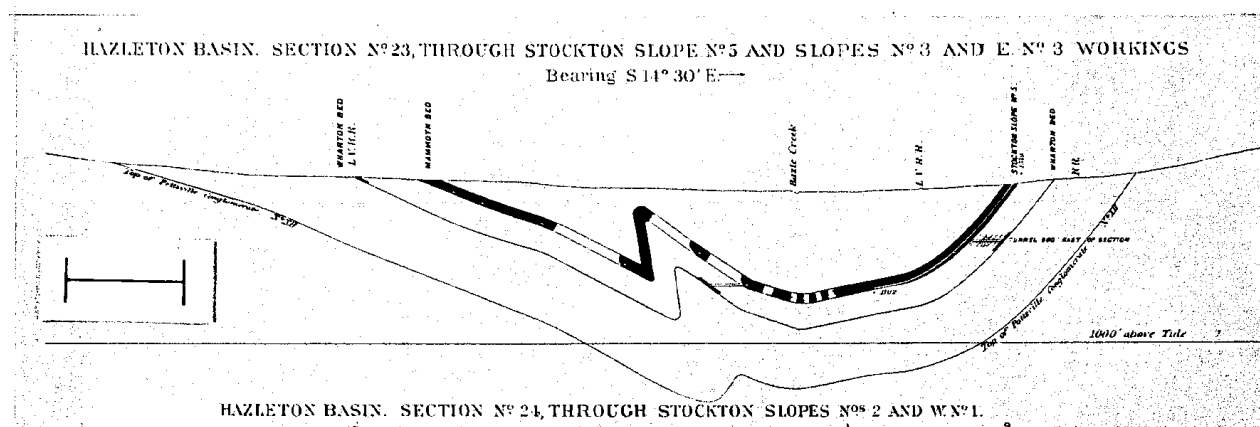


Figure 33. Example of a geologic cross section from cross section sheet 3 for the Eastern Middle Anthracite field. The location of section 23 is shown in Figure 4. Scale equals 400 feet. From Ashburner and others (1885).

(scale 1 inch = 800 feet) were generally considered the most important part of the publications of the Survey and contain a wealth of surface and underground features (though not all necessarily on each map): roads, railroads, towns, coal breakers, drainage, outcrops of principal coals, limits of the coal measures, structure contours (50-foot intervals), strikes and dips, areas mined out and presently being worked, gangways, tunnels, slopes, drifts, airways, and so forth. Political boundaries and arbitrary meridians and parallels are also shown on many of the maps. All subsurface features are color coded according to

coal seam. A limited number of each mine sheet were sold rolled rather than folded in order to facilitate plotting and measuring and to eliminate distortion.

Structure contours were particularly useful for planning future mining activities but were also valuable for estimating the absolute areas of coal beds under a given tract, and thus the coal resources. Consequently, Ashburner (1883a, b) developed a new, graphical method for estimating coal resources in steeply dipping strata based on structure contours, cross sections, and average coalbed thicknesses. This method was much more accurate than those previously used. Unfortunately, due to time constraints and limited appropriations imposed by the Legislature, the use of structure contours had to be discontinued after 16 mine sheets. Nevertheless, the use of this concept was widely praised and accepted, and enabled Ashburner to differentiate, in the words of Lesley (1890, p. 59), "the simple structure of Whelpley and McKinley [assistants of the First Geological Survey of the Anthracite region] into a complicated series of unexpected irregularities; giving precisely that knowledge to the colliery engineers which they most needed."

The mine maps are supplemented by sheets showing columnar sections and cross sections. The columnar sections provide stratigraphic information on the coal measures and detailed bed descriptions of the coals. Care was taken on the cross sections to distinguish between theoretical and proven structure. Topographic sheets (scale 1 inch = 1600 feet) consist largely of maps obtained from outside sources. Generally, these maps were not found to be sufficiently accurate to combine with the mine sheets. In most cases, only in parts of the Northern Anthracite field, where the topography was determined by the Second Survey, was it possible to place the contours on the mine maps. Miscellaneous sheets contain general maps of the region showing the locations of the collieries and graphs indicating the amount of coal shipped.

During the decade that it existed, the Anthracite Survey produced a prodigious amount of detailed information. In addition to its systematic "atlas" studies of the four main anthracite fields, it also conducted a number of other investigations. For example, latitudes and longitudes were determined in Pottsville and Wilkes-Barre by astronomical methods in order to establish fixed reference points for the maps being prepared by the Survey (Doolittle, 1883). The geology and paleontology of the Mill Creek marine limestone of the Northern field were described for the first time (Ashburner and Heilprin, 1886). The Anthracite Survey mapped the coal geology and topography for much of the Western Northern Anthracite field, which contains semianthracite coal (Ashburner, 1886a). The Survey gave this field its name (previously known as the Loyalsock or Bernice and Mehoopany coal fields) and assigned it to the Anthracite region because of its coal rank, which was first recognized by Platt (Sherwood and Platt, 1880). The Anthracite Survey contributed significantly to the reduction of mine waste produced by the anthracite operators. It demonstrated that the quality or composition of coals must be determined by analysis and not by physical appearance, which had been the usual practice. Much of the coal which had been considered bony, and therefore discarded, proved to be high in quality and marketable (Ashburner, 1883a). Smith (1893, 1895) made the first reliable coal-resource estimates for each of the anthracite fields. His calculations were based on the probable average cumulative thicknesses of all coals along a series of cross sections, the areas between the cross sections, and the specific gravities of the coals.

Much of the work of the Anthracite Survey is still valuable today. Ongoing geologic investigations of the Eastern Middle Anthracite field by the Pennsylvania Geological Survey continue to utilize data from these earlier studies. Moreover, while mapping the geology of the Southern and Western Middle fields during the 1950's and 1960's, the staff of the U.S. Geological Survey found the atlases and reports of the Anthracite Survey to be their single most important source of information. Even though the geologists of the Second Survey failed to recognize most of the thrust faulting in the anthracite fields (and thus misjudged the depths of the coal basins and underestimated the coal resources), they did provide a wealth of data on the structure and stratigraphy of the region that otherwise would never have been synthesized and would have been lost. Gordon H. Wood, Jr. (oral communication, 1980) of the USGS considered Ashburner's administration of the Anthracite Survey as one of the finest contributions to late nineteenth century geology.

### PROBLEMS AND PRESSURES

In spite of its ultimate success, the Anthracite Survey encountered and overcame numerous difficulties. Many of these were serious and required compromise and sacrifice; others were amusing and reflect the mundane frustrations experienced by every generation.

#### Fiscal vexations

The greatest problem facing the Second Geological Survey was the uncertainty of renewal or level of funding of each succeeding biennial appropriation by the Pennsylvania Legislature. This limited the Anthracite Survey's ability to plan future activities and led to the curtailment, postponement, or elimination of a number of important studies. It also affected morale and resulted in the resignations of experienced staff, who wanted more secure employment and a good salary. Budget cuts imposed by a legislative act in 1885 were particularly detrimental and led to the loss of about half the assistants assigned to the Anthracite region. Lesley (1886) was especially critical of this legislative action.

On a related matter, the Second Survey was unable to convince the Legislature of the importance of a comprehensive geodetic survey and systematic program of statewide topographic mapping. Since it was established, the Second Survey repeatedly asked for this work to be funded, and the need became more critical when geologic mapping commenced in the Anthracite region. (Its regular appropriations were only sufficient for the Second Survey to undertake topographic mapping as part of various topical studies). Beginning in 1875 at the request of Lesley, intermittent triangulation surveys were conducted by the Federal government for parts of Pennsylvania. However, in 1884, the U.S. Geological Survey and U.S. Coast and Geodetic Survey offered to cooperate with the Second Survey in implementing systematic, statewide geodetic and topographic surveys. Although Pennsylvania would have been required to contribute only about 20 percent of the money, the Legislature did not support the proposal. At the urging of Lesley, the USGS finally initiated some topographic mapping (scale 1:62,500) in the Anthracite region in 1889, but it was too late to be of much use to the Anthracite Survey. (See Dodge, 1987.)

Throughout its reports and in its letters of transmittal and prefatory letters that preceded them, the Second Survey tried to solicit public support by

addressing the importance and practical value of its work. Unfortunately, disapproval of the Survey grew in the mid-1880's partly due to the ignorance of citizens who failed to read the reports or who did not appreciate them. The geologic studies may have been good science, but their utility was questioned. With regard to the Anthracite Survey, even though it carefully explained and justified its actions, some people (including legislators) were genuinely concerned by the slowness of the Survey's mapping and by Ashburner's inability to estimate a completion date because of the increasing complexity of the work. The Second Survey could only do so much to educate the public. At the same time, it had to avoid the appearance of influencing the Legislature for support, but it was not always successful. For example, at least one senator wrongfully accused Ashburner of having "spent his whole time here [in Harrisburg] this winter [of 1884-1885] in trying to lobby a bill through here instead of attending to the work of this [Geological Survey] commission" (Pennsylvania General Assembly, 1885, p. 2371-2372). Undoubtedly influenced by this incident, Ashburner (1886b, p. 274) later remarked:

The legitimate work of the Survey organization is to carry on the work in accordance with legislative acts, and not to see that sufficient appropriations are obtained. All that the Survey can be called upon to do is to submit plans and estimates to the Legislature, and those citizens of the State, who are practically interested in the continuance of the work, should take such action as to insure the granting of necessary appropriations. This applies not only to the work in the anthracite region, but to that in all other districts of the State.

Ironically, an act of 1887 contained the largest biennial appropriation for anthracite work but required the Anthracite Survey to complete its objectives and disband by June 1, 1889. During the last two years of the Survey, many more staff were hired in order to accomplish this almost insurmountable task. Although much other material had already been gathered and compiled, only four anthracite atlases had been published prior to January 1, 1887. The other 16 were issued over the next five years.

Lesley had repeatedly stressed the need for a permanent geological survey, but in this he was unsuccessful. The ultimate demise of the Second Geological Survey can be traced to Legislative criticism over mounting publication costs, the number of volumes produced, and the relative lack of synthesis of the information contained in the reports (Jordan and Pierce, 1981).

### Routine activities

The "Reports of Progress" and surviving records of the Second Survey help to reveal the day-to-day activities of the staff conducting the anthracite investigations. Survey correspondence indicates a constant exchange of information and inquiries between Ashburner and his assistants on a wide range of topics (Figure 34). Many concerns seem remarkably contemporary. There was an endless array of issues with which to contend, ranging from the relative dimensional stability of different drafting media to the establishment of policy regarding the collection and use of confidential data. Yet, as efficient as the members of the Anthracite Survey were, certain mistakes occurred that left an indelible impression on those involved and demonstrated the commonality of human fallibility. What follows is one such example.

Subject

*Second Geological Survey of Pennsylvania,  
Anthracite District: Main Office, 907 Walnut Street, Philadelphia.*

*F. P. LESLEY, State Geologist.*

*CHAS. A. ASHBURNER, Geologist in Charge.*

*Scranton Office, Sept. 4th. 1883*

*Chas. A. Ashburner Esq. -*

*Geologist in Charge Anth. Dist.  
Dear Sir*

Figure 34. Heading and salutation of an 1883 letter from F. A. Hill, Assistant Geologist working in the Northern Anthracite field, to C. A. Ashburner, Geologist in Charge.

At the request of Ashburner, Professor C. L. Doolittle of Lehigh University voluntarily determined the astronomical latitude and longitude for two sites in Pottsville and Wilkes-Barre during the summer and early autumn of 1881.<sup>1</sup> Doolittle (1883) subsequently described his measurements and calculations in detail. His work went well, but what followed did not. Towards the end of his life, Arthur Winslow (1936, p. 3), a former Assistant Geologist of the Anthracite Survey, recalled what happened:

An amusing incident I remember occurred in Wilkes Barre, where an astronomical observation was conducted by Prof. Doolittle of Lehigh University, I believe, to determine the exact latitude and longitude of that place as a check on our mapping. When the work was completed the professor made his report, a monument was erected in the court house yard with the figures of latitude and longitude inscribed thereon, as the official result of the observation of the Second Geological Survey. Hardly was this exposed to public scrutiny than caustic criticisms appeared. One correspondent to the local paper denounced the results as grossly inaccurate, stating that he could give a better longitude result with his grandfather's old turnip watch. Great was the furore aroused. Ashburner rushed hot foot and indignant to the scene. An investigation followed. The explanation developed that the figures transmitted by Prof. Doolittle had been expressed by him in hours, minutes, and seconds, and these had been groven on to the monument as degrees, minutes and seconds. Great was the humiliation that followed, and hasty veiling of the monument for erasures and correcting.

<sup>1</sup>Latitudes were established by using a zenith telescope and measuring differences in the zenith distances of several pairs of stars. The resultant values are expressed in angular units. Longitudes were found by comparing, with the assistance of a telegraph link, the local time (i.e., time based on the meridian through a given place) of an unknown station with that of some location where the longitude was known. Transit times of stars were determined using a transit instrument, clock, and chronograph. Thus, longitudes may be expressed in units of time or angle.

## POSTSCRIPT ON PERSONNEL

The success of the Second Geological Survey of Pennsylvania was the result of excellent leadership and outstanding staff. The Anthracite Survey shared in much of this talent. At one time or another, more than 50 members of the Second Survey were involved in anthracite-related work (Table 5). It was up to the veterans on the staff to set the standards, for the younger assistants of the Anthracite Survey often had just completed their schooling and had started with relatively little prior experience. Yet, through training and hard work, most of them made important contributions and went on to have successful careers after they left the Survey. Many, in fact, found lucrative employment as mining engineers and geologists in the anthracite industry.

As the following examples illustrate, the future accomplishments of the Survey personnel reflected well upon their abilities and competence. J. Peter Lesley (1819-1903) was at the climax of an extraordinary career. He continued as State Geologist until poor health forced him to relinquish nearly all responsibilities in 1893. Charles A. Ashburner (1854-1889) resigned from the Survey in 1886 to work for George Westinghouse, Jr. Thereafter, he became a consulting geologist and was employed by Westinghouse and other business interests. While working in Arizona in late 1889, he fell ill and was forced to return home to Pittsburgh prematurely. Tragically, he died unexpectedly on Christmas Eve, thus ending a brief but very distinguished career. John C. Branner (1850-1922) worked on the Anthracite Survey for several years as a topographer and assistant in the Northern field. He left in 1885 to become a professor of geology at Indiana University (Bloomington) and received his Ph.D. there the same year. Branner went on to have an outstanding career. In the ensuing years, he became State Geologist of Arkansas in 1887, professor of geology at Stanford University in 1891, President of the Geological Society of America for 1904, and President of Stanford University in 1913. By the time he resigned, H. Martyn Chance (1856-1937) had been a member of the Second Geological Survey for 10 years. Although he had distinguished himself on a number of projects throughout the State, he became especially interested in mine ventilation and safety. To understand the occupational health of miners better, he entered Jefferson Medical College and received his M.D. in 1882. After leaving the Survey in 1884, Chance embarked on a successful career throughout the United States as a consulting geologist and mining engineer. He was subsequently elected President of the Mining and Metallurgical Society of America. In his later years, he and his son developed a sand-floatation method for cleaning coal and concentrating ore. The Chance process was eventually used in many cleaning plants in the Anthracite region. Baird Halberstadt (1860-1934) was a member of a prominent Pottsville family, and he spent most of his life in his hometown. He was employed as an aide on the Second Survey for six years. For part of this time, he worked on the Anthracite Survey in the Western Middle field. After resigning from the Survey, he engaged in private consulting work as a mining engineer and coal expert. He was a consulting geologist for the Pennsylvania Department of Agriculture between 1909 and 1919. Halberstadt served with distinction in the Pennsylvania Infantry Volunteers during the Spanish-American War. Frank A. Hill (1858-1915), also from Pottsville, was a member of a family long associated with anthracite mining; his father had been the superintendent of several large collieries. Hill worked as Assistant Geologist responsible for the Northern Anthracite field before becoming Geologist in Charge upon Ashburner's resignation. He continued the work of the Anthracite Survey until it ended in 1889. Afterwards, he was employed by various coal mining companies in Pennsylvania and

Table 5. Summary of staff members associated with the Anthracite Survey, their positions, and years of service.

| Staff member      | Position(s)† | 1880 | 1881 | 1882 | 1883 | 1884 | 1885 | 1886 | 1887 | 1888 | 1889 |
|-------------------|--------------|------|------|------|------|------|------|------|------|------|------|
| Adachi, J.        | 10,8,6       | --   | --   | --   | --   | X    | X    | X    | X    | X    | X    |
| Althouse, H.      | 9            | --   | --   | --   | --   | --   | --   | --   | --   | X    | --   |
| Ashburner, C. A.* | 3,2          | X    | X    | X    | X    | X    | X    | X    | --   | --   | --   |
| Berlin, A. P.*    | 3            | --   | X    | X    | X    | --   | --   | --   | --   | --   | --   |
| Branner, J. C.    | 4,5          | --   | --   | --   | X    | X    | X    | --   | --   | --   | --   |
| Brennan, F. P.    | 6            | --   | --   | --   | --   | --   | --   | --   | X    | --   | --   |
| Chance, H. M.*    | 3            | X    | X    | X    | X    | --   | --   | --   | --   | --   | --   |
| Chapman, M.       | 8            | X    | X    | --   | --   | --   | --   | --   | --   | --   | --   |
| Claghorn, C. R.   | 10,8         | --   | --   | --   | --   | X    | X    | --   | --   | --   | --   |
| Curtis, H. L.     | 9            | --   | --   | --   | --   | --   | --   | --   | X    | --   | --   |
| Emory, G. W.      | 5            | --   | --   | --   | --   | --   | --   | --   | X    | X    | X    |
| Fisher, H. T.     | 6            | --   | --   | --   | --   | --   | --   | --   | X    | X    | X    |
| Flick, W. J.      | 5            | --   | X    | --   | --   | --   | --   | --   | --   | --   | --   |
| Griffith, W.      | 5,3          | --   | --   | --   | X    | --   | --   | --   | X    | X    | X    |
| Hill, F. A.       | 3,2          | --   | X    | X    | X    | X    | X    | X    | X    | X    | X    |
| Hill, G. H.       | 9            | --   | --   | --   | --   | --   | --   | --   | --   | X    | --   |
| Halberstadt, B.*  | 8            | --   | X    | X    | X    | X    | X    | X    | --   | --   | --   |
| Harden, E. B.*    | 4            | --   | --   | --   | X    | X    | --   | --   | --   | --   | --   |
| Harden, O. B.*    | 8,5,4,3      | --   | --   | X    | X    | X    | X    | X    | X    | X    | X    |
| Head, J.          | 9            | --   | --   | --   | --   | --   | --   | --   | X    | --   | --   |
| Herring, E. A.    | 5            | --   | --   | --   | --   | --   | --   | --   | X    | --   | --   |
| Jones, C.         | 9,5          | --   | --   | --   | --   | --   | --   | --   | X    | X    | X    |
| Kada, T.          | 8            | --   | X    | X    | --   | --   | --   | --   | --   | --   | --   |
| Kaercher, E. E.   | 5            | --   | --   | --   | --   | --   | --   | --   | X    | X    | X    |
| Keatley, E. M.    | 8,5          | --   | --   | --   | --   | --   | --   | --   | X    | X    | X    |
| Lehman, G. M.     | 8,5,4        | --   | --   | --   | --   | X    | X    | X    | X    | X    | --   |
| Lesley, J. P.*    | 1            | X    | X    | X    | X    | X    | X    | X    | X    | X    | X    |
| Lloyd, H.         | 9            | --   | --   | --   | --   | --   | --   | --   | --   | X    | --   |
| Lucas, J., Jr.    | 9,5          | --   | --   | --   | --   | --   | --   | --   | --   | X    | X    |
| Lyman, B. S.*     | 3            | --   | --   | --   | --   | --   | --   | --   | X    | X    | --   |
| Merkle, J. F.     | 8            | --   | --   | --   | --   | --   | X    | --   | --   | --   | --   |
| Milnes, G. W.     | 5            | --   | --   | --   | --   | --   | --   | --   | --   | X    | X    |
| Miner, C. H.      | 10           | --   | --   | --   | --   | X    | --   | --   | --   | --   | --   |
| Moister, I. R.    | 3            | --   | --   | --   | --   | --   | --   | --   | X    | X    | X    |
| Morris, G.        | 5            | X    | X    | --   | --   | --   | --   | --   | --   | --   | --   |
| Moyer, H. I.      | 6,8          | X    | X    | X    | X    | --   | --   | --   | --   | --   | --   |
| Parrish, H. E.    | 3            | --   | X    | X    | X    | --   | --   | --   | --   | --   | --   |
| Platt, F.*        | 3            | X    | X    | --   | --   | --   | --   | --   | --   | --   | --   |
| Price, L. D.      | 5            | --   | --   | --   | --   | --   | --   | --   | --   | X    | X    |
| Quin, R. A.       | 5            | --   | --   | --   | --   | --   | --   | --   | X    | X    | X    |
| Reinhard, H. J.   | 5            | --   | --   | --   | --   | --   | --   | --   | --   | --   | --   |
| Schoew, L.        | 5            | --   | --   | --   | --   | --   | --   | --   | --   | X    | X    |
| Scott, C. C.*     | 8,5,7        | --   | X    | X    | X    | X    | --   | --   | X    | --   | --   |
| Shay, C. F.       | 9,5          | --   | --   | --   | --   | --   | --   | --   | X    | X    | X    |
| Sheafer, A. W.*   | 3            | X    | X    | X    | --   | --   | --   | --   | --   | --   | --   |
| Shelly, F.        | 9,5          | --   | --   | --   | --   | --   | --   | --   | --   | X    | X    |
| Sims, H. W.       | 3,5          | --   | --   | X    | X    | X    | X    | --   | --   | --   | --   |
| Smith, A. DW.     | 8,5,3        | --   | --   | --   | X    | X    | X    | X    | X    | X    | X    |
| Smith, W. F.      | 5            | --   | --   | --   | --   | --   | --   | --   | X    | X    | --   |
| Somerville, B.    | 8            | --   | --   | --   | --   | --   | X    | --   | --   | --   | --   |
| Stewardson, E. L. | 10           | --   | --   | --   | --   | X    | --   | --   | --   | --   | --   |
| Wells, B.         | 8,3          | --   | X    | X    | X    | X    | X    | --   | --   | --   | --   |
| Williams, T. J.   | 5            | --   | --   | --   | X    | X    | --   | --   | --   | --   | --   |
| Winslow, A.       | 8,3          | --   | X    | X    | X    | X    | --   | --   | --   | --   | --   |
| Wright, C.        | 9            | --   | --   | --   | --   | --   | --   | --   | --   | X    | --   |

Staff positions:

|                       |                   |
|-----------------------|-------------------|
| 1 State Geologist     | 6 Draftsman       |
| 2 Geologist in Charge | 7 Secretary       |
| 3 Assistant Geologist | 8 Aide            |
| 4 Topographer         | 9 Surveying crew  |
| 5 Assistant           | 10 Volunteer aide |

\*Served in other capacities on the Second Geological Survey before, during, or after work related to the Anthracite Survey. Additional years of service are not shown.

†For each individual, the positions held are listed in chronological order.

Virginia as a manager and executive officer. Benjamin S. Lyman (1835-1920) was technically never a part of the Anthracite Survey, but, as a consulting geologist, he prepared a private report for an area in the Southern field, which he examined in 1887 and 1888. Shortly after Lyman completed the report, the property owners permitted its publication by the Second Survey. At about the same time, Lyman was contracted by the Second Survey (though he was classified as an Assistant Geologist) to study the Mesozoic rocks of Bucks and Montgomery Counties in southeastern Pennsylvania. Earlier in his career, he distinguished himself as a geologist working for the British in India and as first Director of the Geological Survey of Japan. In his later years, Lyman continued his private practice as a consulting geologist. Franklin Platt (1844-1900) left the Second Survey in 1881 to become a private consultant in coal geology. He worked briefly in Nova Scotia and principally in western Pennsylvania where he helped to develop bituminous coal lands in Jefferson County. In 1886, Platt was elected President of the Rochester and Pittsburgh Coal and Iron Company. Arthur Winslow (1860-1938) was an Assistant Geologist on the Anthracite Survey for three years. He first did drafting work for Chance and then was assigned to the Northern field. He later took charge of the investigations in the Eastern Middle field. Some of his work for Ashburner demonstrated considerable aptitude in mathematics. In 1884, Winslow resigned from the Survey to become a consulting geologist. Later he joined the Arkansas Geological Survey and worked with J. C. Branner. Winslow was appointed State Geologist of the Missouri Geological Survey in 1888. Thereafter, he embarked on a successful and lucrative career in gold mining and became manager and president of several gold mining companies. In this centennial year of the founding of the Geological Society of America in 1888, it is noteworthy that eight of the nine men discussed here were members of this prestigious organization. Five were Original Fellows and included Ashburner, Branner, Lesley, Platt, and Winslow. The three elected Fellows were Chance, Halberstadt, and Hill.

Reminiscences by former assistants, such as Arthur Winslow, add a human quality to the work of the Anthracite Survey. As one grows older, Winslow's (1936, p. 3-4) concluding comments become more poignant:

It all seems a long time ago, and it is difficult to recapture the enthusiasms and ambitions which were so stimulating to young men in their twenties.

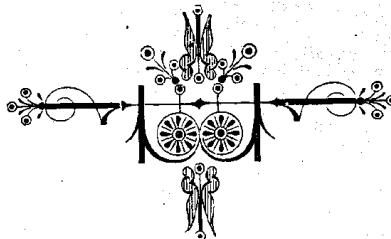
Yet, the object of these young men's interest, the Anthracite Survey, can still be admired and appreciated today -- through both the beauty and utility of its products.

#### REFERENCES CITED

- Arndt, H. H., Averitt, P., Dowd, J., Frendzel, D. J., and Gallo, P. A., 1968, Pennsylvania anthracite, In Mineral Resources of the Appalachian Region: U.S. Geological Survey Professional Paper 580, p. 121-133.
- Ashburner, C. A., 1881a, Progress of the Second Geological Survey of Pennsylvania: Engineers' Club of Philadelphia Proceedings, v. 2, p. 108-114.
- \_\_\_\_\_, 1881b, New method of mapping the anthracite coal-fields of Pennsylvania: American Institute of Mining Engineers Transactions, v. 9, p. 506-518.
- \_\_\_\_\_, 1883a, First report of progress in the Anthracite coal region -- The geology of the Panther Creek basin or eastern end of the Southern field: Pennsylvania Geological Survey, 2nd ser., Report AA, 407 p.

- \_\_\_\_\_, 1883b, New method for estimating the contents of highly plicated coal beds as applied to the anthracite fields of Pennsylvania: Engineers' Club of Philadelphia Proceedings, v. 3, p. 216-231.
- \_\_\_\_\_, 1886a, Report on the Bernice coal-basin in the Loyalsock and Mehoopany coal-field, in Sullivan County, in [Lesley, J. P., ed.], State Geologist, Annual report of the Geological Survey of Pennsylvania for 1885: Pennsylvania Geological Survey, 2nd ser., p. 459-490.
- \_\_\_\_\_, 1886b, Second report of progress in the Anthracite coal-regions -- Part II, in [Lesley, J. P., ed.], State Geologist, Annual report of the Geological Survey of Pennsylvania for 1885: Pennsylvania Geological Survey, 2nd ser., p. 269-436.
- Ashburner, C. A., Berlin, A. P., and Winslow, Arthur, 1885, Eastern Middle Anthracite field, Part 1: Pennsylvania Geological Survey, 2nd ser., Report AA [Atlas], 8 sheets.
- Ashburner, C. A., and Hellprin, Angelo, 1886, Report of the Wyoming Valley limestone-beds, accompanied by a description of the fossils contained in the same, in [Lesley, J. P., ed.], State Geologist, Annual report of the Geological Survey of Pennsylvania for 1885: Pennsylvania Geological Survey, 2nd ser., p. 437-458.
- Binder, F. M., 1974, Coal age empire -- Pennsylvania coal and its utilization to 1860: Harrisburg, Pennsylvania Historical and Museum Commission, 184 p.
- Board of Commissioners of the Second Geological Survey of Pennsylvania, 1880, Special meeting of April 14, 1880, in Minutes of the Board of Commissioners of the Second Geological Survey of Pennsylvania [June 12, 1874 to December 1, 1896]: State Archives, Pennsylvania Historical and Museum Commission, Harrisburg, Record Group 14 of the Department of Internal Affairs, p. 139-144.
- Chance, H. M., 1883, Report on the mining methods and appliances used in the anthracite coal fields: Pennsylvania Geological Survey, 2nd ser., Report AC, 574 p.
- Darton, N. H., 1940, Some structural features of the Northern Anthracite coal basin, Pennsylvania: U.S. Geological Survey Professional Paper 193-D, p. 69-81.
- Dodge, C. H., 1981, The geologic genius of Charles Albert Ashburner: Northeastern Geology, v. 3, p. 86-93.
- \_\_\_\_\_, 1987, The Second Geological Survey of Pennsylvania -- The golden years: Pennsylvania Geology, v. 18, p. 9-15.
- Doolittle, C. L., 1883, Determination of the latitude and longitude of Wilkes Barre in Luzerne County and of Pottsville in Schuylkill County [Appendix A], in Ashburner, C. A., First report of progress in the Anthracite coal region -- The geology of the Panther Creek basin or eastern end of the Southern field: Pennsylvania Geological Survey, 2nd ser., Report AA, p. 243-324.
- Eavenson, H. N., 1942, The first century and a quarter of American coal industry: Baltimore, Waverly Press [privately printed], 701 p.
- Hudson Coal Company, 1932, The story of anthracite: New York, Hudson Coal Company, 425 p.
- Jordon, W. M., and Pierce, N. A., 1981, J. Peter Lesley and the Second Geological Survey of Pennsylvania: Northeastern Geology, v. 3, p. 75-85.
- Lesley, J. P., 1878, Historical sketch of geological explorations in Pennsylvania and other states (2nd ed.): Pennsylvania Geological Survey, 2nd ser., Report A, 200 p., appendix, xxvi p.
- \_\_\_\_\_, 1886, Report of the State Geologist for 1885, in [Lesley, J. P., ed.], State Geologist, Annual report of the Geological Survey of Pennsylvania for 1885: Pennsylvania Geological Survey, 2nd ser., p. xvii-xxxix.
- \_\_\_\_\_, 1890, Obituary notice of Charles Albert Ashburner: American Philosophical Society Proceedings, v. 28, p. 53-59.
- \_\_\_\_\_, 1920, Second Geological Survey under J. P. Lesley, 1874-1888, in Merrill, G. P., Contributions to a history of American state geological and natural history surveys: U.S. National Museum Bulletin 109, p. 434-456.
- Owen, E. W., 1975, Trek of the oil finders: a history of exploration for petroleum: American Association of Petroleum Geologists Memoir 6, 1647 p.
- Pennsylvania General Assembly, 1879, Resolution no. 13 in the House of Representatives, March 24, 1879, in Laws of the General Assembly of the State of Pennsylvania passed at the Session of 1879, in the one hundred and third year of Independence, p. 203-204.
- \_\_\_\_\_, 1885, Geological Survey of the State, in Daily Legislative Record for the Session of 1885, no. 298, June 3, 1885, p. 2367-2372.

- Platt, Franklin, 1881, A special report to the Legislature upon the causes, kinds and amount of waste in mining anthracite: Pennsylvania Geological Survey, 2nd ser., Report A2, p. 1-4, p. 23-134.
- Rodgers, H. D., 1838, Second annual report on the geological exploration of the state of Pennsylvania: Pennsylvania Geological Survey, 1st ser., 91 p.
- Sherwood, Andrew, and Platt, Franklin, 1880, The geology of Lycoming and Sullivan Counties: Pennsylvania Geological Survey, 2nd ser., Report GG, 268 p.
- Smith, A. DW., 1893, Estimate of the original geological anthracite coal-field of Pennsylvania, in Coxe, E. B., Thompson, H. S., and Griffith, William, Commissioners, Report of commission appointed to investigate the waste of coal mining, with the view to the utilizing of the waste: Philadelphia, Allen, Lane, and Scott's Printing House, p. 55-154.
- \_\_\_\_\_, 1895, Report on the Anthracite region, in Lesley, J. P., d'Invilliers, E. V., and Smith, A. DW., A summary description of the geology of Pennsylvania: Pennsylvania Geological Survey, 2nd ser., Final Report, v. 3, pt. 1, p. 1916-2152.
- Wallace, A. F. C., 1987, St. Clair -- A nineteenth-century coal town's experience with a disaster-prone industry: New York, A. A. Knopf, 519 p.
- Winslow, Arthur, 1936, unpublished letter to Dr. George H. Ashley, State Geologist, dated May 25, 1936 [in response to Ashley's request for recollections by former Survey staff as part of the centennial celebration of the founding of the First Geological Survey of Pennsylvania in 1836]: Pennsylvania Geological Survey collection, Harrisburg, 4 p.
- Wood, G. H., Jr., Trexler, J. P., and Kehn, T. M., 1969, Geology of the west-central part of the Southern Anthracite field and adjoining areas, Pennsylvania: U.S. Geological Survey Professional Paper 602, 150 p.
- Wood, G. H., Jr., Kehn, T. M., and Eggleston, J. R., 1986, Depositional and structural history of the Pennsylvania Anthracite region, in Lyons, P. C., and Rice, C. L. (eds.), Paleoenvironmental and tectonic controls in coal-forming basins of the United States: Geological Society of America Special Paper 210, p. 31-47.



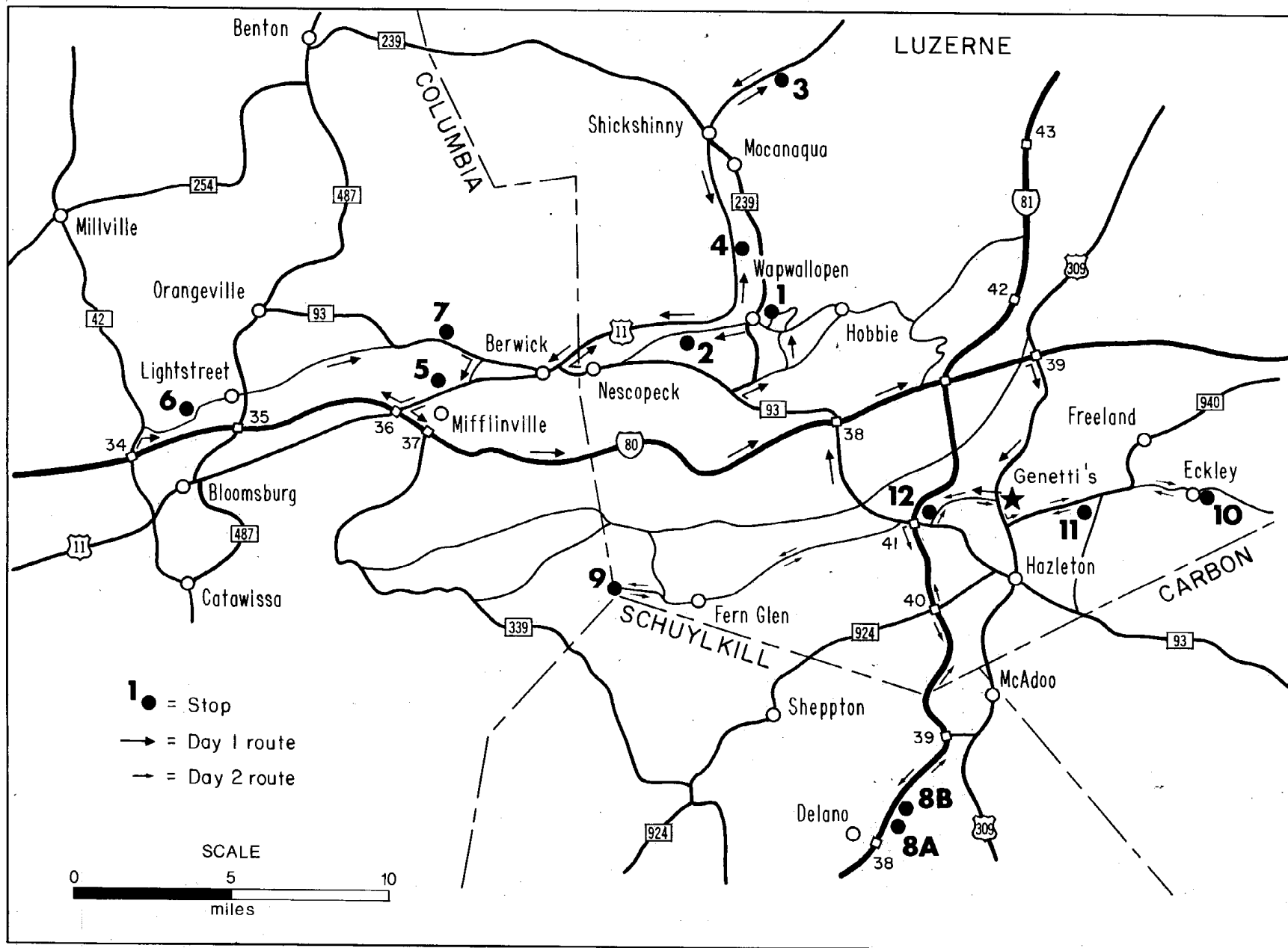


Figure 35. Field trip route with Stop locations.

# ROAD LOG - DAY 1

| Mileage |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|---------|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Inc     | Cum  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 0.0     | 0.0  | START. Leave parking lot in front of Genetti Motor Lodge, Hazleton, PA. TURN RIGHT onto US Route 309.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 0.5     | 0.5  | TRAFFIC LIGHT. TURN LEFT onto SR 3026 (Hazleton By-Pass).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 2.4     | 2.9  | TRAFFIC LIGHT. TURN RIGHT onto PA Route 93.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 0.2     | 3.1  | Entrance to Hazleton Campus of Pennsylvania State University.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 0.4     | 3.5  | Cross over I-81 and begin descent of Buck Mountain.<br>The lip of the escarpment here is held up by conglomerates in the upper member of the Mauch Chunk Formation (well exposed in the interchange area and subject of Stop 12). Ahead is the Conyngham Valley, underlain by the middle member of the Mauch Chunk Formation, and Sugarloaf Mountain, a synclinal remnant capped by a resistant conglomerate in the upper member of the Mauch Chunk.<br>Late Illinoian ice reached to the base of Buck Mountain, filling Conyngham Valley. A large morainic loop of late Illinoian kame deposits swings across the valley 8 miles to the west. The late Wisconsinan margin crosses the valley 3 miles northeast of here. Occasional patches of late Illinoian glacial drift are present on the floor of the valley between the two margins. |
| 0.2     | 3.7  | Upper Mauch Chunk conglomerate and mudstone on the left.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 0.4     | 4.1  | Middle Mauch Chunk sandstone and mudstone on left.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 0.2     | 4.3  | Excavation in red mudstone typical of the middle member of the Mauch Chunk to the left.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 0.8     | 5.1  | Historical Marker to right reads:<br>SUGARLOAF MASSACRE. After an unsuccessful attack on Fort Augusta [at Sunbury], Indians and Tories surprised a detachment of Northumberland Co. militia on Sept. 11, 1780. The site of the massacre is just beyond the town.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 0.3     | 5.4  | Good view of Sugarloaf Mountain to left.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 0.7     | 6.1  | Enter village of Sybertsville.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 0.7     | 6.8  | Subhorizontal middle Mauch Chunk mudstone to left.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 0.3     | 7.1  | Cross Nescopeck Creek.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 0.8     | 7.9  | Pass under I-80, staying on PA Route 93. Directly ahead is Nescopeck Mountain, presumably named for the Shawnee Indian village of "Nescopeck" on the North Branch Susquehanna River. "Nescopeck" is possibly an anglicized corruption of the Shawnee for "black waters" or "dirty waters" (Brasch, 1982).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 1.0     | 8.9  | Boulder colluvium overlying south-dipping sandstone of the Pocono Formation to right.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 0.5     | 9.4  | Crest of Nescopeck Mountain, here formed by the Spechty Kopf Formation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 0.2     | 9.6  | Spechty Kopf sandstone to left.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 0.3-    | 9.9- | To left are intermittent outcrops of sandy parts of fining-upward alluvial cycles in the Duncannon Member of the Catskill Formation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 1.1     | 10.7 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 1.0     | 11.7 | TURN RIGHT onto PA Route 239 at Briggsville.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 0.2     | 11.9 | Cross late Wisconsinan terminal moraine, indistinct in this area except for several kames that have been locally exploited as sources of sand and gravel.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

- |     |      |                                                                                                                                                                        |
|-----|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.7 | 12.6 | Intersection with SR 3012. CONTINUE STRAIGHT AHEAD on SR 3012.                                                                                                         |
| 0.1 | 12.7 | Stone walls constructed of glacial erratics to left.                                                                                                                   |
| 0.2 | 12.9 | Wapwallopen Creek valley to left. The creek here occupies its preglacial valley. Upstream and downstream of this point it flows in narrow, postglacial bedrock gorges. |
| 0.5 | 13.4 | Fields to left mark the buried, preglacial valley of Wapwallopen Creek. The trees beyond line the postglacial bedrock gorge.                                           |
| 0.8 | 14.2 | Intersection of SR 3012 and Ridge Road (Twp. Route 398). BEAR LEFT, staying on SR 3012.                                                                                |
| 0.1 | 14.3 | TURN LEFT onto SR 3013.                                                                                                                                                |
| 0.2 | 14.5 | Cross Wapwallopen Creek. This reach is about 0.5 mi above the upper bedrock gorge.                                                                                     |
| 0.9 | 15.4 | STOP SIGN. TURN RIGHT onto Wapwallopen-Hobbie Road.                                                                                                                    |
| 0.2 | 15.6 | TURN LEFT onto Maple Lane (Twp. Route 394).                                                                                                                            |
| 0.6 | 16.2 | TURN LEFT at Council Cup sign.                                                                                                                                         |
| 0.4 | 16.6 | TURN LEFT onto Council Cup Road (Twp. Route 388).                                                                                                                      |
| 0.4 | 17.0 | TURN RIGHT onto unpaved road at wooden gate.                                                                                                                           |
| 0.3 | 17.3 | Stop in parking lot and debark from buses.                                                                                                                             |
- STOP 1. COUNCIL CUP SCENIC OVERLOOK: PHYSIOGRAPHY, GEOMORPHIC EVOLUTION, AND PLEISTOCENE HISTORY OF THE NORTH BRANCH LOWLAND

LEADERS: Duane D. Braun and Jon D. Inners

Council Cup is a 1,200-foot- (365-m-) high promontory that stands more than 700 feet (210 m) above the bend of the North Branch Susquehanna River ("Bell Bend") at Wapwallopen (Figure 36). Its name derives from a hybrid of English and anglicized German. "Council" commemorates a parley between the white settlers and Indians which, according to local folklore, took place here in the 18th century. "Cup" is a minor corruption of the German "Kupp," meaning summit, top, or knoll.

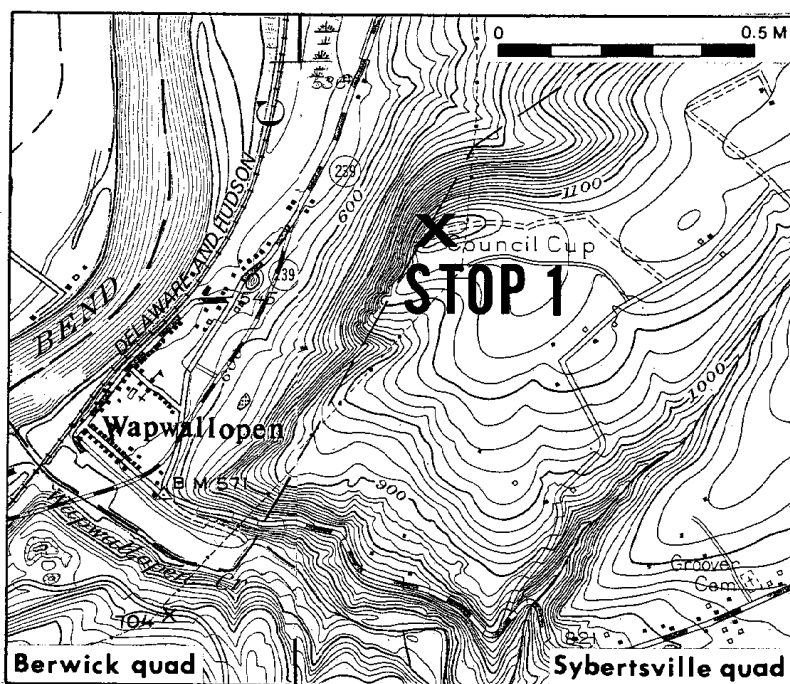


Figure 36. Location map of STOP 1.

The first white man to pass beneath the great cliff of Council Cup was probably Etienne Brulé, one of Samuel de Champlain's lieutenants, who traveled down the Susquehanna from Carantouan (near Sayre) to Chesapeake Bay with an Indian escort in the spring of 1616 (Carmer, 1955). Brulé left no record of his journey, but Champlain mentions that he "continued...along this river, past islands in it and lands that border it, which are inhabited by several nations and many savage peoples."

Council Cup is underlain by gray, medium-bedded siltstones and fine-grained sandstones of the Upper Devonian Trimmers Rock Formation. Bedding in the cliffs along the northwest side of the hill strikes N75E and dips 20-25° to the southeast on the south flank of the Berwick anticlinorium. As elsewhere in the Trimmers Rock throughout this region, two orthogonal joint sets are very well developed: i.e., ENE-trending strike joints (fracture cleavage, in part) and NNW-trending dip joints. The joints are commonly 0.5 to 2 feet (0.15 to 0.6 m) apart, and breakage along them accounts for the ragged profile of the cliffs. It is likely that the northwest face owes some of its steepness to glacial plucking in the late Wisconsin (Figure 37). Many large (2 to 3 feet, or 0.6 to 1 m) blocks of Trimmers Rock siltstone occur in the Honey Hole Gravel Pit about 3 miles (5 km) "down-glacier" (Stop 2).

### Physiography

From the overview at STOP 1, we can see the physiographic setting of the remainder of the Day-1 field trip (Figure 38). The lowland in front of us is in the center of the breached Berwick anticlinorium and is eroded out of Upper Silurian to Middle Devonian shales and carbonates (Stops 6 and 7). The fold axis of the easternmost en echelon anticline plunges N76E (left to right) at 2 to 4° (Inners, 1978); and the lowland pinches out down-plunge to the right. The rolling hills in the lowland have a local relief of 100 feet (30 m) or less. Pennsylvania Power and Light Company's Susquehanna Steam Electric Station occupies a high kame terrace that stands at an elevation just slightly lower than the tops of shale hills in the lowland (Stop 4). In the distance to the west an anticlinal ridge appears in the center of the Berwick anticlinal lowland. Its



Figure 37. Council Cup as seen from Wapwallopen. Part of the broad apron of sharpstone talus that extends downslope from the foot of the cliff is visible on the extreme left.

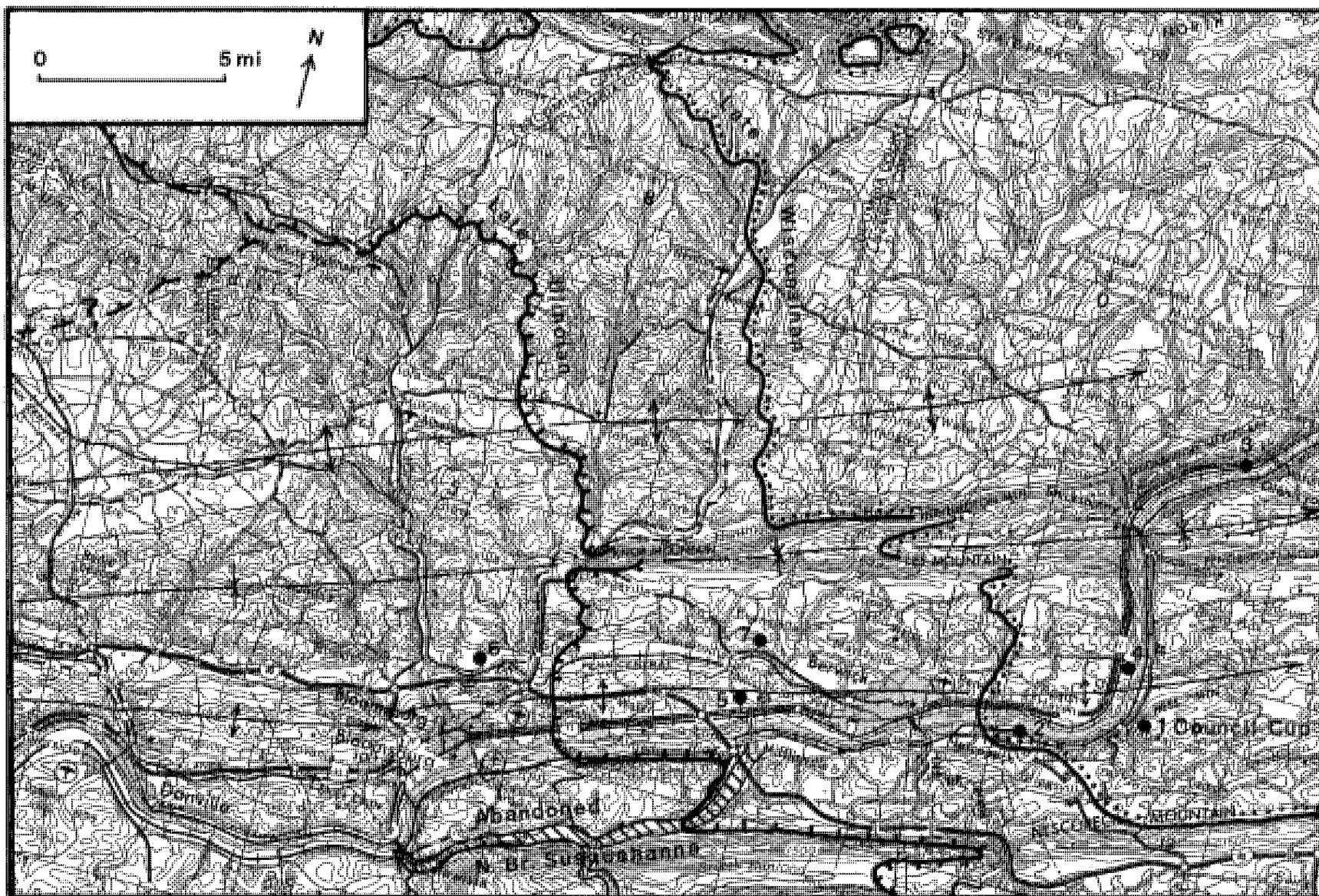


Figure 38. Topographic map of the Day-1 field trip, showing stop locations, structural axes, glacial margins, and the abandoned North Branch Valley at Mifflinville.

near end (east) at Bloomsburg, called Turkey Hill, is underlain by the hematite-bearing, Rose Hill Formation. Farther to the west is the higher anticlinal Montour Ridge underlain by the Tuscarora sandstone. (See Table 1 for stratigraphic column).

The North Branch Susquehanna River enters the lowland opposite the overlook (north) (Figure 39) and then flows along the south side to Bloomsburg where it turns southward into the adjacent rolling upland (Figure 38). The North Branch falls less than 50 feet (15 m) in 23 miles (37 km) from Shickshinny to Bloomsburg and provides a low-gradient local base level for tributary streams.

A distinct scarp slope rises on either side of the lowland to the elevation of hilltops on a rolling upland (Figure 40). The scarp slope is underlain by interbedded gray sandstone and shale of the Trimmers Rock Formation. (These two opposite-facing escarpments are locally known as River Hill [south side] and Summer Hill [north side]). The remainder of the upland is underlain by the interbedded red mudstone, red sandstone, and non-red sandstone of the Irish Valley and Sherman Creek Members of the Catskill Formation. The local relief is typically 300-400 feet (90-120 m). Broad convex hilltops are far wider than the intervening narrow straight-sided to concave-sloped valleys of local streams that originate within the upland or on the immediately adjacent strike ridge. Adjacent hilltops on the rolling upland tend to have similar elevations (are accordant). The upland, when viewed at an oblique angle, as from Council Cup, appears as a nearly horizontal plain due to the summit accordance.

Rising about 600-700 feet (180-210 m) above the rolling uplands are prominent strike ridges, Nescopeck Mountain on the left (south) and Lee-Penobscot on the right (north) (Figures 38). These homoclinal ridges (hogbacks) are underlain at their crests by sandstones of the Pocono or Spechtly Kopf Formations.



Figure 39. View north from STOP 1 toward the water gaps cut by the North Branch Susquehanna River as it exits from the Wyoming-Lackawanna basin. Mountains: 1 = Lee; 2 = Penobscot; 3 = unnamed Pottsville ridge; 4 = Shickshinny; 5 = North. Immediately below the overlook are broad outwash and floodplain terraces along the North Branch.

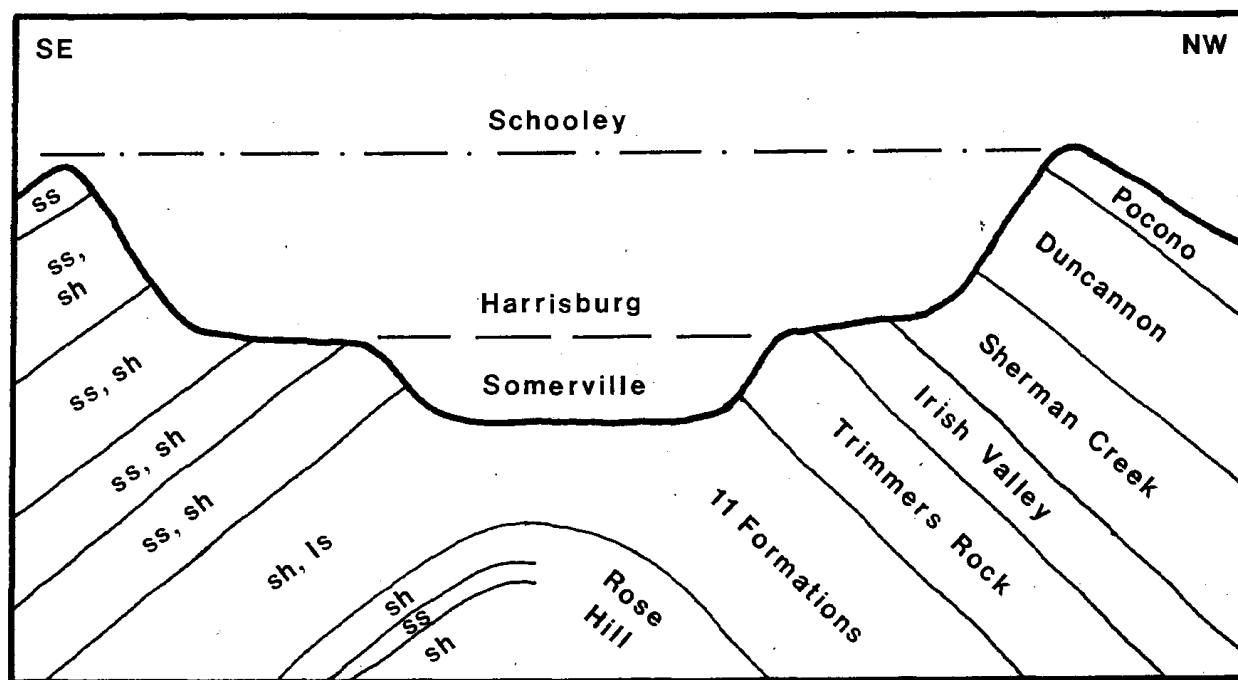


Figure 40. Generalized geologic cross section of the breached Berwick anticlinorium, showing relationship of bedrock units to topography. Three postulated erosion surfaces (peneplains) are also shown.

Their scarp faces, that face towards us, are underlain by interbedded red mudstone and gray sandstone of the Duncannon Member of the Catskill Formation. Nescopeck Mountain marks the extreme northern rim of the Eastern Middle Anthracite field. Lee-Penobscot Mountain marks the southern rim of the Northern Anthracite field.

Looking north through the North Branch Susquehanna River water gap (Figure 39), a low ridge projects into the gap from the left (west) side. This ridge is underlain by conglomerate of the Pottsville Formation and marks the axis of the Wyoming coal basin and the Lackawanna synclinorium. The next large ridge beyond is Shickshinny Mountain, underlain by the Pocono. Its dipslope faces us and marks the north rim of the Northern field. That dipslope is undercut by the North Branch Susquehanna and is failing in a series of large rock block slides, the largest of which we will see at Stop 3. To the left of the water gap, Lee and Shickshinny Mountains merge to form Knob Mountain, the up-plunge elongate nose of the Lackawanna synclinorium. Aligned with the North Branch Susquehanna water gap is the Shickshinny Creek gap through Shickshinny Mountain.

Beyond that gap, another rolling upland underlain by the Catskill Formation is visible. That rolling upland is a breached anticlinal "valley" marking the down-plunge end of the Milton anticline. Farther to the north, on the skyline, is North Mountain, underlain by sandstones of the Pocono Formation and its equivalent, the Burgoon Sandstone. North Mountain is part of the Allegheny topographic front that marks the edge of the Appalachian Plateau.

### Geomorphic evolution

The landscape viewed from Council Cup appears to have three different levels, the highest marked by the crests of the major strike ridges, the middle

marked by the rolling uplands, and the lowest marked by the gently rolling lowland followed by the North Branch Susquehanna River (Figure 40). This tiered landscape is commonly explained as being a result of three episodes of development of low-relief erosion surfaces (peneplains). The first and oldest peneplain is preserved only on the crests of the major strike ridges due to the resistance of the ridge-forming sandstone to erosion. Davis (1889) called this first peneplain the Schooley peneplain and assigned it a Late Cretaceous age. The second or intermediate-level partial peneplain was called the Harrisburg peneplain (Campbell, 1903). The third and lowest partial peneplain is called the Somerville peneplain (Davis and Wood, 1890). A three-cycle uplift and stillstand of the Appalachians is necessary to produce the observed levels.

A diametrically opposed explanation of the triple-tiered landscape is that of Hack (1960, 1965, 1975). He maintains that downwasting of the Appalachians was continuous and uninterrupted by periods of baseleveling (peneplanation). The three levels visible are closely correlated with three basic differences in the resistance of the bedrock to erosion. The most resistant sandstone units form the major strike ridges, the interbedded sandstone and shale units form the intermediate-level rolling upland, and shale and carbonate units form the lowest gently rolling lowland. The landscape has been eroding in a state of dynamic equilibrium where the whole system downwastes at more or less the same rate and has been in a mature (all in slope) condition throughout the Tertiary as it continuously downwasted.

A comparison of Hack's and Davis' theories on the evolution of the Appalachian Valley and Ridge landscape is as follows:

| Davis and followers -<br>Geographic Cycle                                                                                                                       | Hack and followers -<br>Dynamic Equilibrium                                                                                                                                                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Time Dependent                                                                                                                                               | 1. Time independent - steady state                                                                                                                                                                |
| 2. Cyclic uplift and stillstand                                                                                                                                 | 2. No cycles -- continuous uplift -- varying rate                                                                                                                                                 |
| 3. Episodic or cyclic erosion                                                                                                                                   | 3. Continuous erosion -- varying rate                                                                                                                                                             |
| 4. Sequential landscape development -- youth-maturity-old age, relief reduction                                                                                 | 4. Non-sequential landscape development -- perpetual maturity                                                                                                                                     |
| 5. Overall structure truncated by topography                                                                                                                    | 5. Structure and topography closely adjusted                                                                                                                                                      |
| 6. Rocks of differing resistance preserve peneplain remnants of differing ages                                                                                  | 6. Rocks of differing resistance develop differences in elevation and slope angles                                                                                                                |
| 7. Summit accordance -- evidence for peneplanation, truncation of structure                                                                                     | 7. Summit accordance -- from subequal stream spacing on rocks of similar resistance                                                                                                               |
| 8. Deep weathering and thick residuum on hilltops in the rolling intermediate-level uplands -- evidence for landscape stability during Harrisburg peneplanation | 8. Deep weathering and thick residuum -- temporarily preserved by lag deposits of chert or sandstone, but weathering continues today with residuum production keeping up with lag deposit erosion |

Recently Sevon (1985) has proposed that only one erosion surface exists, the intermediate or Harrisburg surface. That surface is a double planation surface (Budel, 1982) with gently rolling lowlands (a few to several 10's of feet of relief) on weaker, more weatherable rock and steep-sloped ridges (100's of feet of relief) on rock more resistant to weathering and erosion. The Harrisburg surface developed from Late Cretaceous through Early Miocene time (W. D. Sevon, personal communication, 1987) under humid subtropical climate weathering that permitted formation of a low relief surface on the more weatherable rock types. From mid-Miocene to present (15 million years) only partial to nearly complete removal of the weathered mantle and dissection of the surface has occurred under conditions of alternating wet to dry and/or cold to warm climate.

The more recent explanations of Hack (1960) and Sevon (1985) differ primarily with regard to the reality of the intermediate Harrisburg surface and the significance of deeply weathered residuum, residual ore deposits, and boulder lag deposits upon the rolling hills of the surface. Sevon (1985), as did others (Hewett, 1917; King, 1950; Pierce, 1966), interprets the residual materials to represent a discrete episode of intense weathering occurring underneath a stable low relief erosion surface. Hack (1965) interprets the residual deposits as part of a continuous process (with varying rate) still acting today. Thick residual materials temporarily collect where lag gravels slow the rate of surface erosion and permit chemical weathering to outpace the surface erosion.

At present the explanations for the triple-tiered landscape range from the presence of three to zero low relief erosion surfaces. Most geomorphologists today doubt that three erosion surfaces are present in the Appalachians. If any erosion surface is postulated, it is a single dissected surface, either the Schooley or the Harrisburg surface. All hypothesis concerning the evolution of the Appalachian landscape, whether they involve none, one, or more erosion surfaces, have their weaknesses. With recent renewal of interest in the geomorphic evolution of the landscape, better hypotheses may come forth in the years ahead.

### Pleistocene history

Council Cup is 3 miles (5 km) inside the late Wisconsinan terminus (Figure 38) and may well have projected above the ice as a small nunatak. Glacial deposits are traceable to an elevation 50 ft (15 m) below the crest but are not present at the overlook itself. The large gravel operation below (Stop 2), near the left bank of the North Branch Susquehanna River, marks the head of outwash or frontal kame fan of the late Wisconsinan terminus. The margin crossed the lowland just about perpendicular to strike, with the ice flowing almost parallel to strike. Ice crossed Nescopeck Mountain to the east of where it is visible from this vantage point. Ice covered Lee and Shickshinny Mountains 2 miles (3 km) to the west of North Branch Susquehanna water gap (Inners, 1978).

Thick glaciofluvial deposits mantle the strike valley lowland. The rolling upland to the south of the river is mantled by a relatively thin veneer of till that forms an indistinct end moraine. The rolling upland on the north side of the river, particularly at the base of Lee Mountain, has a thicker veneer of till and ice-contact deposits that forms a distinct knob and kettle landscape (Inners, 1978).

Upstream of the late Wisconsinan margin along the North Branch Susquehanna Valley are a series of kame and kame delta deposits that mark temporary still-

stands of the receding ice front. Proglacial lake varves are observed between kame complexes (Peltier, 1950; Inners, 1978). In several kame deltas for up to 12 miles (19 km) from the terminus, the topset-foreset contact is at an elevation of 600-620 feet (183-189 m), the elevation of the crest of the frontal kame. This suggests that a proglacial lake was impounded behind the frontal kame as ice receded. The meltwater would incise the frontal kame and lower the lake level. The incision would be gradual, driven only by regrading of the kame fan to a gentler slope due to cessation of coarse bedload from the ice front.

In the distance, where the anticlinal ridge rises out of the center of the lowland, the late-Illinoian margin crosses the lowland (Figure 38). At Mifflinville, a great frontal kame blocked a former course of the North Branch through the Trimmers Rock-Catskill upland and forced the river to take a new path through the lowlands (Stop 5; Figure 38). The late Illinoian margin follows the base of Nescopeck Mountain, probably crossing the mountain near the Nescopeck Creek water gap. Interstate Route 80 passes through that gap today (mile 95.6 on the Day-1 Road Log). The very western end of Knob Mountain probably projected from the ice as a nunatak. Pre-Illinoian ice completely buried the region, extending to the northern edge of the Western Middle Anthracite field and to around Selinsgrove in the Susquehanna River lowland.

#### LEAVE STOP 1.

- |     |      |                                                                                                                                                                                                           |
|-----|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.3 | 17.6 | Erratic of "white" Pottsville conglomerate (6 feet in diameter) in hedgerow to right.                                                                                                                     |
| 0.1 | 17.7 | TURN RIGHT at end of entrance road.                                                                                                                                                                       |
| 0.8 | 18.5 | STOP SIGN. TURN RIGHT onto Wapwallopen-Hobbie Road at blind curve. DANGEROUS INTERSECTION! First of several cuts in south-dipping Trimmers Rock Formation to right.                                       |
| 0.2 | 18.7 | The deep postglacial valley of Wapwallopen Creek to the left is known locally as "Powder Hole." It was the site of a large DuPont gunpowder and dynamite plant from the mid-1800's into the early 1900's. |
| 0.2 | 18.9 | Proximal turbidites and shelf sands of the lower Trimmers Rock Formation to right. The outcrop is capped by late Wisconsinan kame gravels.                                                                |
| 0.4 | 19.3 | STOP SIGN. TURN LEFT onto PA Route 239.                                                                                                                                                                   |
| 0.1 | 19.4 | Cross Wapwallopen Creek near its mouth.                                                                                                                                                                   |
| 0.2 | 19.6 | CONTINUE STRAIGHT (west) on SR 3036, where PA Route 239 bends to left.                                                                                                                                    |
| 0.7 | 20.3 | Cottages to right were almost completely covered by water during the Agnes Flood of 1972. The North Branch rose 15 feet over its banks, reaching nearly to the level of the railroad tracks on the left.  |
| 0.7 | 21.0 | Hess Brothers sand-and-gravel operation in proximal part of late Wisconsinan frontal kame to left.                                                                                                        |
| 0.8 | 21.8 | Cross railroad tracks.                                                                                                                                                                                    |
| 0.1 | 21.9 | Ascend to top of Woodfordian frontal kame.                                                                                                                                                                |
| 0.2 | 22.1 | TURN LEFT into A. Barletta and Sons gravel pit.                                                                                                                                                           |

## STOP 2. HONEY HOLE GRAVEL PIT: GLACIAL AND ECONOMIC GEOLOGY OF A LATE WISCONSINAN FRONTAL KAME

LEADERS: Duane D. Braun and Jon D. Inners (with additional comments by Fred Barletta and Joseph Bove, A. Barletta and Sons)

The Honey Hole operation of A. Barletta and Sons is the largest producer of commercial crushed stone from sand-and-gravel in this part of northeastern Pennsylvania. Gravel has been quarried from pits to either side of the production plant where we are parked (Figure 41). The buses drove by the currently active eastern pit as they approached the STOP. After examining the inactive western pit where the sequence of deposits are more readily accessible, we will take a brief tour of the upper crusher plant and the asphalt plant operations.

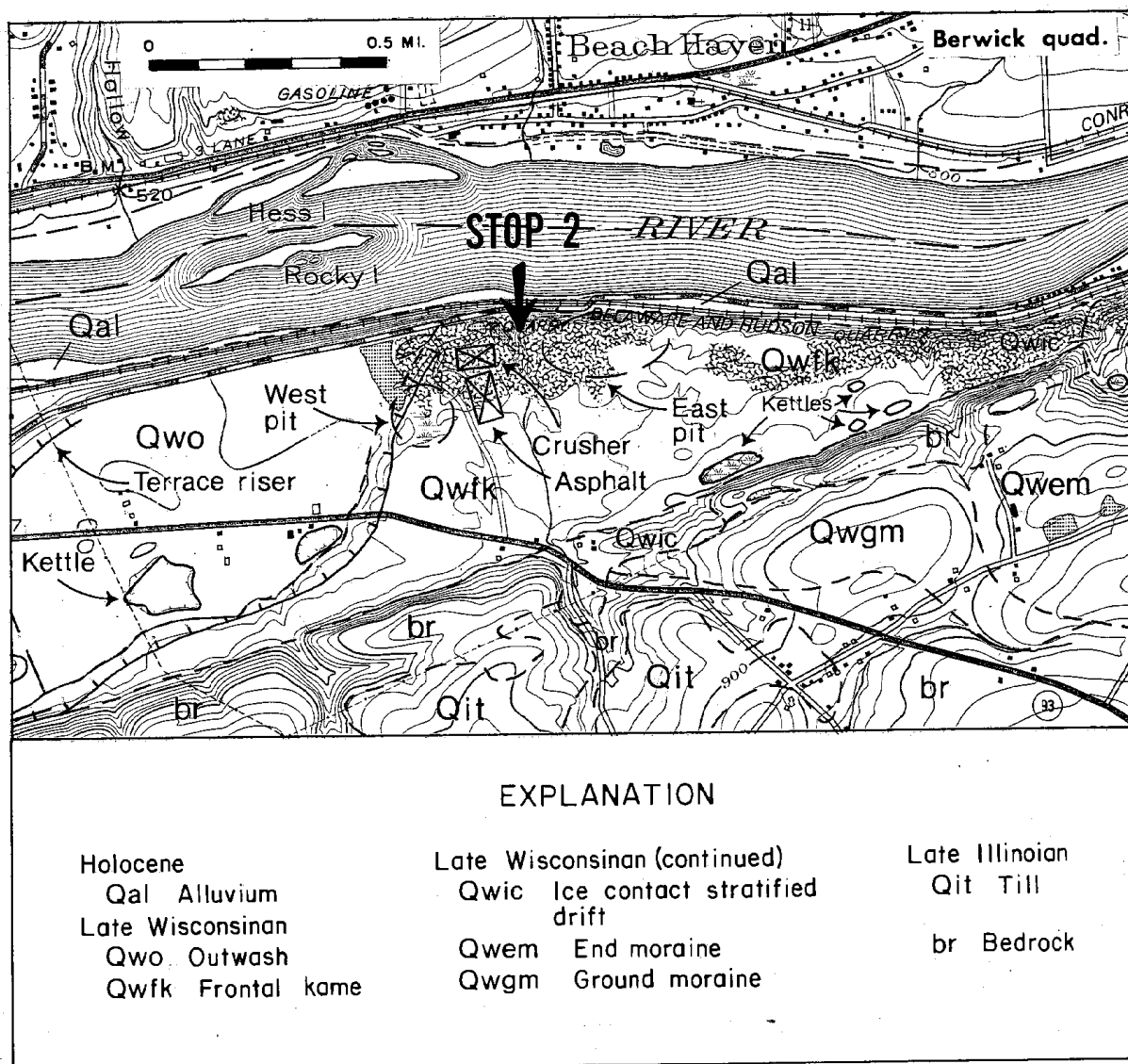


Figure 41. Location and surficial geologic map of STOP 2. (Geology after Inners, 1978).

## Glacial geology

The Honey Hole gravel pit is in the frontal kame fan or head of outwash of the 18-20 ka late Wisconsinan terminus (Figure 41). The overall sequence of deposits coarsens upward (Figure 42), reflecting the gradual approach of the ice. Basal sands are overlain by gravels that are in turn overlain by diamict and ice contact stratified drift. The ground surface exhibits distinct knob-and-kettle topography.

Lithologic composition of the cobbly gravels at Honey Hole mainly reflects the importance of local bedrock to the glacial load (Inners, 1978, Fig. 9A). More than 35 percent of the clasts are non-red, very fine- to fine-grained sandstone derived from the Trimmers Rock and Catskill Formations; and another 30 percent are red sandstone, siltstone, claystone and shale from the Catskill and Mauch Chunk. Less than 15 percent of the clasts are non-red conglomerate, sandstone, and quartzite of probable Pocono or Pottsville origin. Exotic clasts include gray, glassy, Onondaga chert (2 percent) from eastern New York State and pink to gray granite and gneiss (2 percent) from the Adirondack region.

The late Wisconsinan ice advanced at most about 1 mile (1.6 km) beyond the west edge of the site before retreating. After ice recession, the moraine was incised and the broad outwash plain at 600-620 feet (183-189 m) immediately west of the pits was formed. The 600-620 foot surface is the uppermost and most extensive terrace level downstream of the terminus. This suggests that it represents a period of stability in the ice front after ice had retreated a short distance to the east of the terminus. Alternatively, the 600-620 foot surface represents a stable outlet of the proglacial lake that developed behind the frontal kame as the ice retreated northeasterly.

The kame fan was gradually incised by glacial meltwater until the ice, at about 14 Ka, retreated north of the Valley Heads Moraine at the south end of the Finger Lakes in New York. Terraces only 20 feet (6 m) above the present North Branch Susquehanna channel, at about 500 feet (152 m), have been correlated with the Valley Heads Moraine (Peltier, 1949). From 14 Ka to present the river has cut down 20 feet (6 m) to about 400 feet (146 m) and is now incising bedrock.

## Economic geology

Barletta's original Honey Hole sand and gravel operation was in the kame fan of the late Wisconsinan terminus at the base of Green Mountain in the Conyningham Valley (east of mile 109.0 on the Day-1 Road Log). That pit was in the distal sandy part of the kame fan and provided insufficient gravel for their needs. The operation was moved to this gravel-rich site in 1953. The property is underlain by about 43,000,000 yd<sup>3</sup> (33,000,000 m<sup>3</sup>) of sand and gravel. Approximately 10,000,000 yd<sup>3</sup> (8,000,000 m<sup>3</sup>) has been mined in the last 25 years. This represents about 25 percent of the deposit and leaves a 75-year reserve remaining on the property. An equal amount of sand and gravel underlies farmland immediately to the west of the present operation.

The operation has two crusher plants producing 2B stone, 1B stone, and sand. Production capacities for the two crushers and the asphalt plant are given below:

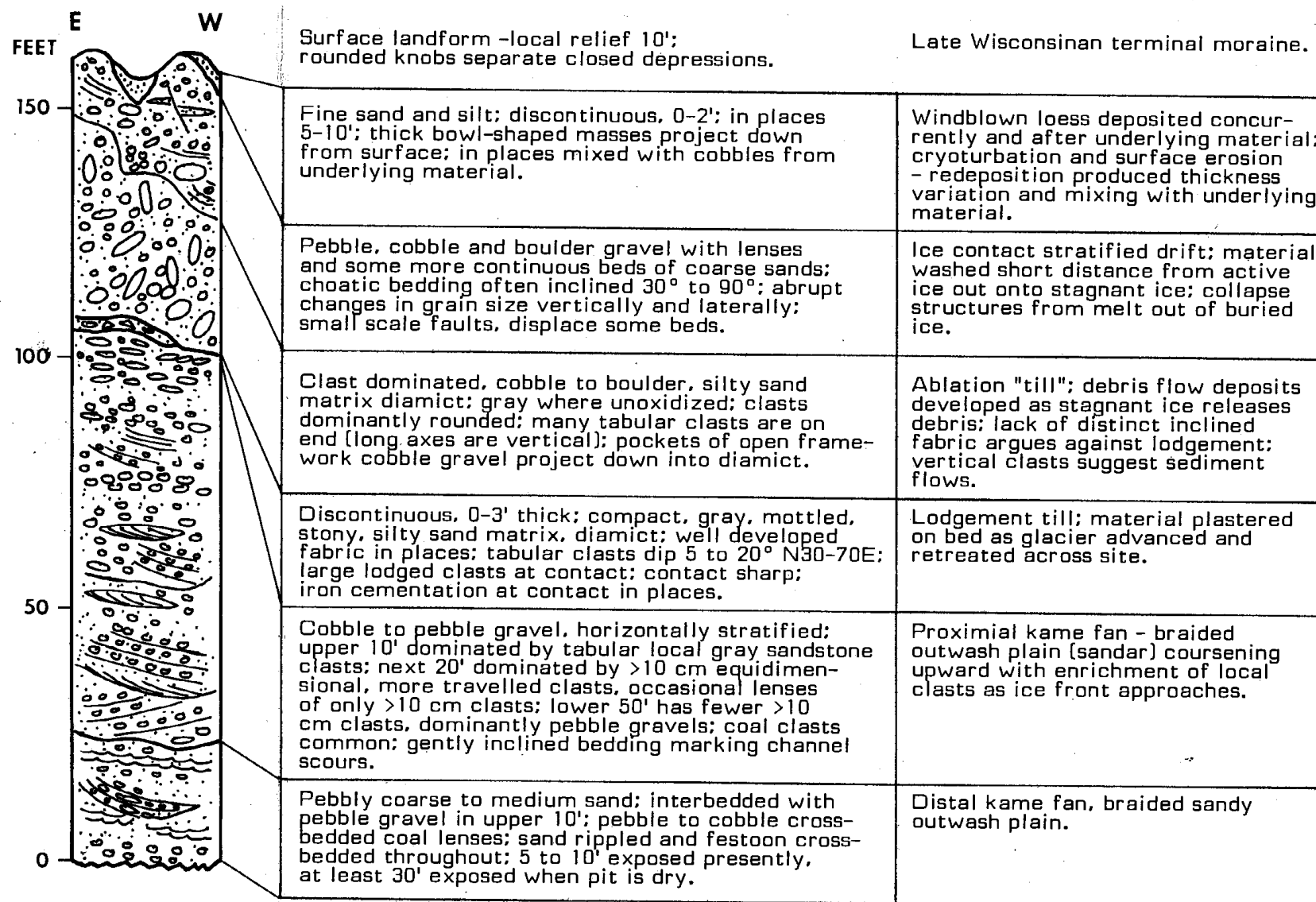


Figure 42. Stratigraphic column of the Honey Hole Gravel Pit.

## PLANT PRODUCTION CAPACITIES

|            | Lower Crusher<br>(started 1953) | Upper Crusher<br>(started 1970) | Asphalt Plant<br>(started 1984) |
|------------|---------------------------------|---------------------------------|---------------------------------|
| Total Day  | 800 ton                         | 2,000 ton                       | 3,000 ton                       |
| Total Hour | 75-100 ton                      | 200-225 ton                     | 350 ton                         |

### Typical Daily (by product)

|      |         |         |
|------|---------|---------|
| 2B   | 400 ton | 620 ton |
| 1B   | 160 ton | 580 ton |
| sand | 220 ton | 800 ton |

The upper crusher plant operation starts with a 48-inch across primary cone crusher that breaks the larger clasts. Fragments are screen sized and those greater than 4 inches are recycled to the primary crusher. The 4-inch and smaller fragments go through two secondary jaw crushers. Fragments from secondary crushers are screen-sized with the greater than 2B sizes recycled to the secondary crushers, the 2B and 1B sent to stockpiles, and the sand sent to a liquid-sand classifier or sizer. From the sand classifier, concrete sand and asphalt sand go to stockpiles and the fines are washed into a settling lagoon.

Wash water is taken from the North Branch Susquehanna to supply the operation. A 350-horsepower electric pump with a 12-inch discharge lifts water 170 feet at 2,000 gpm to the upper crusher. A 150-horsepower electric pump lifts water 140 feet at 1,500 gpm to the lower crusher. The pumps consume \$15,000 per month in electricity.

Years ago the wash water was sent through a series of settling lagoons and returned directly to the Susquehanna River. In recent years the wash water has been sent to a primary settling lagoon and then into the bottom of the western pit. There the water infiltrates through the sands in the lower part of the pit and returns to the river as groundwater flow.

The asphalt plant is a modern, computerized, continuous-feed plant. From cold start it is capable of producing its first ton of asphalt in 10 minutes and reaching its maximum 350 ton/hr production in one hour. The asphalt is stored in two 200 ton insulated and heated silos and can be held for up to 3 days. In the last three 9-month-long paving seasons the plant has produced 500,000 tons of asphalt with only 2-3 days downtime.

Several quality-control problems directly related to geology exist at Honey Hole. The first is the abundance of anthracite fragments within the sand and gravel, necessitating thorough washing of the material to meet PENNDOT specifications. A second problem with the deposit is that its upper layer is texturally a diamict and occasionally contains clasts that are too large for the primary crusher. In the larger eastern pit the diamict is presently separated from the underlying stratified gravel and stockpiled for use as random fill. The third and most serious defect of the Honey Hole gravels is the local abundance of weathered limonitic, "Illinoian pebbles" (Peltier, 1949, p. 31) and "clay-ironstone" concretions (called "siderite nodules" by Inners 1978) derived from the lower member of the Mahantango Formation. In the early 1960's, at a

time when a coarser aggregate was being used in pavement concrete, many of these weathered clasts passed through the crushers and were incorporated into the aggregate used in the concrete for I-80 in the vicinity of the Luzerne-Columbia county line. Within a year or two, innumerable pits appeared in the roadway due to the wetting and expansion of the soft, limonitic material (R. H. Howe, Pennsylvania Department of Transportation, personal communication, 1977). To correct the problem, a few thousand "pop-outs" occurring along several miles of highway were individually cored out of the pavement to be replaced by new concrete. Petrographic procedures which were instituted at PennDOT labs shortly thereafter make a recurrence of this incident extremely unlikely.

- LEAVE STOP 2, continuing west on SR 3036.
- 0.2 22.3 Passing across high terrace which marks the beginning of late Wisconsinan outwash train.
- 0.5 22.8 Descend riser in high outwash terrace group.
- 0.6 23.4 STOP SIGN at Y-intersection. CONTINUE STRAIGHT AHEAD, now on PA Route 93.
- 0.4 23.8 Cross railroad tracks in old channel swale on intermediate terrace. At height of Agnes Flood, inundation of this swale left Nescopeck (ahead) an island.
- 0.1 23.9 Enter borough of Nescopeck.
- 0.6 24.5 Historical Marker to left reads:  
PETER F. ROTHERMEL. The noted painter was born in Nescopeck on July 8, 1812. His huge master-piece, "Battle of Gettysburg," ordered by the State Legislature is on display at the William Penn Museum in Harrisburg. [He died in 1895].
- 0.4 24.9 Enter Columbia County and cross North Branch Susquehanna River on new Berwick-Nescopeck Bridge, completed in 1982 as the fourth bridge between the two boroughs. Remnants of the abutments of the 1906 truss bridge can be seen to the right. At this point progradation of the alluvial fan of Nescopeck Creek has constricted the North Branch to a narrow channel partially blocked by resistant ledges of Old Port shaly limestone and chert ("Nescopeck Falls"). On May 3, 1826, the steamboat "Susquehanna," on an excursion upstream, tried to run the rapids on a full head of steam. About the middle of the ascent, she struck one of the ledges and her boiler burst. The explosion killed or mortally injured four people on the boat. This disaster ended any serious thoughts of using the Susquehanna River for steamboat travel.
- 0.2 25.1 TRAFFIC LIGHT. TURN RIGHT onto US Route 11 in borough of Berwick. Evan Owen founded Berwick in 1786, naming it after Berwick-on-Tweed, England. It was incorporated in 1818.
- 0.3 25.4 Enter Luzerne County.
- 0.4 25.8 Splendid view from high outwash terrace south across river to Nescopeck terraces, River Hill (Trimmers Rock Formation), and Nescopeck Mountain (Spechty Kopf-Pocono Formations).
- 0.5 26.3 Two historical markers to right read:  
NESCOPECK. From the mouth of Nescopeck Creek an Indian path went east over the mountains by way of present Hazleton to the Lehigh near Mauch Chunk [i.e., current PA Route 93]; then to the "Forks of the Delaware" at Easton.

- NESCOPECK. After Braddock's defeat in 1755, the Delaware town of Nescopeck, across the river, was rendezvous for Indians hostile to Pennsylvania. A friendly Seneca, Silver Heels, saw 140 warriors dance the war dance here.
- 0.8 27.1 Descend from high terrace to intermediate terrace and cross Salem Creek valley (Sybert Hollow) - a late Wisconsinan ice-marginal drainageway (Inners, 1980).
- 0.5 27.6 Cobble gravel of high outwash terrace in deep cut behind Riverview Block Co. to left. The "terminal moraine" crosses the North Branch lowland in this vicinity.
- 0.4 28.0 Outcrops of cleaved and nodule-bearing Mahantango shale to left.
- 0.2 28.2 Village of Beach Haven. Founded and named for Nathan Beach, an early advocate of the North Branch Canal and promoter of Hazleton-area anthracite.
- 0.4 28.6 Cut and burrow pit in cleaved and fossiliferous (*Athyris*, *Pleurodictyum*, rugose corals, etc.) Mahantango shale to left (across from Salem Township Fire Co. No. 1). This is probably the same fossiliferous zone to be seen at Stop 7 later today.
- 0.3 28.9 Cleaved Mahantango shale to left.
- 0.2 29.1 Begin long ascent from intermediate to high terrace.
- 0.4 29.5 Top of high outwash-kame terrace.
- 0.6 30.1 Begin descent from high to intermediate outwash terrace.
- 0.1 30.2 Cobble gravel of high outwash terrace visible in cut to left.
- 0.1 30.3 Historical marker on right reads:  
WAPWALLOPEN. Name of former Indian town near the mouth of Wapwallopen Creek. Indian trails connecting old Wyoming, the "Warrior's Path," and the Juniata and West Branch Susquehanna valleys intersected here.
- 1.0 31.3 Gate 10 of Susquehanna Steam Electric Station to left.
- 0.2 31.5 Outcrops of cleaved Mahantango shale to left.
- 0.4 31.9 Susquehanna Riverlands of PP&L to right (Stop 4 and Lunch).
- 0.8 32.7 Small pit in Woodfordian kame terrace to left.
- 0.3 33.0 Site of former sand-and-gravel pit in large kame terrace.  
Inclined foresets once visible here were suggestive of deltaic deposition in a temporary lake backed up behind the frontal kame. Peltier (1949) described this pit in some detail. Note bouldery ice-contact deposits at north end.
- 0.8 33.8 Inactive gravel pit of Columbia Asphalt Company to left. Inclined delta foresets also characterize this kame deposit.
- 0.6 34.4 To left are steeply north-dipping ledges of pyritic Pocono sandstone at east end of Lee Mountain.
- 0.3 34.7 First of several cuts in folded Mauch Chunk red mudstone and sandstone near the hinge of the Lackawanna synclinorium.
- 0.6 35.3 T-intersection with PA Route 239 in borough of Shickshinny.  
CONTINUE STRAIGHT on US Route 11. Shickshinny is said to mean "five mountains." The community has been the victim of frequent floods, and was especially hardhit by the Agnes Flood.
- 0.3 35.6 Cross Shickshinny Creek.
- 0.1 35.7 Outcrops of north-dipping Pocono sandstone to left behind church.
- 0.2 35.9 Site of 1972 (Agnes) and 1986 debris flows on steep hillside to left.
- 0.5 36.4 Bare bedding plane to left marks site of another Agnes debris flow.

- 0.5    36.9    To left are south-dipping ledges of Catskill-Pocono transition strata.
  - 0.3    37.2    Large abandoned quarry to left exposes mainly Catskill-Pocono transition beds.
  - 0.8    38.0    Broad hump in road marks site of old debris flow that highway cuts through at this point.
  - 0.3    38.3    Large postglacial rockslide on Shickshinny Mountain on both sides of road ahead.
  - 0.6    38.9    BEAR RIGHT into PennDOT storage area.
  - 0.1    39.0    Stop and debark from bus.
- STOP 3. US ROUTE 11 STORAGE AREA: POST-GLACIAL ROCK BLOCK SLIDE ON SHICKSHINNY MOUNTAIN

LEADER: Duane D. Braun

We are standing on the "wreck" of what is probably the largest clearly recognizable landslide in Pennsylvania (Figures 43 and 44). Behind us to the north, the dipslope of Shickshinny Mountain rises nearly 1,000 feet (300 m) above the North Branch Susquehanna River. This slope is underlain mainly by interbedded red mudstones and gray sandstones of the Duncannon Member of the Catskill Formation. The landslide involved the whole 790-foot-(240-m-) high slope, moved out 1,250 feet (380 m) onto the floodplain, and partly diverted the river. The slab of bedrock that moved was 66-90 feet (20-27 m) thick, 2,135 feet (650 m) in length downslope, and 2,460 feet (750 m) wide along slope. It had an area of 930,140 yd<sup>2</sup> (777,600 m<sup>2</sup>) and a volume of 20,260,000-27,450,000 yd<sup>3</sup> (15,500,000-21,000,000 m<sup>3</sup>)! Slippage occurred within the red mudstone part of one fining-upward alluvial cycle, carrying one complete cycle and the lower part of a second cycle downslope. Since the failure involved intact bedrock, it is classified as a rock block slide (Varnes, 1978).

Only the center of the slide mass travelled the full downslope distance. To either side and upslope of a knob at the center of the mass are a series of en echelon scarps and knobs that represent pieces of the slide flanks that were left behind on the face of the dipslope (Figure 43).

The lobate toe of the slide mass rises 100 feet (30 m) above and projects halfway, 1,250 feet (380 m), across the valley floor; this markedly narrows the 750-1000 foot- (230-300 m-) wide channel to 560 feet (170 m). The edge of the toe is a series of elongate knobs separated by elongate closed depressions that radiate out from the center of the toe. The rock at the crests of the knobs is shattered into blocks a few yards across or smaller. On the eastern part of the toe, 10-20 feet (3-6 m) of glacial deposits mantle the broken bedrock. Railroad and canal cuts around the edge of the toe expose 30-50 feet (10-15 m) of near horizontal red sandstone bedrock in the core of the slide. In places the joints and bedding planes are tight and in other places they are open several millimeters to several centimeters. Overlying the intact bedrock is 30-50 feet (10-15 m) of jumbled blocks of broken bedrock. The apex and downstream side of the slide toe retains an irregular lobate form, suggesting that the slide toe did not extend farther across the valley and that the river has little eroded the slide toe. The length of run-out onto the floodplain suggests that these movements were relatively rapid, possibly several yards per second, or more. (Observers of a large [122,000 yd<sup>3</sup>, or 93,000 m<sup>3</sup>] rock slide that occurred about 2 miles [3 km] northeast along strike in 1947 report that it took place in less than five minutes, with most movement within a minute or two).

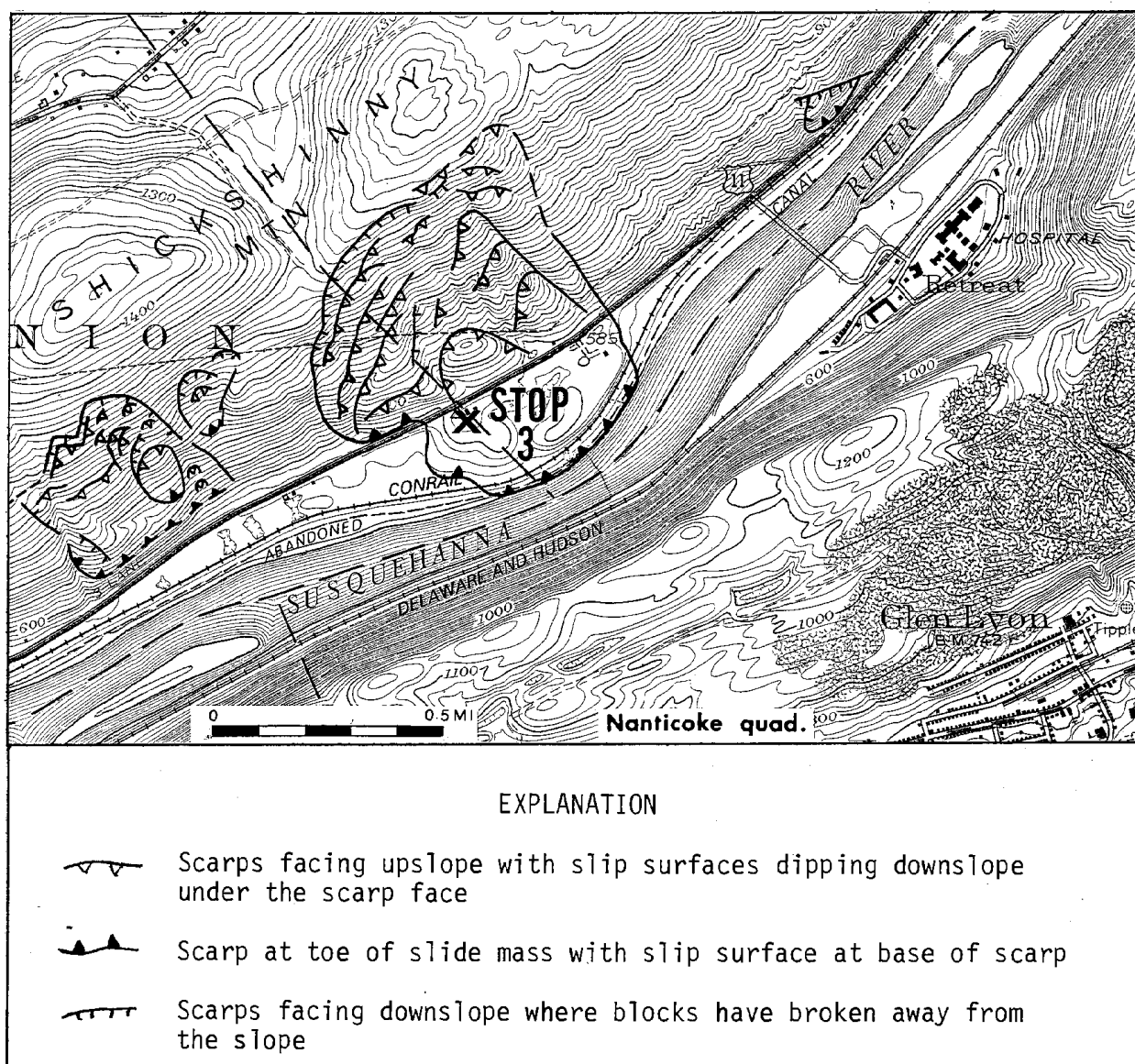


Figure 43. Location map for STOP 3, showing outline of the largest Shickshinny Mountain rock block slide. Two nearby slides are also delineated.

The west edge of the slide mass at the base of the slope is exposed along US Route 11 in a 60-foot- (18-m-) high and 330-foot- (100-m-) long road cut perpendicular to the edge of the toe. In the center of the cut, red sandstone and shale layers have a strike of N20E and a dip of 40°SE which represents a rotation of 45° from the regional strike of N65E and a steepening of 20° from the typical dip on the mountain side. Proceeding eastward along the cut towards the middle of the slide mass, the dip rapidly declines to near horizontal at the base of the central knob in the slide mass. In this intact bedrock mass some joints and bedding planes have opened a few millimeters but most are still closed. Westward from the highest part of the cut, a wedge shaped mass of broken bedrock underlies the southeast-dipping intact bedrock and marks the very western edge of the slide. The wedge shaped mass is composed of a jumble of



Figure 44. Aerial photograph of the rock block slide at STOP 3.

angular blocks of red sandstone and mudstone, each a yard or more across, having all bedding orientations from horizontal to vertical. The tilted intact bedrock can be traced from the top of the road cut northward to where it connects with the northwest side of the central knob of the slide mass.

#### Giant rockslides on Shickshinny Mountain: why?

Thirteen rock block slides having an aggregate volume of about 56,000,000 yd<sup>3</sup> (43,000,000 m<sup>3</sup>) have been mapped on the dipslope of Shickshinny Mountain between West Nanticoke and Shickshinny, a distance of approximately 9 miles (14.4 km) (Braun and others, 1988; in press). Several of them are similar in thickness and downslope length to giant rock block slides in Virginia (Schultz, 1986).

Why is there such a concentration of large rock slides on this particular stretch of mountain? Several interrelated factors are involved: 1) The strike-ridge dipslope is underlain by a rock unit containing both resistant, thick-bedded sandstones and weak, massive mudstones. 2) Dip of the beds on the slope is only about 20°. And 3) the North Branch Susquehanna has sharply undercut the sandstone-mudstone bedding planes in the Duncannon.

The major peculiarity of Shickshinny Mountain in this area is that its crest and dipslope are underlain by the Duncannon (and a thin band of Catskill-Pocono

transition strata) rather than by the more resistant Pocono Formation. From West Nanticoke nearly to Shickshinny, where the North Branch Susquehanna River, has undercut the dip slope of the mountain, the Pocono occurs beneath the floodplain or channel of the river. This reach of the Susquehanna is the only part of its course along strike where it flows between the two major sandstone-and-conglomerate ridges that surround the southwestern two-thirds of the Wyoming-Lackawanna basin. The river's flood plain is narrower in this reach than in any other except where the river cuts across strike ridges.

Porewater pressure is the mostly likely triggering factor for the landslides, as suggested by the fact that several historic rock block slides in the region were associated with high moisture conditions (Braun and others, in press; Braun and others, 1987; Inners and others, 1988). For example, the 1947 rock slide occurred a few hours after a torrential 2-hour, 6-inch rainfall. Differences in scale between the largest and smallest slides in the region suggest the possibility that there are also differing triggering conditions for the different size slides. It may be that the largest slides require something more than a single storm to trigger them and that they may be related to longer term seasonal or even multiple-year high-moisture conditions.

### Age of the Shickshinny Mountain slides

Except for the 1947 slide, all of the large rock block slides on Shickshinny Mountain are prehistoric. They cut late Wisconsinan glacial deposits that are about 18 Ka (Cotter, 1983; Cotter and others, 1985). The maximum age of many of the slides can be further limited to younger than late Wisconsinan periglacial activity because their headwall scarps show little sign of being frost riven, unlike outcrops on top of the ridge that were exposed to frost activity immediately upon late Wisconsinan ice recession. Earliest cessation of periglacial activity at the site is assumed to have occurred when tundra was replaced by spruce forest. Based on data on spruce migration (Watts, 1983), the estimated arrival time of spruce at Shickshinny Mountain provides a maximum age for the slides of about 11 Ka.

A younger maximum age can be estimated for the slide at this STOP because it extends into and partly diverts the North Branch Susquehanna River channel. The slide toe outcrops at the low-water mark of the channel, 3-6 feet (1-2 m) above the river bed, and probably extends down to the bottom of the bed. The age of the slide becomes a question of when the river cut back down through overlying glacial deposits to reach the glacially scoured bedrock floor of the present channel. Ash (1950) records that bedrock is 318 feet (97 m) below river level about 6 miles (10 km) upstream of the site. Archeological sites elsewhere along the North Branch Susquehanna indicate that the river has cut through the late Wisconsinan outwash deposits to near its present level in the last 2-4 Ka (J. Donahue, University of Pittsburgh, unpublished data), suggesting a 4 Ka maximum date for the this slide.

#### LEAVE STOP 3.

- |     |      |                                                                                                            |
|-----|------|------------------------------------------------------------------------------------------------------------|
| 0.1 | 39.1 | TURN LEFT on US Route 11 and retrace route back to Riverlands.                                             |
| 0.6 | 39.7 | Good view of glacially oversteepened scarp slope of Pottsville-Mauch Chunk ridge on south side of river.   |
| 1.9 | 41.6 | Slight curve in road at site of postglacial rock block slide in Pocono Formation on mountainside to right. |
| 0.8 | 42.4 | Enter borough of Shickshinny.                                                                              |

- 3.9 46.3 TURN LEFT at entrance to Riverlands and the Susquehanna Energy Information Center (PP&L).  
 0.1 46.4 STOP SIGN. TURN RIGHT.  
 0.1 46.5 Cross old Pennsylvania Canal, North Branch Division.  
 0.1 46.6 TURN RIGHT into parking lot of Group Picnic Area.  
 Debark from buses.  
 STOP 4 AND LUNCH. SUSQUEHANNA RIVERLANDS:  
 SUSQUEHANNA STEAM ELECTRIC (NUCLEAR) STATION OF PP&L AND NORTH  
 BRANCH CANAL

LEADER: Jon D. Inners (with additional comments by Albert W. Craven, Pennsylvania Power and Light Company)

Susquehanna Riverlands is a 400-acre recreation area on the alluvial flat between U.S. Route 11 and the North Branch Susquehanna River adjacent to the Susquehanna Steam Electric Station. Owned and administered by the Pennsylvania Power and Light Company (PP&L), its extensive day-use facilities include nature study, fishing, picnicking, and hiking. A mile-long section of the old North Branch Canal that passes north-south through the middle of the recreation area has been cleaned out and partially restored.

#### SUSQUEHANNA STEAM ELECTRIC STATION

The Susquehanna nuclear power station occupies a 1,000-acre site on the west side of the North Branch Susquehanna River in Salem Township, Luzerne County, about 5 miles east-northeast of Berwick. It is owned by PP&L (90 percent) and Allegheny Electric Cooperative, Inc. (10 percent).

Power for the generation of electricity is supplied by two General Electric boiling water reactors, each of which is housed in a 161-foot-high containment structure of reinforced concrete. Generating capacity for each unit is 1.05 megawatts. The electricity is distributed on 230,000-volt (Unit No. 1) and 500,000-volt (Unit No. 2) lines to a service area that covers more than 10,000 mi<sup>2</sup> in central-eastern Pennsylvania and New Jersey.

The plant was conceived and built over a fifteen-year period, beginning with PP&L's initial announcement in 1970 that the company planned to "go nuclear." Following approval of the construction permit by the Atomic Energy Commission (predecessor of the Nuclear Regulatory Commission), work on the physical plant began on November 3, 1973. Bechtel Power Corporation was the prime contractor. In comparison to the construction histories of many nuclear plants in the United States, that of Susquehanna was relatively short and uneventful. Unit No. 1 began commercial operation on June 8, 1983, and Unit No. 2 on February 12, 1985.

#### Bedrock geology

Susquehanna nuclear station lies near the north edge of a broad glacial terrace at an altitude of 700+ feet, or about 200 feet above the North Branch. Prior to construction grading, several east-west, strike-parallel bedrock ridges rose 50 to 60 feet above the general level.

Bedrock over most of the site consists of well indurated, medium-dark-gray, locally calcareous, silty clay shale and siltstone of the lower member of the

Mahantango Formation (Figure 45a). The calcareous intervals typically contain a profuse and diverse fauna of brachiopods, crinoids, corals, and other invertebrates (see Stop 7). Strata encountered in the foundation excavations occur in the upper 200 or 300 feet of the member.

The plant site is situated on the north limb of the Berwick anticlinorium. Bedding at the south and north edge of the site has the expected northward dip, but a low, third-order anticline causes a gentle reversal to the southeast in the vicinity of the turbine-reactor building (Figure 45a). A low-angle thrust fault dipping 15 to 30 degrees to the south-southeast comes to the surface beneath the circulating-water pumphouse and the turbine-reactor building. This fault was encountered in many of the preliminary design borings (Pennsylvania Power and Light Co., 1975), and during the summer of 1975 was exposed as a zone of quartz-filled gash fractures, slickensides, and minor subvertical to southeast-dipping faults in some of the foundation excavations. A pervasive pressure-solution cleavage in the shales generally dips steeply to the south-southeast, but probably fans the third-order anticline. In moderately to strongly weathered shale, cleavage is often the most prominent planar discontinuity.

Bedrock conditions at the site caused no significant design or construction problems.

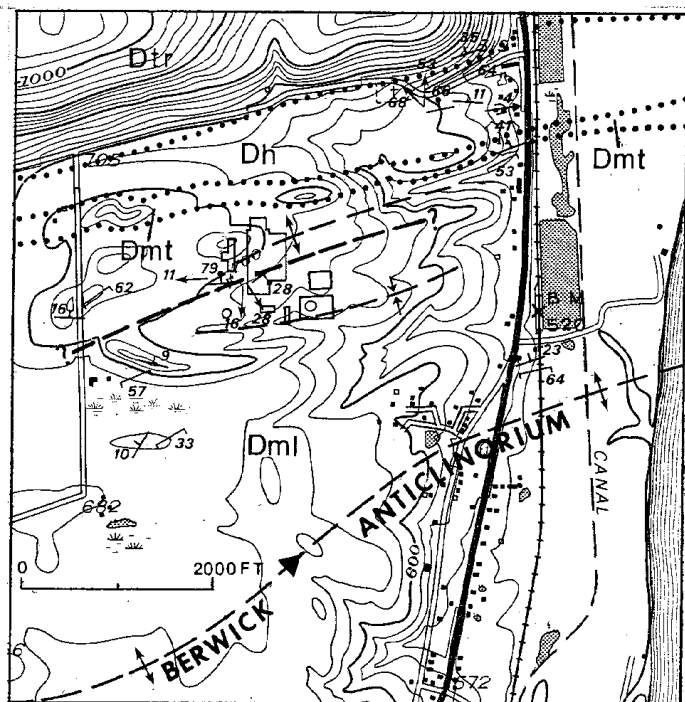
### Surficial geology

A variety of Late Wisconsinan glacial and periglacial deposits overlie an irregular bedrock surface at the Susquehanna site (Figures 45b and 46). In the northwestern part of the area, poorly sorted, bouldery glacial till (ground moraine) fills shallow swales between several discontinuous bedrock ridges, while in the eastern and southern part, cobbly sand and gravel (kame terrace and proximal outwash deposits) forms a more level surface through which a few bedrock knobs protrude. A 5-to 10-foot bouldery, ice-contact (?) layer commonly occurs at the base of the sand-and-gravel deposits. Overlying much of the area, but especially well developed to the east and south is a mantle of Nescopeck Loess several feet thick. North of an east-west bedrock ridge that marks the limit of the main construction area, kame terrace-outwash gravels fill a bedrock valley that exceeds 100 feet in depth (Figure 46; Pennsylvania Power and Light Co., 1975). During plant construction, a well which tapped a thick saturated zone within this valley fill (Williams and Eckhardt, 1987) provided abundant groundwater for various purposes (R. Wood, Pennsylvania Power and Light Co., personal communication, 1975).

Considerations of foundation strength and stability apparently dictated that all major buildings, as well as the two 540-foot-high cooling towers, be erected in the area of comparatively shallow bedrock south of the deep drift-filled valley noted above.

### River hydrology

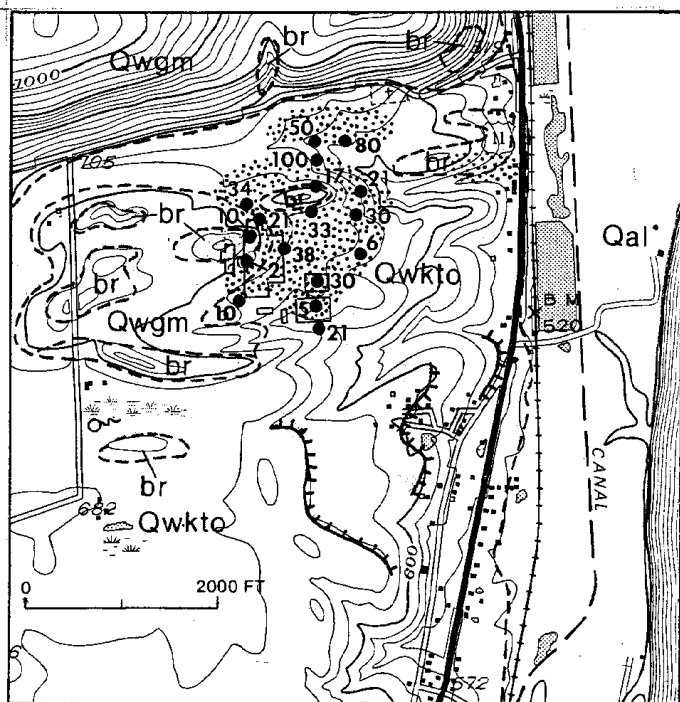
When both reactors are in operation, approximately 40,000 gallons of water per minute are withdrawn from the Susquehanna River to supply cooling water to the plant. Of this, nearly 30,000 gal/min is evaporated off to form the billowing plumes of vapor that rise out of the cooling towers to be seen for miles around on favorable days. The remaining 10,000 gal/min is returned to the river at a temperature 20 to 30°F higher than the ambient temperature.



a

#### EXPLANATION

- Dtr Trimmers Rock Formation
- Dh Harrell Formation
- Dmt Tully Member } Mahantango Formation
- Dml Lower member }
- ..... Concealed geologic contact
- - - Trace of fault
- - - Anticlinal axis
- - - Synclinal axis
- 16 Bedding
- 33 Cleavage
- 28 Fault
- 11 Slickenline
- - - Axis of small anticline



b

#### EXPLANATION

- br Bedrock
- Qal Holocene alluvium
- ..... Nescopeck Loess
- Qwkto Woodfordian kame terrace and outwash, undivided
- Qwgm Woodfordian ground moraine
- - - Approximate geologic contact
- 10 Thickness, in feet, of surficial deposits in bore holes
- - - Top of terrace riser
- o Spring

Figure 45. Geology at the site of the Susquehanna nuclear power plant. a. Bedrock; b. Surficial. (After Inners, 1978.)

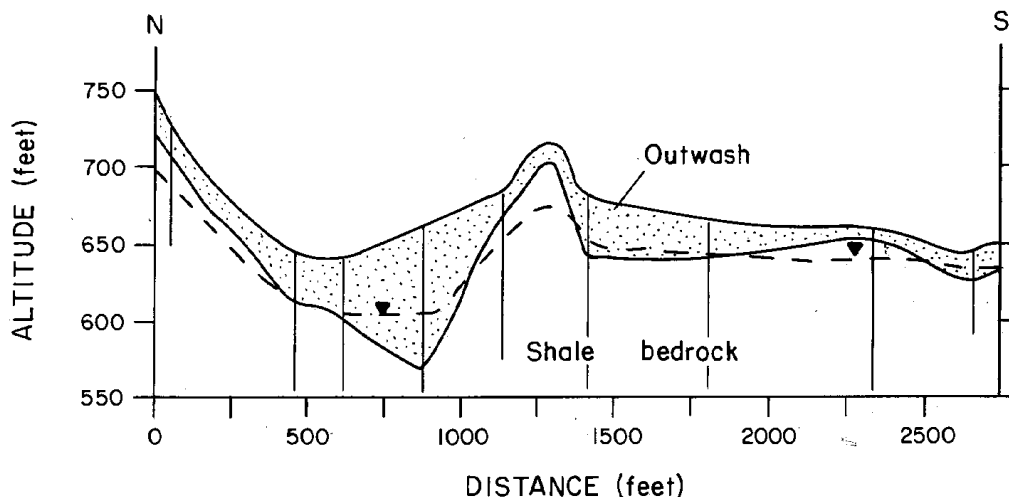


Figure 46. Geologic cross section showing the bedrock profile, surficial deposits and water-table configuration along a north-south line through the main construction area (after Williams and Eckhardt, 1987).

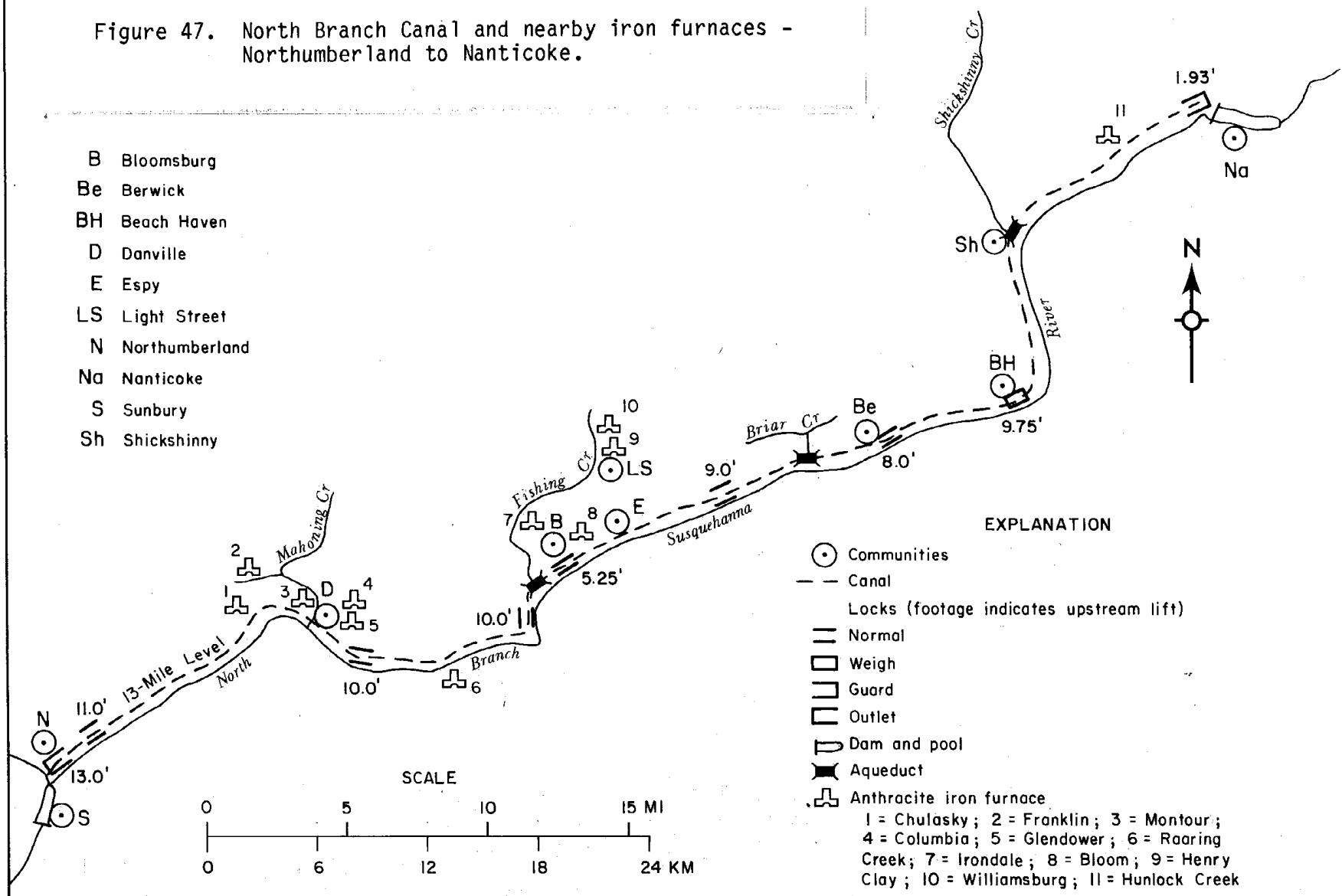
Due to the wide seasonal fluctuations in the flow of the Susquehanna, supplying sufficient cooling water to the plant without an "overdraft" on the river has been a long term concern of PP&L. In 1987 (a "normal" year), river flow past the plant varied from a low of 2400 ft<sup>3</sup>/s (10.7 x 10<sup>5</sup> gal/min) to a high of 46,000 ft<sup>3</sup>/s (20.6 x 10<sup>6</sup> gal/min) (Terry Soya, Ecology III, Inc., personal communication, 1988). Structural modifications now under way at the Cowanesque dam and reservoir, about 150 miles upstream in Tioga County, will soon allow the Army Corps of Engineers to augment seasonal low flows at the request of the Susquehanna plant.

#### THE NORTH BRANCH CANAL

The tree-lined canal that crosses the Riverlands is one of better preserved segments of the great waterway that once extended for more than 165 miles along the North Branch Susquehanna River from its mouth to the New York State line. The North Branch Canal was constructed in three main segments -- a lower division from Northumberland to Nanticoke (1828-1831), a short Wyoming Division from Nanticoke to Pittston (1831-1834), and a North Branch Extension from Pittston to Athens (1836-1856). Though it never came close to paying for itself, the North Branch Canal opened the Wyoming Valley coal deposits to national markets and was a major stimulus to the anthracite trade in the years before the American Civil War (Powell, 1978).

The following brief discussion concerns itself with the construction and geologic conditions along the longest-lived and economically most important section -- the 55-mile canal between Northumberland and Nanticoke (Figure 47). Much of this information is from a recent history of the entire North Branch Canal system published by the Center for Canal History and Technology (Petrillo, 1986).

Figure 47. North Branch Canal and nearby iron furnaces - Northumberland to Nanticoke.



### Construction of the lower North Branch Canal

A canal which follows a large river is both good "news and bad news." The good news is: The river valley provides a relatively easy natural gradient for construction, and a plentiful supply of water is available to feed the canal. The bad news is: The canal bed is likely to be composed of porous sands and gravels that permit water to seep out of the ditch, and the canal is prey to river floods. Just as the first two items in many ways dictated the location of the lower North Branch Canal, the last two -- especially floods -- caused serious construction and maintenance problems throughout its seventy year history.

Groundbreaking for the North Branch Canal took place at Berwick on July 4, 1828, just three months after the State Legislature passed an initial fiscal authorization. By the next year, costs were out of hand; and the chief engineer, Dr. Charles T. Whipple, instituted several economies, the most important being utilization of only one main water feeder for the entire 55-mile reach from Nanticoke to Northumberland and construction of "temporary" wooden locks to last 10 years -- or until money was available to construct stone locks. Digging of the canal was completed early in 1831, but attempts to fill it with water were unsuccessful. In June, Whipple was relieved as chief engineer, and his replacement, James Ferguson, intensified efforts to make the canal water tight. A clay lining was applied along much of the length of the canal, using a process called "puddling." This involved the placing of several feet of compacted earth and clay (presumably damp and near "optimum moisture") on the bottom and sides of the canal. Finally, on September 30, 1831, the entire canal had a full channel; and by November traffic was moving in both directions.

The completed canal, though hardly an engineering masterpiece, was a significant work for its time. It had maximum dimensions of 28 feet wide at the bottom, 40 feet wide at the top or waterline, and 4 feet deep. (At this depth, boats of 50 to 60 tons could pass through the canal). The towpath was usually on the bank near the river, the opposite side being known as the berm bank. Major structures along the canal were the seven lift locks (to overcome the 60-foot difference in elevation between the end points), an outlet lock at Northumberland, a guard lock at West Nanticoke (to protect the canal from freshets), a great timber and stone dam at Nanticoke (to form a feeder pond), and five aqueducts (to carry the canal across large streams) (Figure 48). Total finished cost was \$1,096,178.34.

Maintenance and reconstruction on the canal was a seemingly endless task. After the spring floods that marked the end of the annual three- to four-month winter shut-down, the canal and feeder dam often required extensive repairs. More severe flood damage resulted from such events as the ice-jam at Shickshinny early in 1832 and the catastrophic deluge of May-June 1889. On June 27, 1854, heavy rains caused a landslide at Shickshinny which filled the canal for a distance of 110 yards and closed the line for 10 days. The first major reconstruction took place in 1840 when the lift locks were entirely rebuilt of stone (Figure 49) and a new guard lock was built at West Nanticoke. In 1847 a weigh lock 92 feet long by 17 feet wide was constructed at Beach Haven so that downstream cargoes could be weighed before passage through the toll-collecting station at Berwick. In 1859-60 the canal was deepened to 5 feet and in 1872-73 to 6 feet, allowing passage of 75- to 80-ton and 120-ton boats, respectively. As part of this last reconstruction, the bottom width was increased to an average of 35 feet and the locks were lengthened to accommodate tandem 120-ton boats.



Figure 48. Ruins of the Briar Creek aqueduct, 800 feet south of U.S. Route 11 in Briar Creek borough, Columbia County. Most of the stone blocks are Keyser-Tonoloway limestone.

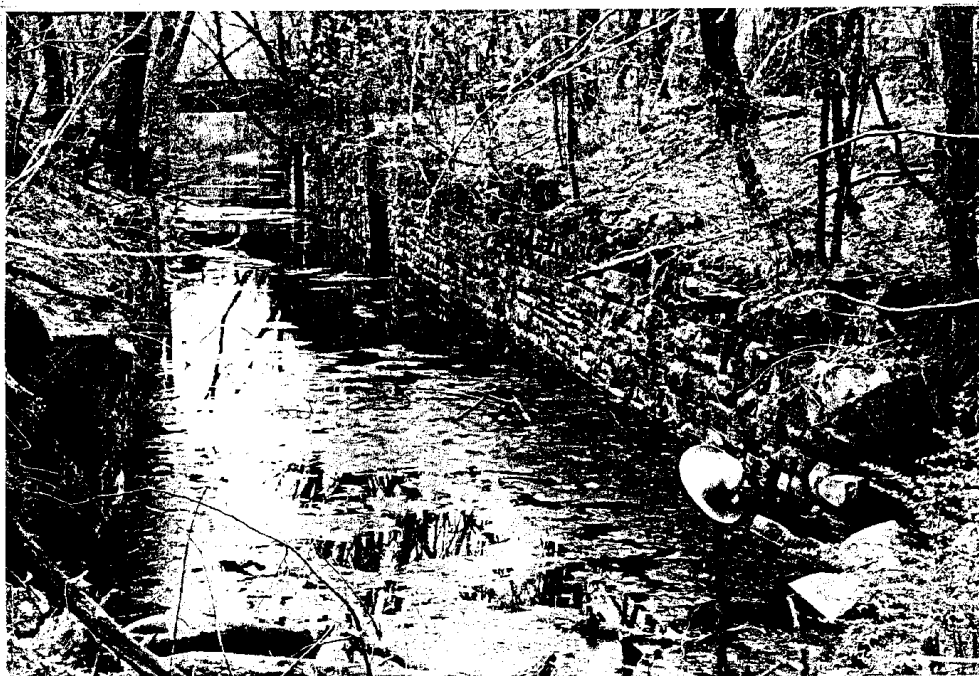


Figure 49. Ruins of Lock 3 just downstream from the Fishing Creek aqueduct at Rupert, Columbia County.

## Glory days and decline

The North Branch Canal had its most significant impact on the economy of the region between 1840 and 1870. This was the heyday of the anthracite iron industry in the Danville-Bloomsburg area (Inners and Williams, 1983) and of the inexorable growth of the coal trade in the Northern Anthracite field. During this period there were more than 10 blast furnaces at least intermittently operating in proximity to the canal route (Figure 47). The canal carried anthracite coal from the Wyoming Valley to the furnaces, pig iron from the furnaces to various foundries (such as that of Jackson and Woodin at Berwick), and wrought iron products from the foundries to markets both down- and up-river. In addition, limestone from the quarries at Lime Ridge was transported on the canal to the great Lackawanna iron works at Scranton. Other products which moved by canal included lime, flour, and lumber.

But the major commodity was anthracite. The amount of coal passing through Berwick increased from 10,000 tons in 1835 to 115,000 ton in 1843, and from 320,000 tons in 1852 to nearly 500,000 tons in 1854! In the mid-1850's, competition from the railroads began to be felt; and even during subsequent peak years, coal tonnages did not greatly exceed 500,000. Ironically, the North Branch canal was carrying considerable anthracite to the Montour iron works in Danville, which manufactured T-rails for the railroads, which in turn were becoming serious competitors for the coal-carrying canals (Petrillo, 1986). When coal transport became less important in the last quarter of the century, a heavy demand for mine props in the flourishing Northern field resulted in movement of hundreds of large log rafts up the canal from Northumberland.

Extinction of the canal was only a matter of time after 1856. In that year the Lackawanna and Bloomsburg Railroad was completed from Scranton to Northumberland, mainly on the west side of the river. Then, in April 1858, the state sold the North Branch Canal to the Sunbury and Erie Railroad -- which was later acquired by the Pennsylvania Railroad. In 1867, the "Pennsy" created a subsidiary, the Pennsylvania Canal Company, and tried to revive the canal. The deepening and lock-reconstruction noted above was a major part of this effort. When the Pennsylvania Railroad completed a line from Catawissa to Wilkes-Barre on the east side of the river in August of 1882, the fate of the North Branch Canal was sealed.

It struggled on for nearly twenty years, however. In 1899 the boatyard at Espy which had turned out the great 120-ton "snappers" was closed. The next year, only 68,677 tons of freight passed through the Beach Haven weigh-lock. And on April 11, 1901, the Pennsylvania Canal Company formally announced the abandonment of the North Branch Canal.

|     |      |                                                                                                          |
|-----|------|----------------------------------------------------------------------------------------------------------|
|     |      | LEAVE STOP 4, following access road to entrance.                                                         |
| 0.3 | 46.9 | STOP SIGN. TURN LEFT onto US Route 11.                                                                   |
| 0.5 | 47.4 | Good view of Council Cup to left.                                                                        |
| 4.4 | 51.8 | Top of high outwash terrace west of Sybert Hollow. US Route 11 follows this surface for the next 2.3 mi. |
| 1.0 | 52.8 | Enter village of East Berwick.                                                                           |
| 0.7 | 53.5 | TURN RIGHT onto Walnut Street, following US Route 11, at Luzerne-Columbia County line.                   |
| 0.1 | 53.6 | TURN LEFT on E. Second Street, still following US Route 11.                                              |

- 0.3 53.9 TRAFFIC LIGHT at intersection with Market Street and PA Route 93.  
CONTINUE STRAIGHT on US Route 11.
- 0.2 54.1 Descend prominent riser within high terrace complex.
- 0.1 54.2 Visible between the houses to the right is the Berwick Industrial Development Association complex, once the sprawling plant of the American Car and Foundry Corporation (ACF). The Berwick operation was originally founded as Jackson and Woodin by Mordecai W. Jackson and William H. Woodin in 1849 and became part of ACF in 1899. The first all-steel subway (1904) and railroad passenger (1905) cars in the world were built here. During World War II, the ACF plant provided vast quantities of materiel (including tanks, trucks, and artillery shells) to the Allied effort. ACF closed down the Berwick plant as part of a major retrenchment in 1962, only recently returning to occupy a small portion of the complex.
- 0.2 54.4 GET IN LEFT LANE BEFORE TRAFFIC LIGHT AND CONTINUE STRAIGHT AHEAD on US route 11 where PA Route 93 bears off to right.
- 1.5 55.9 Descend riser in intermediate terrace group and enter borough of Briar Creek, named for the nearby stream. The original village grew up around a gristmill built by Jesse Bowman in 1820.
- 0.7 56.6 Cross Briar Creek. At the height of the Agnes Flood, several feet of water covered the highway here.
- 0.5 57.1 Dipslope of red mudstone of the Bloomsburg Formation behind barn to right.
- 0.4 57.5 South-dipping Bloomsburg red mudstone in several old borrow pits to right of road. The Alliance Clay Products Company at Mifflinville used a mixture of "shale" from these pits and Harrell shale from the base of the River Hill escarpment to manufacture bricks in the 1950's and early 1960's.
- 0.7 58.2 Wills Creek shale to right below housing development.
- 0.2 58.4 TURN RIGHT onto Twp. Route 646 just beyond storage warehouse.
- 0.2 58.6 TURN onto third and unpaved road to RIGHT.
- 0.1 58.7 Nescopeck Loess overlying late Illinoian till in ditch to left.
- 0.1 58.8 Pull off onto right side of road. Debark.
- STOP 5. WILLOW SPRINGS OVERLOOK: ABANDONED VALLEY OF THE NORTH BRANCH SUSQUEHANNA RIVER NEAR MIFFLINVILLE

LEADER: Duane D. Braun

In the distance to the south across the North Branch floodplain is the village of Mifflinville and the broad valley of underfit Tenmile Run (Figure 50). The valley, 1 mile (1.6 km) wide at its flaring mouth, is cut in the rolling upland underlain by sandstone and shale of the Trimmers Rock and Catskill Formations. To the south, it curves to the right, out of sight, to run parallel to Nescopeck Mountain (Figure 38). A low divide separates the Ten-mile Run Valley from another valley that extends farther to the southeast to Catawissa Creek at Mainville. Seismic refraction work and well data show that the divide is underlain by up to 200 feet (60 m) of sand and gravel, capped by 7-10 feet (2-3 m) of weathered and disrupted sand and gravel that is texturally a diamict. The divide is asymmetric, the northeast side has a steep slope and the southwest has a very gentle slope. This is the typical longitudinal profile of a kame fan, the steep northeast side is the ice-contact or head-of-outwash face and the gentle southwest side is the outwash surface sloping away from the ice front. The bedrock floor beneath the divide and the valleys to either side

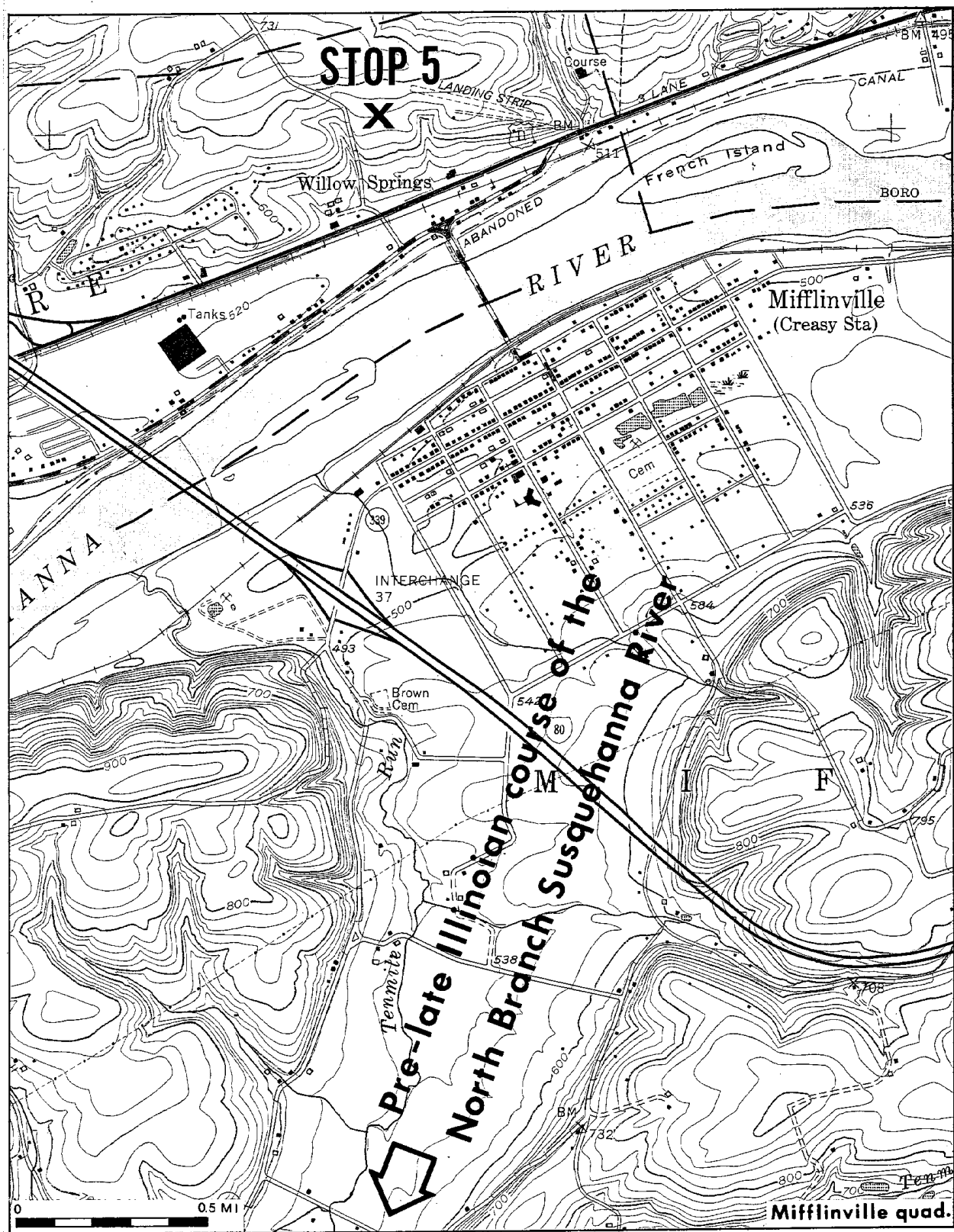


Figure 50. Location map of STOP 5, showing the upper end of the abandoned course of the North Branch at Mifflinville.

of it slopes continuously southwestward from the North Branch to Catawissa Creek. The overall scale and slope of the partially buried bedrock valley indicate that it was cut by the North Branch Susquehanna River (Braun and others, 1984).

The strike valley in easily eroded shales and carbonates that the North Branch Susquehanna presently follows provided an alternative route for the river at the end of the glaciation that deposited the kame fan, so that the river abandoned rather than re-excavated its partially filled original course (Figure 38). Presumably a similar kame fan occupied the strike valley but at an elevation that permitted the river a lower postglacial drainageway. This is the only known site where glacial deposits have forced the North Branch Susquehanna to abandon a segment of its preglacial course.

The deposits are part of the terminal late Illinoian Bloomsburg Margin. The thickness and volume of deposits is equivalent to that at the late Wisconsinan terminal margin 10 miles (15 km) to the east (Stop 2). This implies a similar length of time of ice front stability (stillstand) and supports the contention that the deposit marks the terminal position of the late Illinoian ice.

#### LEAVE STOP 5.

- 0.1 58.9 TURN LEFT onto Twp. Route 646.
- 0.4 59.3 STOP SIGN. TURN RIGHT onto US Route 11.
- 0.2 59.5 South-dipping, olive-gray shale of the Wills Creek Formation to right.
- 0.1 59.6 P. L. Lawton, Inc., truck terminal on right.
- 0.6 60.2 BEAR RIGHT onto entrance ramp to I-80 West.
- 0.4 60.6 MERGE onto I-80 West.
- 1.2 61.8 Poor crops of south-dipping Bloomsburg red mudstone to right.
- 1.8 63.6 Splendid view of River Hill escarpment and "Harrisburg surface" developed on Trimmers Rock and Catskill Formations.
- 0.3 63.9 En echelon, eastward-plunging anticlines of the Berwick anticlinorium ahead. Nearer of two forms Turkey Hill, the site of Bloomsburg University.
- 1.0 64.9 Cross buried, pre-Illinoian valley of Fishing Creek.
- 0.3 65.2 Interchange 35 (Bloomsburg-Lightstreet). CONTINUE STRAIGHT AHEAD, passing under PA Route 487.
- 0.2 65.4 Deep cut in late Illinoian kame deposits of the Bloomsburg Margin.
- 0.3 65.7 Sand-and-gravel operation of Columbia Asphalt Company on both sides of road. The major source of material is the broad late Wisconsinan-Holocene floodplain of Fishing Creek.
- 0.7 66.4 New channel of Fishing Creek to right was excavated in the mid-1960's to eliminate the necessity of building two additional bridges on I-80.
- 1.3 67.7 Fishing Creek gap through Turkey Hill to left. The smooth profiles of the hills on either side of the gap trace the anticlinal arch of the Centre Member ("iron sandstone") of the Rose Hill Formation.
- 0.2 67.9 Cross Fishing Creek. This large stream rises in several branches on North Mountain, 20 mi to the north, and drains an area of approximately 400 mi<sup>2</sup>. When ice was at the late Wisconsinan "terminal moraine," northeast of here, Fishing Creek drained a

- greater length of ice margin and had a greater discharge than did the North Branch Susquehanna River at Berwick.
- 0.5 68.4 BEAR RIGHT onto exit ramp at Interchange 34 (Bloomsburg-Buckhorn).
  - 0.4 68.8 BEAR RIGHT onto PA Route 42 (north).
  - 0.2 69.0 Illinoian stratified drift, exposed to left, underlies the broad flat area on which the service plaza and shopping mall are built.
  - 0.6 69.6 Brown building to right marks the former site of a quarry and borrow area that exposed an abbreviated(?) section of the Keyser-Old Port-Onondaga interval.
  - 0.2 69.8 STOP SIGN. TURN RIGHT onto SR 4009.
  - 0.1 69.9 Cross Little Fishing Creek.
  - 0.2 70.1 TURN LEFT onto SR 4008.
  - 0.3 70.4 North-dipping olive shale and mudstone of the Wills Creek Formation to left. Fishing Creek to right.
  - 0.1 70.5 T-intersection with SR 4011. CONTINUE STRAIGHT on SR 4008.
  - 0.1 70.6 More Wills Creek shale on left.
  - 0.2 70.8 Road to former Bloomsburg Sanitary Landfill to left. The landfill pits were cut in deeply weathered late Illinoian kame deposits.
  - 0.1 70.9 Outcrops of Bloomsburg red mudstone to left.
  - 0.5 71.4 Moyer Ridge Member of the Bloomsburg Formation to left. Note the quartz-mineralized joints in the quartzose red siltstone and fine-grained sandstone beds.
  - 0.3 71.7 Sharp bend in road at former entrance (stone pillars) to Camp Creasy (Girl Scouts). On left is the base of an intermittently exposed section of the Wills Creek Formation that extends for 1,000 feet along the road.
  - 0.1 71.8 To right on the floodplain of Fishing Creek is one of the dredge pits of the Columbia Asphalt Company.
  - 0.2 72.0 Stop buses on right side of road. Debark.
- STOP 6. CAMP CREASY ROADCUT: GEOMETRY OF THE LIGHT STREET FAULT AND ASSOCIATED MINOR STRUCTURES**

**LEADER: Norman M. Gillmeister**

For more than a century geologists have noted anomalous geologic relationships in Upper to Middle Devonian rocks on the north limb of the Berwick anticlinorium near Bloomsburg (see White, 1883). Inners (1978, 1981), Way (in press), and Inners and Way (1979) accounted for missing stratigraphic section and obvious structural incongruities by postulating a major south-dipping thrust fault that extends for at least 27 miles from Mooresburg in Montour County to Berwick in Columbia County. Recent detailed structural analysis indicates that the situation may be much more complex than previously thought.

This outcrop area (Figure 51) provides one of the best exposures of the Light Street fault and of a number of minor structures in its footwall and hanging-wall rocks. Inners (1981) mapped the Light Street fault in this area as a ramp fault originating on a décollement at depth. The fault in this outcrop separates limestones of the Tonoloway Formation from black shales of the Marcellus Formation (Figure 52), so that the Keyser, Old Port, Onondaga, and part of the Marcellus Formations are missing. The contact is sharp and can be traced up a small swale, just to the north of the intricately folded exposure of lime-

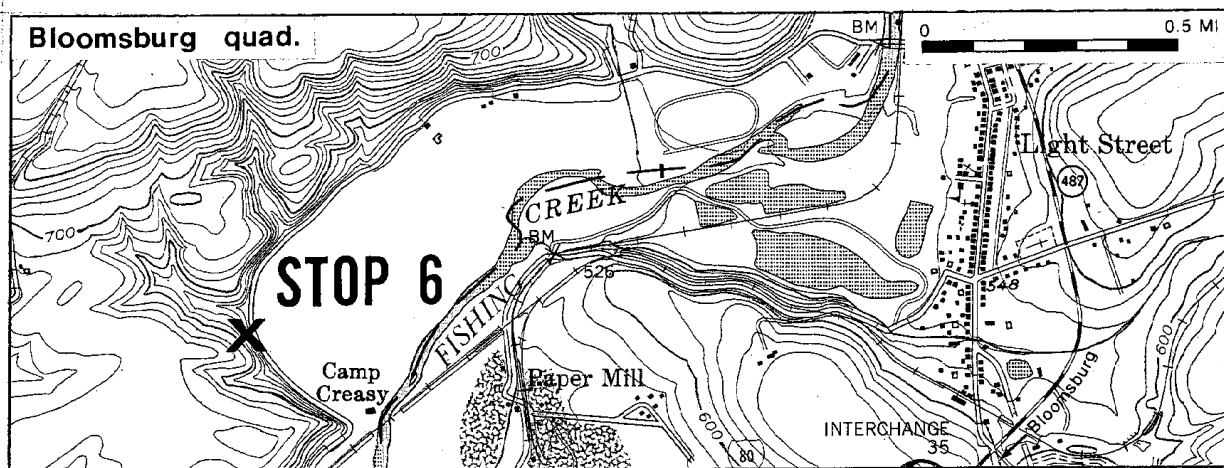


Figure 51. Location map for STOP 6.

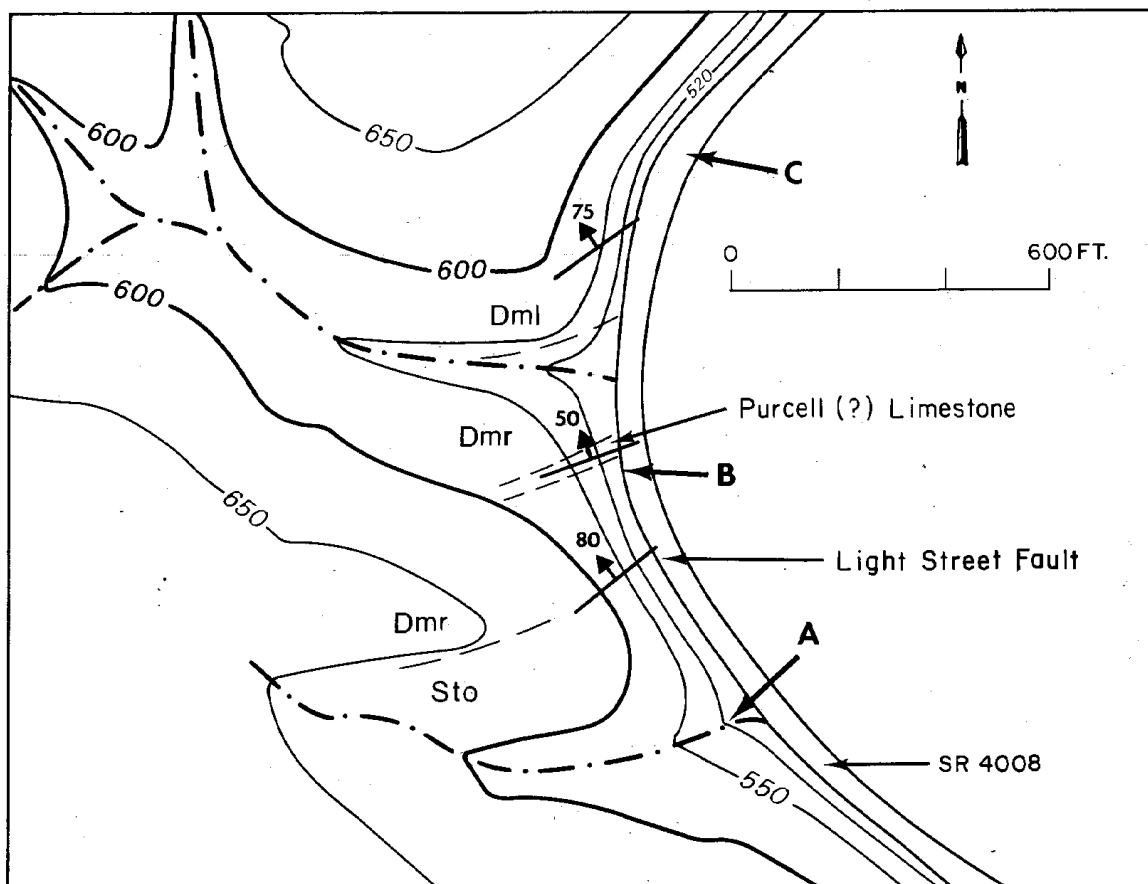


Figure 52. Geologic sketch map of the Camp Creasy area.

stone along the margin of the road. A small excavation half-way up the swale shows the fault surface as a narrow zone of quartz and kaolinite gouge separating fractured and veined Tonoloway from relatively undisturbed-appearing black shale. The fault strikes toward N 50°E and dips steeply (83°) to the north. The

stratigraphic relations and the attitude of the fault at this exposure are consistent with a normal sense of displacement along the fault, north side down.

The limestones in the footwall of the fault are characterized by two zones of minor kink folds that are bounded by planar zones of relatively undisturbed bedding. The folds are disharmonic as seen in outcrop and also disharmonic with respect to the attitude of the major fold (Berwick anticlinorium) which plunges at about 4° toward 70°. The folds in both the upper and lower deformed zones plunge toward the west with considerable scatter in their axial attitudes (see Figure 54a). Two of the planar bounding surfaces for the deformed zones have essentially north-south strikes and dip 30-40° west. This is consistent with the fact that the lower deformed horizon can be traced from a roadside exposure at the Light Street fault, along the slope to the south, and into bedrock exposures at the mouth of the next ravine.

Formation of the folds is apparently related to pressure solution. Specimens of planar-bedded limestone collected between the lower and upper folded horizons are characterized by stylolites that are parallel to bedding and may terminate against hydraulic fractures filled with sparry calcite and quartz. These stylolites are defined by prominent deposits of insoluble residues (Figure 53a). Less prominent anastomosing stylolites, parallel to bedding, but in an en echelon pattern, are also found in these rocks. These stylolites are pre-tectonic, since similar features are deformed in the kink folds. Additional stylolites that are perpendicular to bedding characterize rocks collected from the folded zones. These stylolites are of sutured pattern and also may terminate on sparry calcite or calcite) quartz veins. They do, however, bound planar segments of kink folds, providing the surfaces of discontinuity between sectors of individual folds (Figure 53b). An increasing degree of pressure solution has in some cases led to the development of right-angle butt joints of bedding, producing chevron folds (Figure 53c). Other stylolites formed on the inner arc of folded layers and are complemented by extensional veins that formed on the outer arc (Figure 53d), similar to features observed by Groshong (1975).

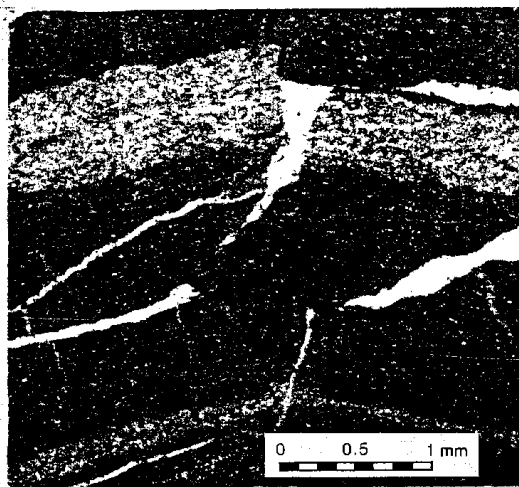
The earlier-formed stylolites that are parallel to bedding may have played an important role during folding, inasmuch as their insoluble residue deposits hinder the transport of material perpendicular to bedding. Deformation can proceed as an essentially constant volume process in a closed system bounded by enveloping surfaces of insoluble material. Pressure solution causes removal of material and apparent offset of bedding, but the total thickness of material between the enveloping surfaces is maintained by precipitation of the dissolved material in veins. The carbonate-quartz veins act as a reservoir linked to the stylolites, as observed by Rispoli (1981). The enveloping surfaces of insoluble material also act as slip surfaces during folding, as shown by the development of micro-duplex structures within them (Figure 53e).

Relevant structural data are summarized in Figures 54 and 55.

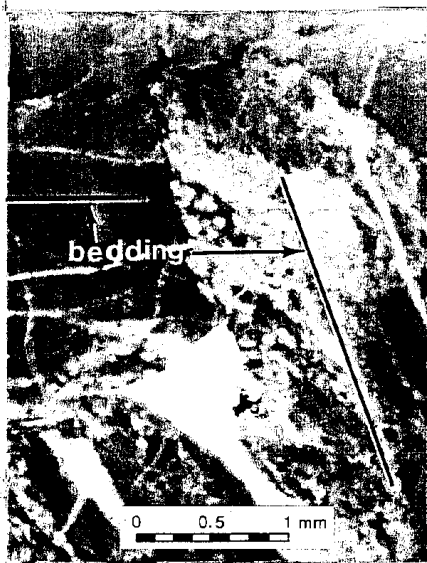
Bedding in the limestones, outside of the deformed zones, is oriented as would be expected on the north limb of the Berwick anticlinorium, typically N75°E, 35°N (Figure 54b; solid squares). Immediately north of the Light Street fault, shales of the Marcellus Formation are kink-folded, with an upper fold limb that dips about 30°N and a lower limb that is essentially vertical (Figure 54b; open diamonds). The axial surface dips about 35° to the south. Brachiopods (Leiorhynchus) can be found on the bedding surfaces. Figure 55a summarizes the



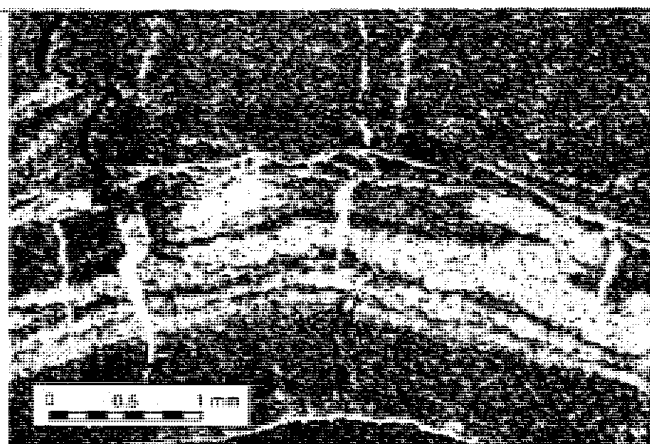
a



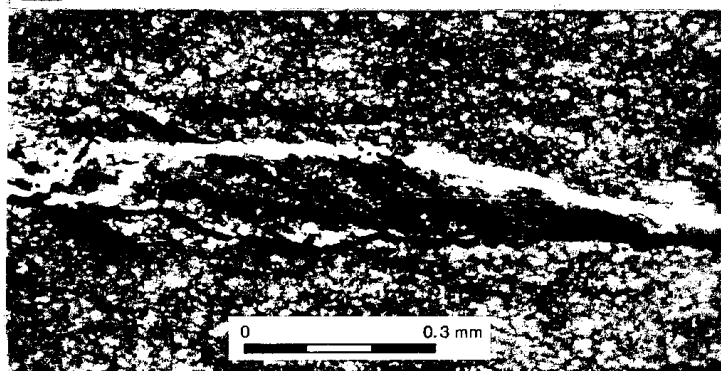
b



c



d



e

attitude of bedding to the north of the kink fold. The scatter represents the effect of normal faulting.

Normal faults dip steeply to the north and the most northerly one is (near letter C on Figure 52) characterized by several splays in a fault zone two feet wide. Displacement is not easy to determine in an homogeneous appearing sequence of gray and black shales of the Marcellus and Mahantango Formations. Structural information for all faults is summarized in Figure 55b.

A general chronological sequence for the generation of the various structures that are present in the area can be deduced. Pressure solution surfaces parallel to bedding and associated dilatational veins were formed first. This was followed by layer-parallel shortening that resulted in pressure solution perpendicular to bedding, the formation of a second set of dilatational veins, and kink folding. These structures were then cut by the normal faults. It is not clear if the kink fold in the shales of the Marcellus Formation is genetically related to the Light Street fault or predates it.

Cleavage generated by pressure solution is not evident in the shales or carbonates at this outcrop or for considerable distances along strike. Toward the east, in the vicinity of Dennis Mills and Briar Creek Lake, the same argillaceous rocks that are exposed here are characterized by a prominent cleavage (see discussion for Stop 7).

- ◄ Figure 53. Photomicrographs of thin sections showing microfractures in carbonate rocks from Camp Creasy.
- a. Stylolite parallel to bedding with insoluble residue (left), terminating against vein filled with sparry calcite. Note apparent offset of bedding by the two veins and absence of stylolites to right of veins. Crossed nicols.
  - b. Stylolites with insoluble residue deposits separating planar sectors of kink fold. Note offsets of bedding. Crossed nicols.
  - c. Sutured butt joint produced by pressure solution. Bedding meets at almost right angles. Crossed nicols.
  - d. Folded carbonate bed with stylolites on inner arc and extensional veins on outer arc. Crossed nicols.
  - e. Tectonically activated bedding-parallel stylolitic surface. (Note insoluble residues). Slip along that surface has generated a micro-duplex. Crossed nicols.

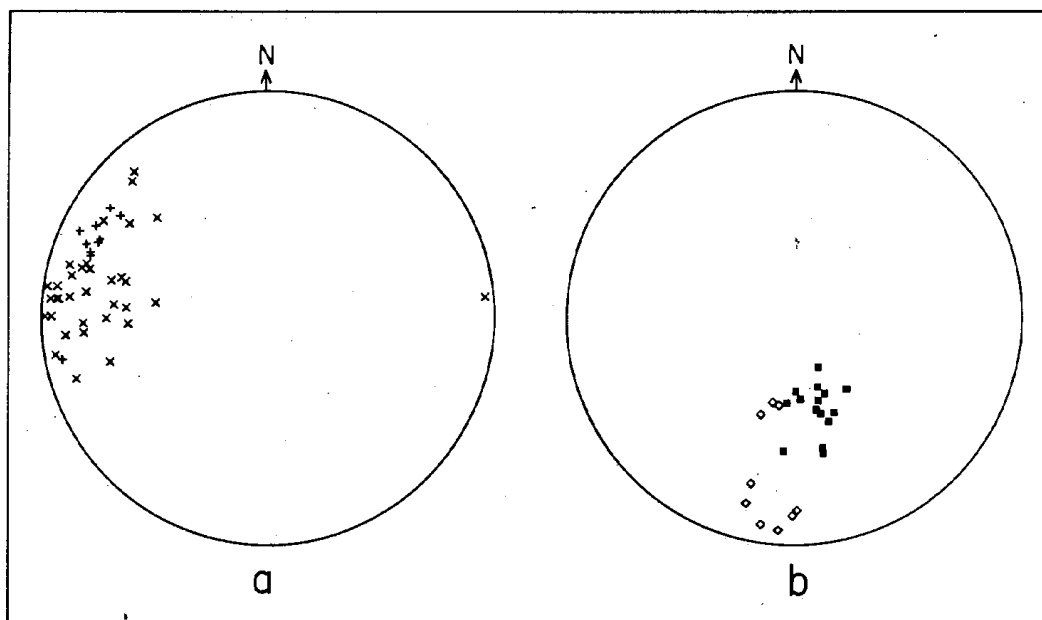


Figure 54. Stereograms (Schmidt net, lower hemisphere projections of structural elements from letter A to B on Figure 52.  
 a. Attitude of minor kink fold axes in Tonoloway Formation. (x's = folds in lower deformed zone; +s - folds in upper folded zone).  
 b. Poles to bedding. (Squares = bedding in Tonoloway; diamonds = bedding in Marcellus).

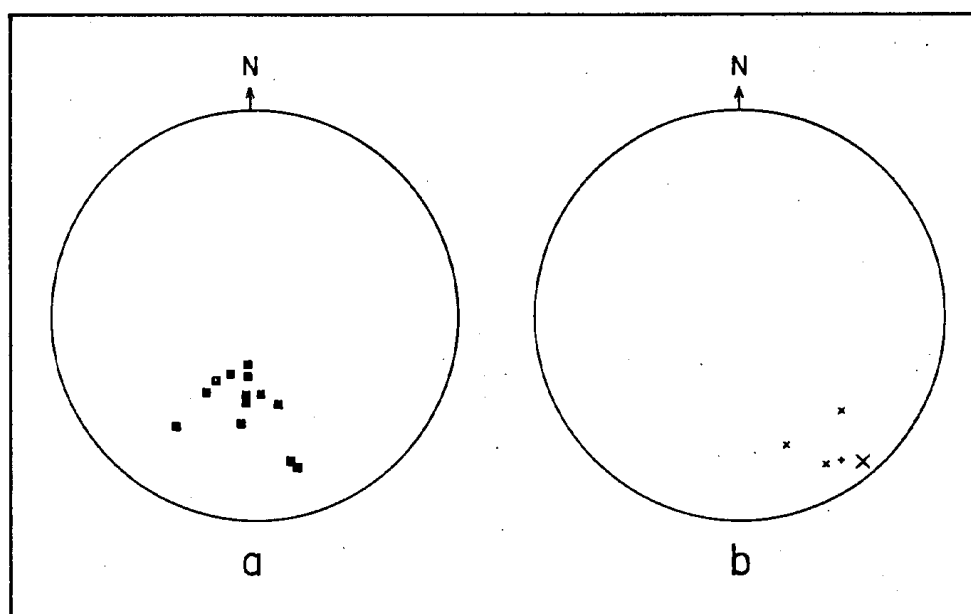


Figure 55. Stereograms (Schmidt net, lower hemisphere projections of structural elements from letter B to C on Figure 52.  
 a. Perpendiculars to bedding.  
 b. Perpendiculars to normal fault surfaces. (X = attitude of Light Street fault; x = attitude of individual fault splays; + = average attitude of fault near C).

- LEAVE STOP 6, continue east on SR 4008.
- 0.1 72.1 First of a series of cuts in north-dipping Mahantango shale to left.
  - 0.5 72.6 Broad floodplain of Fishing Creek to right.
  - 0.4 73.0 T-intersection with SR 4013. CONTINUE STRAIGHT on SR 4008 (now paved).
  - 0.3 73.3 High cut slope in north-dipping black shale of the middle Mahantango Formation to left. Note excellent jointing. The white patches are deliquescent masses of pickeringite, a hydrated magnesium-aluminum sulfate.
  - 0.2 73.5 Cross Fishing Creek.
  - 0.1 73.6 Ascend riser onto late Wisconsinan outwash terrace.
  - 0.1 73.7 STOP SIGN. TURN RIGHT onto Main St. in Lightstreet. Originally laid out in 1817, the village went through a series of names before it was finally named after Light Street in Baltimore. In the mid-1800's, Lightstreet boasted two anthracite iron furnaces - the Henry Clay Furnace in the middle of the village and the Williamsburg Furnace at the north end (Lesley, 1859).
  - 0.1 73.8 TURN LEFT onto Easy Street (SR 1008).
  - 0.1 73.9 STOP SIGN at intersection with PA Route 487. CONTINUE STRAIGHT AHEAD on SR 1008.
  - 0.1 74.0 Housing development to right sits on Illinoian ice-marginal kame deposits. Domestic wells pass through 50 to 100 feet of sand and gravel before reaching bedrock.
  - 1.1 75.1 To right is broad, featureless valley of the West Branch of Briar Creek. The smooth conformation of the valley is probably due in part to virtual elimination of the Keyser and Old Port Formations along the Light Street fault. To left is the "Summer Hill" escarpment, formed by north-dipping Trimmers Rock siltstone.
  - 0.5 75.6 Shale-chip rubble overlying Trimmers Rock shale and siltstone in burrow pits behind house trailers to left.
  - 2.7 78.3 Abandoned quarry in the Tonoloway limestone to left at bend in road. This quarry apparently lies south of trace of the Light Street Fault.
  - 0.8 79.1 STOP SIGN in village of Fowlersville. TURN LEFT onto SR 1037.
  - 0.1 79.2 STOP SIGN. TURN RIGHT onto PA Route 93.
  - 0.6 79.8 Long outcrop of cleaved and faulted Mahantango shale to left.
  - 0.2 80.0 TURN LEFT onto access road to shale pit. Stop buses and debark. STOP 7. DENNIS MILLS ROADCUT AND BORROW PIT: DEFORMATIONAL STYLES ALONG THE LIGHT STREET FAULT AND PALEONTOLOGY OF THE MAHANTANGO FORMATION

LEADERS: Norman M. Gillmeister and Dale A. Springer

At this STOP (Figure 56), we will examine: 1) complex structures that are developed along the Light Street fault zone in some of the same rocks seen at Stop 6 and 2) an extremely fossiliferous zone in the Mahantango shale. All the rock exposed here belongs to the lower member of the Mahantango Formation (Inners, 1981). Recent excavations for borrow material have created much better exposures than were available several years ago, but continued digging may eventually destroy the site.

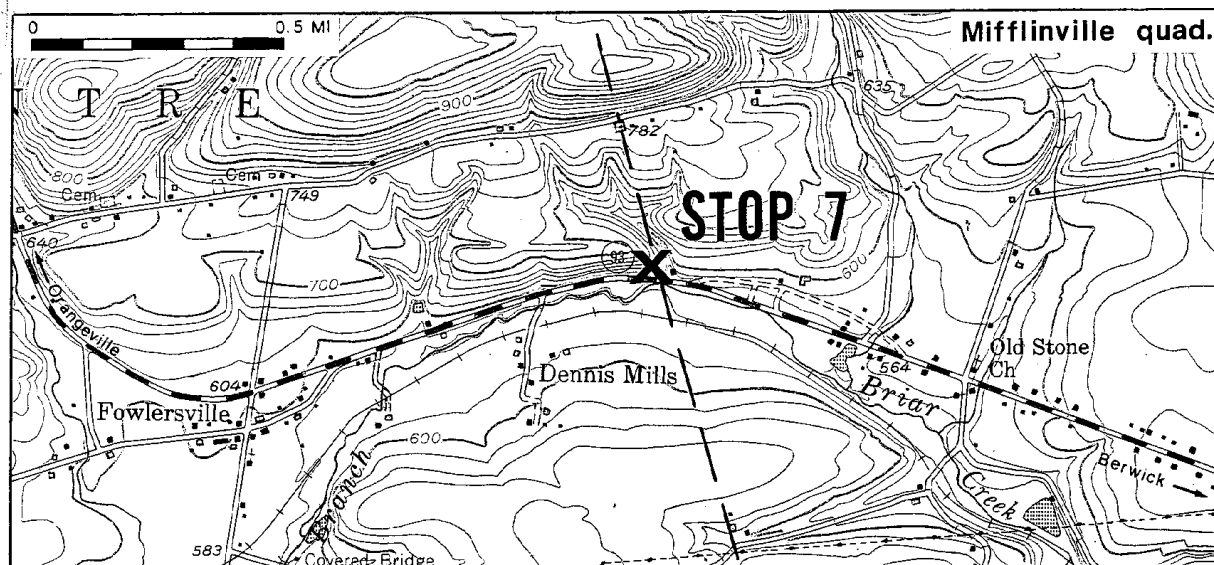


Figure 56. Location map of STOP 7.

### Structural geology

Inners (1981) mapped the Light Street fault as trending east-west on the opposite (south) side of the West Branch Briar Creek valley. He noted passage of the fault through poor exposures along an abandoned railroad grade, 2,000 feet to the southeast (p. 79); at this point, limestones of the Tonoloway Formation occur within a few tens of feet of grayish-black Marcellus shales. He also described north-dipping faults at nearby roadcuts on PA Route 93 (this STOP), which he believed bore an antithetic relationship to the south-dipping Light Street "thrust" fault (p. 81).

A sketch map of the exposures at STOP 7 is shown in Figure 57 and relevant structural data are summarized in Figures 58 and 59.

The most prominent planar structural feature in the area is apparent where we get off the buses. It is a south-dipping feature that is dominant in all exposures along the creek and road to the north. At first glance, it appears to be bedding, but another look is warranted since we are on the north limb of the major anticline. The shales along Route 93 are homogeneous and non-fossiliferous, but faint lineations are visible on the prominent planar partings. The planar fabric is a pressure solution cleavage oriented essentially at right angles to north-dipping bedding, and the lineations are bedding-cleavage intersections. These relationships are shown in Figure 58a.

A number of faults can also be examined at this outcrop. All are normal faults that belong to two sets having an almost right-angle relationship to each other. A north-dipping fault with a breccia zone up to a foot thick is exposed near road level (see Inners, 1981, Fig. 25). This fault strikes about N80°E and can be traced to the west, where it disappears under the road. It reappears further west and continues to a small borrow pit located near the western edge of Figure 57. The fault at that locality consists of a single, smooth, plane, with no breccia present, indicating that breccia is developed only locally. This fault marks a break in the attitude of cleavage. Cleavage in the footwall

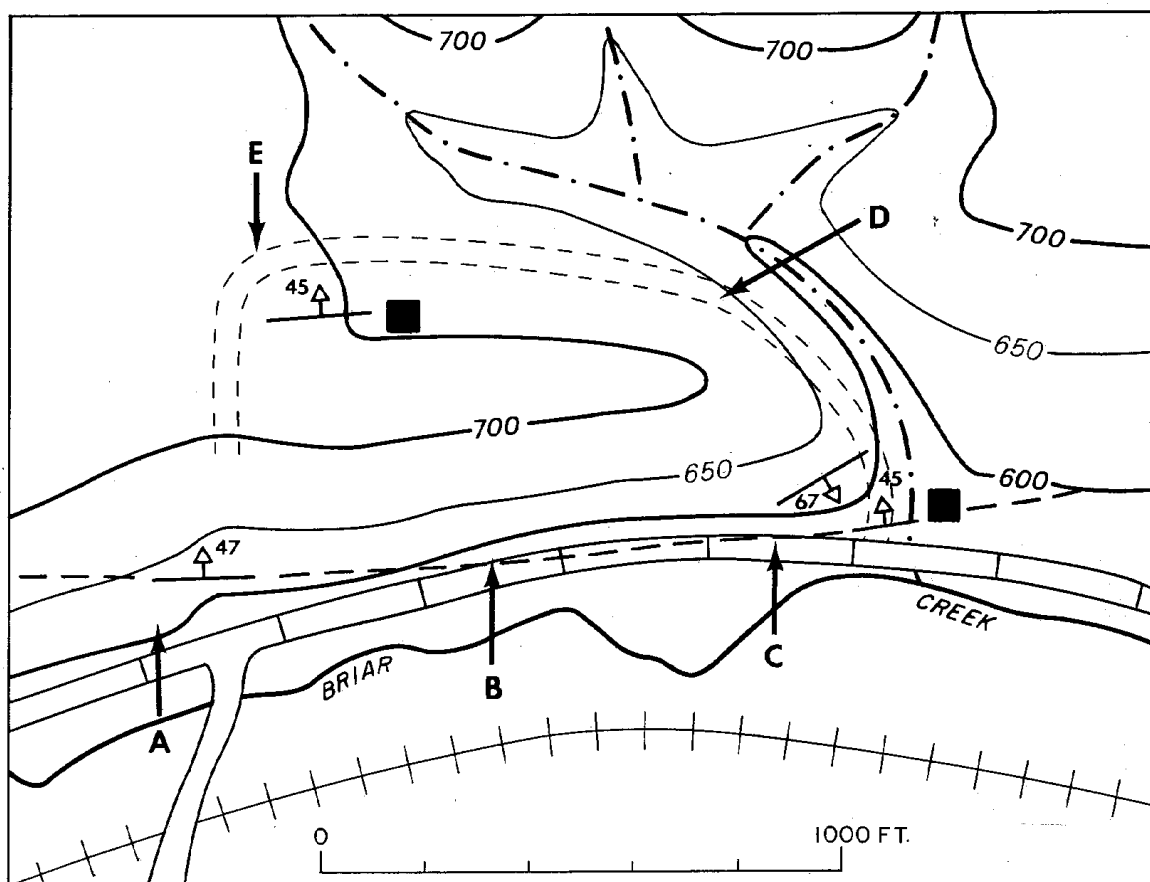


Figure 57. Geologic sketch map of STOP 7.

dips gently to the north (Figures 58a and 59a), as opposed to the south-dipping cleavage in the hanging wall (e.g., Figure 59b). Bedding must be nearly vertical in the footwall rocks.

The south-dipping faults in this outcrop do not have any associated breccia zones. Their surfaces are planar to undulating and are characterized by prominent slickenlines (Figure 60). Quartz-filled tension gashes above and below the fault surfaces are oriented at right angles to the pressure solution cleavage, producing a variety of "pencil" shale. Figure 58b illustrates the geometric relations of the normal fault features.

The bedding-cleavage relationship in these rocks is clearly demonstrated further north along the dirt road shown on Figure 57. The Mahantango shales become fossiliferous in this direction (see below) so that bedding is clearly outlined by fossil-rich layers. These dip about 50° to the north. The effects of pressure solution on the fossils are obvious. Brachiopods are distorted and finely crenulated, corals are preferentially solved parallel to the cleavage trace (Figure 61) and crinoid columnals are truncated by the cleavage. Crinoid columnals that appear undeformed are actually somewhat flattened at right angles to bedding, if an originally circular shape is assumed. Their length to width ratios are in the range of 1.1:1 to 1.2:1. Columnals that are clearly pressure solved have length to width ratios that vary from 1.2:1 to 1.8:1, with most falling in the range of 1.3:1 to 1.5:1. Pressure solution has obviously been

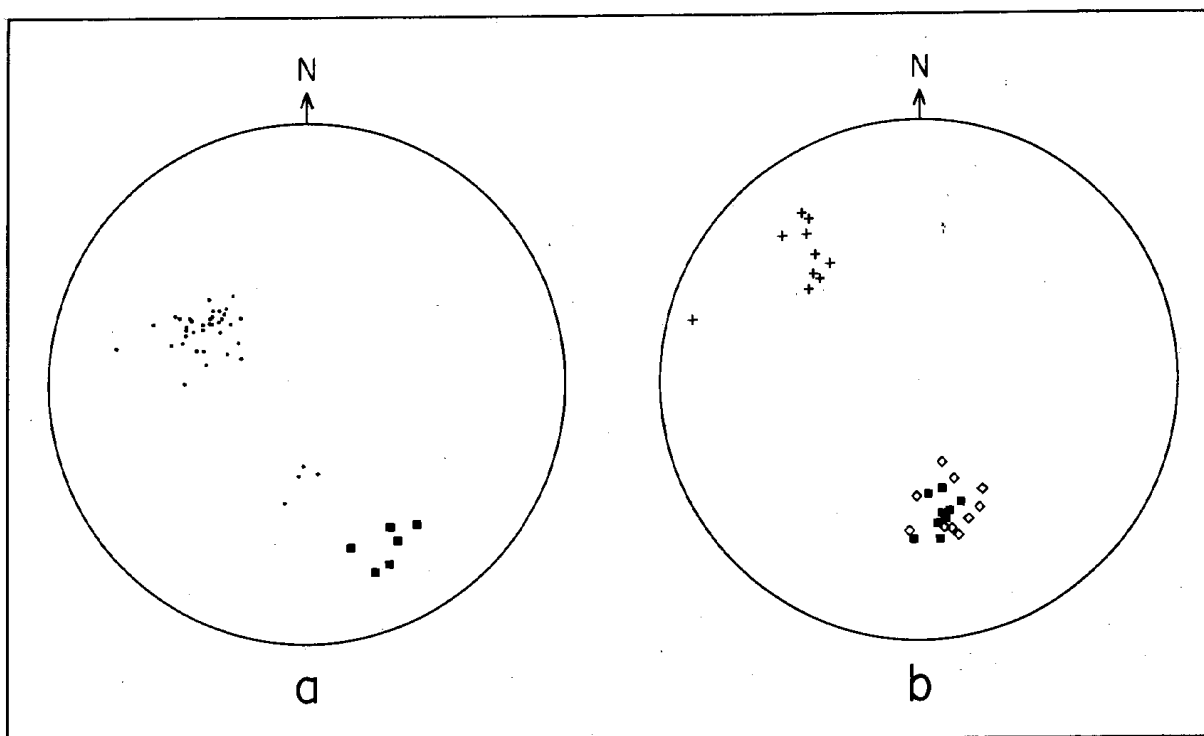


Figure 58. Stereograms (Schmidt net, lower hemisphere projections) of structural elements between D and E at STOP 7.

- Attitude of cleavage and bedding. (Dots = poles to pressure solution cleavage; squares = poles to bedding).
- Attitude of poles to normal fault surfaces and of associated slickenlines. (+ 's = south-dipping faults; diamonds = slickenlines on south-dipping faults; squares = north-dipping fault with breccia zone).

an important mechanism of pre-folding deformation in these rocks, leading to large rock volume losses (i.e., layer-parallel shortening) and to the generation of a prominent cleavage.

Another north-dipping normal fault with a locally developed breccia zone can be mapped near the new equipment storage building shown in Figure 57. The attitudes of the fault and associated slickenlines are shown in Figure 59d. Bedding and cleavage orientations in that vicinity are shown in Figure 59c. North-dipping cleavage on the hanging wall of this fault has approximately the same orientation as cleavage in the footwall of the north-dipping fault along Route 93.

It is clear that tensional structures are common in the Mahantango shales at this locality. It is also clear that these types of structures would not be noticed in the course of geologic mapping unless relatively fresh artificial cuts are present.

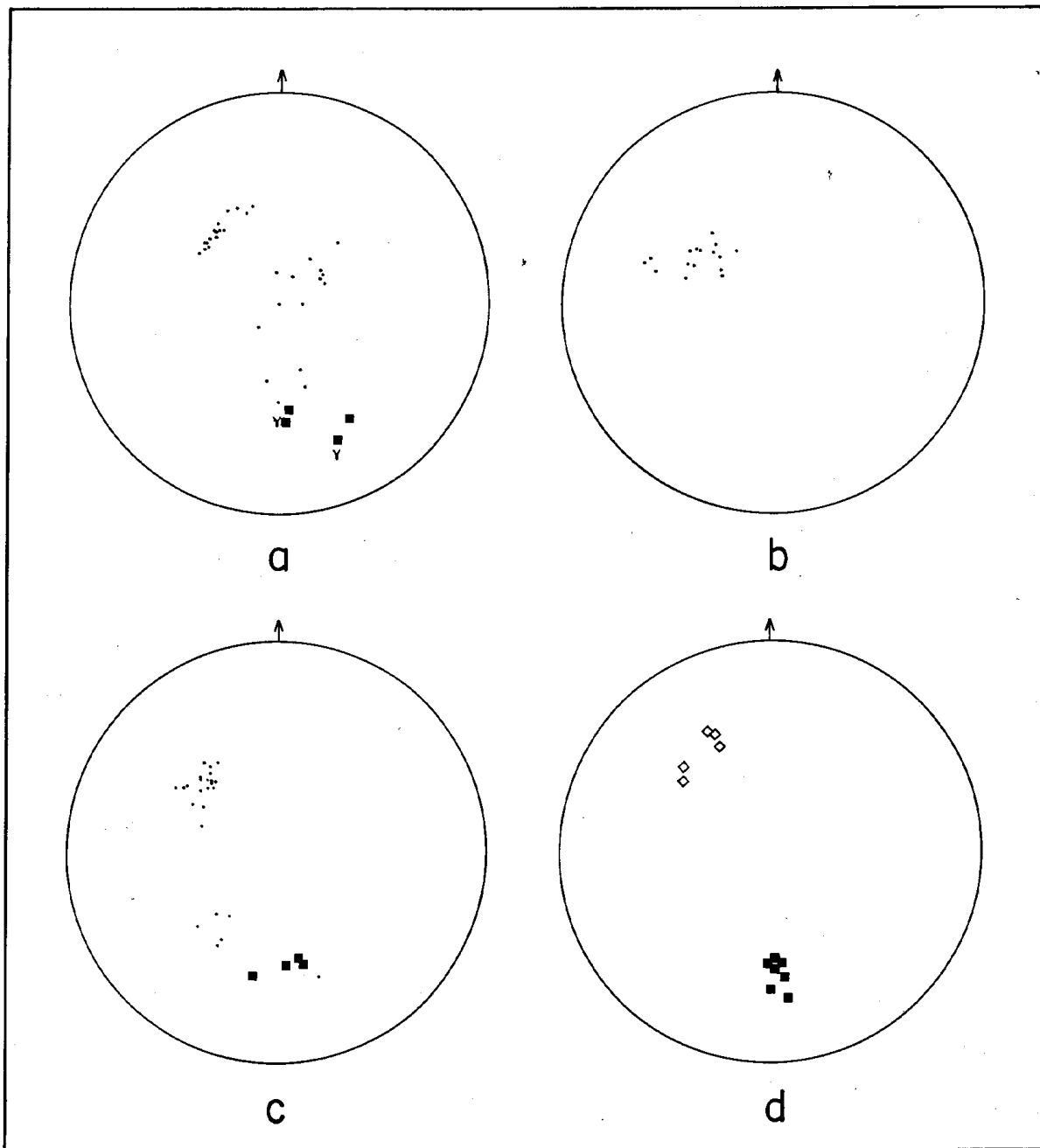


Figure 59. Stereograms (Schmidt net, lower hemisphere projections) of additional structural data from STOP 7.

- a. Between A and B of Figure 57.
- b. Between B and C of Figure 57.
- c. Between C and D of Figure 57.

(For all of the above: Dots = poles to pressure-solution cleavage; squares = poles to bedding; Y's = poles to fault surfaces).

- d. Fault data for the same area as in c (above). (Squares = poles to normal faults; diamonds = attitude of slickenlines).

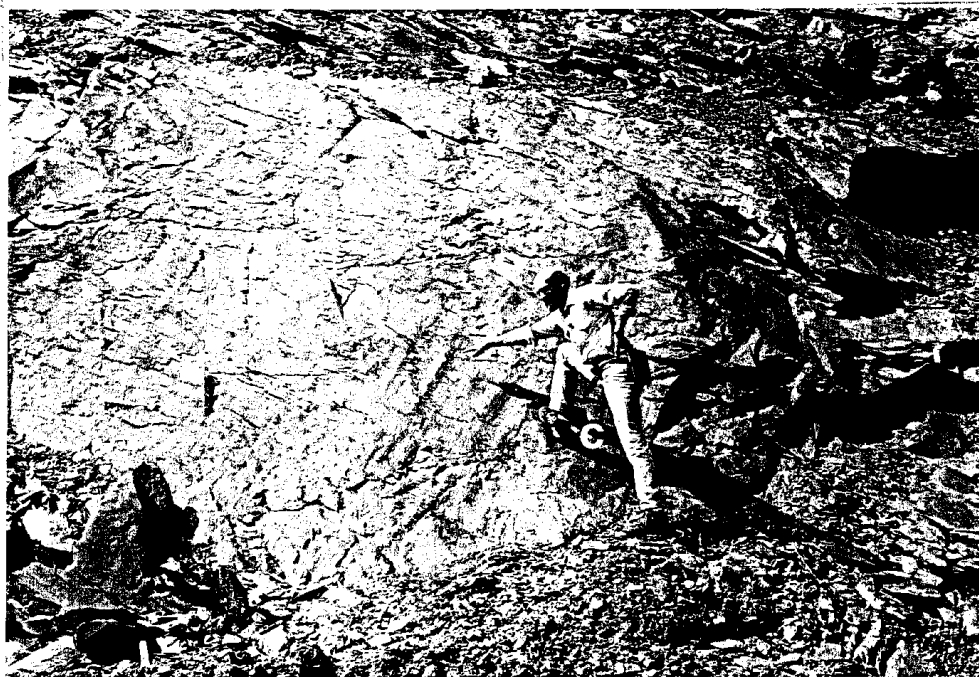


Figure 60. South-dipping normal fault with undulating fault surface and prominent slickenlines. The fault cuts pressure solution cleavage (c). Bedding is not visible.



Figure 61. Pressure-solved Favosites colony. (b = bedding; c = cleavage; i = bedding-cleavage intersections). Knife is 7 inches long.

## Paleontology

The Mahantango Formation has long been known for a diverse and well-preserved fossil fauna (Figure 62) that includes numerous brachiopods, bivalves, crinoids, bryozoans, and corals. Trilobites, gastropods, and nautiloid cephalopods are also moderately common. Preservation is usually as molds (internal, external, or composite), although some shell material may remain, particularly in brachiopod, coral, and crinoid specimens. In some localities, the upper part the unit yields partially pyritized fossils. Burrows are relatively common in some horizons, and more pervasive bioturbation sporadically disrupts bedding.

The outcrop at Dennis Mills is typical of Mahantango exposures in the local area. The rocks are deformed and dissected by faults and a prominent cleavage. Bedding can be traced in fossiliferous (or concretionary) horizons, but is often obscured by the cleavage. The style of deformation also makes it difficult to recover undistorted fossil specimens.

Fossils appear to be absent from the lower portion of the outcrop, except for a few widely-scattered and questionable fragments. The first unequivocal body fossils (tiny, disarticulated, distorted brachiopods) occur at the curve in the access road, about 100 yards up from Route 93. Specimens are, however, sparse at this level. Small (diameter = 1-3 mm), Chondrites-like burrows can be found in the dark grey siltstones surrounding these fossils. Diversity and abundance of fossils remain low through the next few meters. Fossil-rich layers become common approximately 15 feet above the first appearance of body fossils. Fossiliferous layers are usually 1-5 cm thick, and often have scoured or irregular bases. Although exact geometry is difficult to document due to the persistent cleavage, some of the fossil bands appear to be lenticular on a scale of several feet. Very thin (single-shell-thick) fossiliferous layers can be found by breaking the rock along discontinuous, iron-stained "seams".

Ramose bryozoans (Rhombopora? and Acanthoclema?), short crinoid stem segments and isolated columnals, Mucrospirifer, Pleurodictyum, Ptychopteria, Cypricardella, and several very small bivalves (4-5 mm in length) genera not identified are typical of layers in this part of the section. Most bivalve specimens appear to be disarticulated, but not broken. Many of the spiriferid brachiopods occur as steinkerns (whole, if somewhat distorted, internal molds). Bryozoan fragments, crinoid stems, and burrows are occasionally surrounded by (sideritic?) iron deposits. The first fossiliferous zone is about 5 to 7 feet thick. This is followed by a zone in which the lithology appears to be the same (i.e., dark-gray, non-calcareous siltstone, weathering buff to brown), with the exception of numerous nodular layers that parallel bedding. Fossils are rare in this zone, limited mainly to scattered fragments and burrows in sediments between the nodular layers. Fossil-rich and fossil-poor/nodule-rich zones appear to alternate upsection, at least through the central portion of outcrop accessible along the road.

Diversity and abundance of invertebrate fossils appear to be greatest in the middle portion of the Mahantango at Dennis Mills. This part of the outcrop appears to contain the Athyris-Pleurodictyum-rugose coral beds mapped by Inners (1981) from Briar Creek Lake (1.5 miles east of here) eastward into the Berwick quadrangle. Common articulate brachiopods include spiriferids (Mucrospirifer, Mediospirifer, Spinocyrtia), atrypids (primarily Athyris), orthids (particularly Rhipidomella, Tropidoleptus), and strophomenids (Prototeptostrophia, Devonochonetes). The inarticulate brachiopod, Orbiculoidea, has also been found.



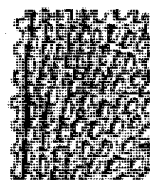
*Rhombopora*  
x10



*Acanthoclema*  
x10



*Taeniopora* x1



*Fenestella* x1



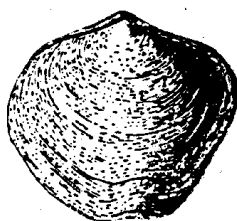
*Rhipidomella* x1



*Tropidoleptus*  
x0.8



*Mucrospirifer* x0.8



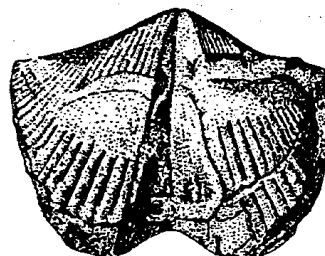
*Athyris* x0.8



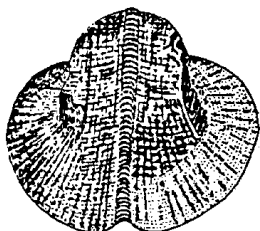
*Devonochonetes* x1.5



*Protopleptostrophia*  
x0.8



*Spinocyrtia* x0.8



*Bucanopsis* x0.8



*Tropidodiscus* x0.8



*Holopea* x0.8



*Michelinoceras* x1



*Palaeozygopleura* x1



*Cypricardinia*  
x1.6



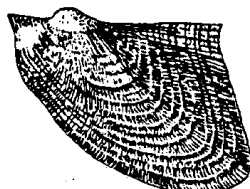
*Nuculoidea* x1.2



*Nuculites* x1



*Palaeoneilo* x0.8



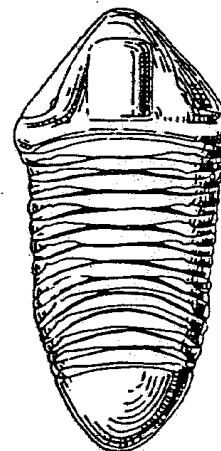
*Ptychopteria* x1



*Cypricardella* x1



*Edmondia* x0.5



*Trimerus*  
x0.5

◀ Figure 62. Typical Mahantango Formation fossils. (From Hoskins and others, 1983, except Rhombopora and Acanthoclema from Moore and others, 1952).

Bivalve diversity and preservation are striking. In addition to Ptychopteria and Cypricardella, the bivalve fauna includes Nuculites, Paleoneilo, a small grammysioid (possibly Edmondia), and Cypricardinia. Several other bivalve genera are also present, but have yet to be positively identified.

Among the bryozoans present, the most easily recognizable genus is Taeniopora, distinguished by its (relatively) large, flat, ribbon-like branches, each of which bears a low keel down its center. Fragments of several fenestrate bryozoan genera are also moderately common (?probably Polypora and Fenestella). Poor preservation of many of the tiny ramose bryozoans does not facilitate their identification.

Only four genera of coral appear to be present at Dennis Mills. The tabulates are represented by a relatively large (diameter = 20 cm), "pressure-solved" colony of Favosites (Figure 61), by very small colonies of Pleurodictyum, and by broken, branching colonies of "Trachypora"; the rugose corals are represented by specimens of Heterophrentis, a small (length four to five centimeters), solitary horn coral.

The classic Devonian high-spined gastropod, Paleozygopleura ("Loxonema"), and the laterally compressed bellerophontid, Tropidodiscus, occur in moderate numbers throughout the outcrop. Other gastropods are less common. Several badly-worn internal molds of a low-spined form similar to juvenile Holopea have been recovered, as has a partial external mold of a Bucanopsis-like bellerophontid.

Echinoderm material, in the form of crinoid columnals, is one of the most abundant elements of the Mahantango fauna at Dennis Mills (and elsewhere in the region). Columnals vary in size from approximately one millimeter to one centimeter in diameter. Calical plates have not been recovered from this section, nor have any attempts been made to identify the crinoidal material that is present.

Other minor faunal elements include trilobite fragments (mostly phacopids such as Phacops and Greenops, and Trimerus) and orthoconic nautiloids.

The best collecting is usually from float bulldozed down the outcrop about halfway up the road to the quarry. Most specimens are distorted to some extent, and the pervasive cleavage can create problems for those attempting to collect from unweathered material.

|     |      |                                                                                                  |
|-----|------|--------------------------------------------------------------------------------------------------|
|     |      | LEAVE STOP 7. TURN LEFT on PA Route 93.                                                          |
| 0.7 | 80.7 | To left is "The Old Stone Church" (1808), the first Methodist church in the North Branch valley. |
| 1.4 | 82.1 | TURN RIGHT onto Rittenhouse Mill Road.                                                           |
| 0.4 | 82.5 | Riser of intermediate outwash terrace in Ber Vaughn Park to left.                                |
| 0.2 | 82.7 | STOP SIGN. TURN RIGHT onto US Route 11.                                                          |
| 3.1 | 85.8 | Pass under I-80 and IMMEDIATELY BEAR LEFT onto entrance ramp to I-80 East (toward Hazleton).     |

|     |       |                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-----|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.5 | 86.3  | MERGE with I-80 East.                                                                                                                                                                                                                                                                                                                                                                                                                |
| 0.4 | 86.7  | Cross North Branch Susquehanna River.                                                                                                                                                                                                                                                                                                                                                                                                |
| 1.1 | 87.8  | Cross Illinoian recessional ice-margin at mouth of abandoned valley of the North Branch (directly ahead to right).                                                                                                                                                                                                                                                                                                                   |
| 3.2 | 91.0  | Rest Area.                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 1.7 | 92.7  | Enter Luzerne County.                                                                                                                                                                                                                                                                                                                                                                                                                |
| 1.9 | 94.6  | Ahead to the right is a great amphitheater carved into the scarp slope of Nescopeck Mountain by the southward migration of an incised meander of Nescopeck Creek.                                                                                                                                                                                                                                                                    |
| 0.2 | 94.8  | The deep, ragged cut to the left was made in the mid-1960's for a channel change of Nescopeck Creek that eliminated building two high bridges over the creek. The rock exposed is dominantly red sandstone and mudstone of the Sherman Creek Member of the Catskill Formation. It is reliably reported that severe construction problems were encountered here because the design engineers ignored the steep south dip of the beds. |
| 0.5 | 95.3  | Deep roadcut in the Sherman Creek (left) and Duncannon (right) Members of the Catskill Formation.                                                                                                                                                                                                                                                                                                                                    |
| 0.3 | 95.6  | Enter Nescopeck Gap. Near the south end of the gap (on the east side) a coal mine reportedly produced a small amount of shaly "anthracite" during the Depression years. A caved drift in the lower part of the Pocono Formation marks the site of the mine.                                                                                                                                                                          |
| 0.8 | 96.4  | Cross Nescopeck Creek. Black Creek, which drains the north edge of the Eastern Middle Anthracite field, enters the Nescopeck just to the right of the bridge. The late Illinoian ice margin swings across the Conyngham Valley 2 miles west (to right) of this point. It temporarily diverted Black Creek westward to the Catawissa Creek drainage.                                                                                  |
| 0.4 | 96.8  | Long, deep cut in folded and faulted siltstones, mudstones and sandstones (dominantly red) of the lower and middle members of the Mauch Chunk Formation.                                                                                                                                                                                                                                                                             |
| 0.8 | 97.6  | To left are cleaved red siltstone and mudstone of the Mauch Chunk Formation. Many small rock block slides occur on the face of the cut.                                                                                                                                                                                                                                                                                              |
| 0.4 | 98.0  | Sugarloaf Mountain and the Buck Mountain-Butler Mountain escarpment in distance to right.                                                                                                                                                                                                                                                                                                                                            |
| 0.3 | 98.3  | Mauch Chunk red beds exposed beneath both abutments of concrete bridge over I-80.                                                                                                                                                                                                                                                                                                                                                    |
| 3.3 | 101.6 | Cross over PA Route 93 at Interchange 38.                                                                                                                                                                                                                                                                                                                                                                                            |
| 0.4 | 102.0 | Middle Mauch Chunk sandstone to left.                                                                                                                                                                                                                                                                                                                                                                                                |
| 3.2 | 105.2 | Pass over I-81 at Interchange 38. The late Wisconsinan "terminal moraine" extends southeastward across the Conyngham Valley in this general area.                                                                                                                                                                                                                                                                                    |
| 0.8 | 106.0 | Sandstone of the middle member of the Mauch Chunk Formation exposed on both sides of highway.                                                                                                                                                                                                                                                                                                                                        |
| 1.9 | 107.9 | BEAR RIGHT at exit ramp of Interchange 39.                                                                                                                                                                                                                                                                                                                                                                                           |
| 0.2 | 108.1 | STOP SIGN. TURN RIGHT onto US Route 309 (south).                                                                                                                                                                                                                                                                                                                                                                                     |
| 1.1 | 109.2 | Cross Nescopeck Creek. Extensive glaciofluvial deposits border the creek for several miles above this point.                                                                                                                                                                                                                                                                                                                         |
| 0.5 | 109.7 | Morainal topography against mountainside to left marks the late Wisconsinan terminal position.                                                                                                                                                                                                                                                                                                                                       |
| 0.3 | 110.0 | Climb above and outside late Wisconsinan ice terminus.                                                                                                                                                                                                                                                                                                                                                                               |
| 0.2 | 110.2 | Red mudstone and sandstone of the Mauch Chunk Formation crop out at crest of spur ridge on Green Mountain.                                                                                                                                                                                                                                                                                                                           |

- 0.4 110.6 TRAFFIC LIGHT. CONTINUE STRAIGHT on US Route 309.
- 1.1 111.7 Begin ascent of Buck Mountain; Conyngham Valley to right. Late Illinoian frontal kame deposits to the west and east of this area indicate that the late Illinoian ice margin was against the north side of Buck Mountain but no constructional landforms remain.
- 0.6 112.3 Sandstone near the top of the middle member of the Mauch Chunk Formation to left.
- 0.2 112.5 To left is the beginning of a long cut exposing redbed-bearing, alluvial fining-upward cycles in the upper member of the Mauch Chunk.
- 0.3 112.8 Crest of Buck Mountain. Ledges to left are conglomeratic beds in the upper Mauch Chunk that are equivalent to the lower Tumbling Run Member of the Pottsville Formation.
- 0.3 113.1 Amscot Coal Co. fine-coal recovery plan to left. The long high-wall exposes the seat rock of the Mammoth seam on the north side of the Little Black Creek basin. This was the site of the deep mines of the Lattimer Colliery. Extensive exposures of pre-Illinoian glacial deposits occur to the east along strike.
- 0.2 113.3 TRAFFIC LIGHT at intersection with Hazleton By-Pass. CONTINUE STRAIGHT AHEAD on US Route 309.
- 0.5 113.8 TURN LEFT into parking lot of Genetti Motor Lodge.  
END OF 1ST DAY.

# ROAD LOG - DAY 2

| Mileage |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|---------|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Inc     | Cum |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 0.0     | 0.0 | START. Leave parking lot in front of Genetti Motor Lodge. TURN RIGHT onto US Route 309 (north).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 0.3     | 0.3 | Enter Milnesville, one of many communities that are the descendants of "coal patch" towns in the Eastern Middle field.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 0.1     | 0.4 | About 1 mile to the east of here is the village of Lattimer, site of the infamous "Lattimer Massacre" of September 10, 1897. A red sandstone monument at the "Y" in the road at the west end of the village reads:<br>"LATTIMER MASSACRE. Seeking collective bargaining and civil liberty, immigrant miners on strike were marching in protest from Harwood to Lattimer. Here, on Sept. 10, 1897, they were met by armed deputy sheriffs. The ensuing affray resulted in the deaths of more than twenty marchers."<br>The stone was placed by the AFL-CIO and the United Mine Workers of America on the 75th anniversary of the clash. It also contains the names of those killed, all Slavs and Hungarians. |
| 0.1     | 0.5 | TRAFFIC LIGHT. TURN LEFT onto SR 3026 (Hazleton By-Pass).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 0.2     | 0.7 | On both sides of the road are strippings over the old Hollywood Colliery workings. The Mammoth seam, normally about 30 feet thick was here tectonically thickened to over 100 feet in the trough of the Hollywood syncline. Extensive stripping has been carried on here since the 1870's. The recently reclaimed area just north of the highway marks early 1980's strippings of Brook Contracting Co. on sub-Mammoth seams.                                                                                                                                                                                                                                                                                |
| 0.5     | 1.2 | Outcrops of gray quartz-lithic sandstone of the Llewellyn Formation on the right. To the left is a stripped-out syncline in the Mammoth.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 1.7     | 2.9 | TRAFFIC LIGHT. TURN RIGHT on PA Route 93.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 0.2     | 3.1 | Entrance to Hazleton Campus of Pennsylvania State University to right.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 0.3     | 3.4 | Pass over I-81. Outcrops of upper Mauch Chunk and Pottsville Formations in interchange area (STOP 12).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 0.1     | 3.5 | TURN LEFT onto SR 3020.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 0.1     | 3.6 | TURN LEFT onto entrance ramp to I-81 South.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 0.2     | 3.8 | Pottsville/Mauch Chunk contact in cut to left.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 0.2     | 4.0 | MERGE into I-81 South.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 0.3     | 4.3 | Pottsville/Mauch Chunk contact exposed in core of anticline to left and on north limb to right (Station 8 of Figure 82).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 0.1     | 4.4 | Cross Black Creek.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 0.2     | 4.6 | Pottsville conglomerate exposed in broad anticline on both sides of road.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 0.3     | 4.9 | Stony Creek basin to right.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 0.6     | 5.5 | Cut in south-dipping Pottsville conglomerate.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 0.6     | 6.1 | Deep cuts in sandstones, siltstones, claystones, and coals of the lower Llewellyn Formation. The Gamma and Buck Mountain seams were once deep-mined and stripped in this part of the Hazleton basin.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 0.3     | 6.4 | Interchange 41. Pass under PA Route 924.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

- |     |      |                                                                                                                                                                                                                                                     |
|-----|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.3 | 7.7  | Deep cut through the upper member of the Mauch Chunk Formation at the axis of the Pismire Ridge anticline. Polymict conglomeratic sandstone forms a protective cap over the underlying siltstones and claystones. (Station 7 of Figure 82).         |
| 0.7 | 8.4  | Water filled strippings mark the narrow northern part of the Honeybrook basin. To the west along strike near Oneida, bedrock is overlain by more than 10 feet of reddish till that is in turn overlain by 10 to 16 feet of quartz pebble colluvium. |
| 0.4 | 8.8  | Cross Catawissa Creek.                                                                                                                                                                                                                              |
| 0.3 | 9.1  | Pass under haul road. Mauch Chunk and Pottsville Formations (south-dipping) exposed to right (Station 6 of Figure 82).                                                                                                                              |
| 0.5 | 9.6  | Enter Schuylkill County and cross broad southern part of the Honeybrook basin.                                                                                                                                                                      |
| 1.1 | 10.7 | Spring Mountain cut. Spectacular exposure of thrust fault in Pottsville/Mauch Chunk interval at the core of the Spring Mountain syncline.                                                                                                           |
| 0.3 | 11.0 | 45-megawatt cogeneration plant of Northeastern Power Company (NEPCO), a subsidiary of the Reading Company, to the left. The plant will use anthracite mining refuse from old collieries in the Silver Brook basin.                                  |
| 0.1 | 11.1 | To right is a view of the anticlinal Ringtown Valley. The valley is floored by the Mauch Chunk Formation and rimmed by the Pottsville Formation.                                                                                                    |
| 0.2 | 11.3 | South-dipping sandstones and shales of upper member of the Mauch Chunk Formation at Interchange 39.                                                                                                                                                 |
| 0.5 | 11.8 | Southbound entrance ramp to I-81 to right.                                                                                                                                                                                                          |
- MAIN ROADLOG CONTINUES ON PAGE 154

\*\*\*\*\*

#### OPTIONAL ROAD LOG (FOR CARS)

- |       |       |                                                                                                                                                                                                                  |
|-------|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (0.0) | (0.0) | START. Leave parking lot in front of Genetti Motor Lodge. Turn left onto US 309 (south). Ahead is Hazleton (the "Mountain City"), the highest city in Pennsylvania (maximum altitude about 1,800 feet).          |
| (0.7) | (0.7) | TRAFFIC LIGHT at intersection with PA Route 940. CONTINUE STRAIGHT AHEAD on Route 309 (N. Church Street).                                                                                                        |
| (0.5) | (1.2) | TRAFFIC LIGHT at intersection with PA Route 924. CONTINUE STRAIGHT on US Route 309.                                                                                                                              |
| (0.2) | (1.4) | Crest of Church Hill (Council Ridge) at Hazleton-St. Joseph's Medical Center (to left). This anticlinal Mauch Chunk-Pottsville ridge separates the Big Black Creek (north) and Hazleton (south) basins.          |
| (0.3) | (1.7) | TRAFFIC LIGHT at W. Diamond Street. CONTINUE STRAIGHT AHEAD on US Route 309.                                                                                                                                     |
| (0.4) | (2.1) | TRAFFIC LIGHT at Broad Street (PA Route 93). CONTINUE STRAIGHT on US Route 309.                                                                                                                                  |
| (2.0) | (4.1) | Abandoned Hazleton Brick Company works to right at T-intersection with Hazleton By-Pass. For over 50 years (ending in 1980), the plant manufactured bricks from red and olive mudstone in the upper Mauch Chunk. |
| (0.2) | (4.3) | Crest of Pismire Ridge, the anticlinal highland separates the Hazleton (north) and Honeybrook (south) basins.                                                                                                    |

- (0.6) (4.9) To left are the skeletal ruins of old Beaverbrook Coal Company breaker.
- (0.2) (5.1) Refuse bank of Beaverbrook Colliery to left.
- (0.1) (5.2) Enter Carbon County.
- (0.1) (5.3) Village of Audenried, site of two of the notorious Molly Maguire murders in the 1860's.
- (0.2) (5.5) Concrete wall on left marks former entrance to the Spring Brook Section of the Spring Mountain Colliery (Lehigh Valley Coal Company).
- (0.2) (5.7) Enter Schuylkill County. Abandoned Audenried Breaker of Beltrami Enterprises stands amid vast wasteland of mine refuse to right.
- (0.3) (6.0) Enter Borough of McAdoo.
- (0.1) (6.1) TRAFFIC LIGHT. CONTINUE STRAIGHT on US Route 309.
- (0.1) (6.2) TRAFFIC LIGHT. CONTINUE STRAIGHT.
- (0.7) (6.9) To right are alluvial fining-upward cycles in the upper member of the Mauch Chunk Formation near the crest of Spring Mountain (Station 5 of Figure 82).
- (0.3) (7.2) Ahead is the Silver Brook basin and the nearly completed cogeneration plant of Northeastern Power Company (NEPCO). Though topographically similar to basins in the Eastern Middle field and often included with them, the Silver Brook basin is actually a small outlier of the Western Middle field.
- (0.3) (7.5) BEAR RIGHT onto long entrance ramp to I-81.
- (0.4) (7.9) BEAR LEFT onto I-81 South at fork in entrance ramp.
- (0.7) (8.6) To left is a view west down the axis of the anticlinal Ringtown Valley, a typical Mauch Chunk valley rimmed by Pottsville ridges.
- (0.3) (8.9) MERGE with I-81 South.

\*\*\*\*\*

- 0.6 12.4 Ledges of Pottsville conglomerate can be seen on distant ridge to left.
- 0.2 12.6 Cross bridge over Lofty Creek valley.
- 0.4 13.0 Long cut mainly in Tumbling Run Member of Pottsville Formation.
- 1.5 14.5 Long cut in upper member of the Mauch Chunk Formation and Tumbling Run and Schuylkill Members of the Pottsville Formation starting at underpass.
- 0.4 14.9 BEAR RIGHT onto exit ramp at Interchange 38 (Delano). A pre-Illinoian ice margin wrapped around the synclinal nose of the Western Middle Anthracite field and deposited till at Delano. It spread outwash through a sluiceway in the low ridge ahead and down Mahanoy Creek.
- 0.3 15.2 Cut exposing south-dipping contact of Sharp Mountain and Schuylkill Members of the Pottsville Formation. Note typical development of frost-riven ledges and "tors" in Sharp Mountain Member.
- 0.1 15.3 STOP SIGN. TURN LEFT and pass under I-81.
- 0.1 15.4 TURN LEFT onto entrance ramp to I-81 North.
- 0.2 15.6 MERGE with I-81 North.
- 0.2 15.8 STOP buses just beyond bridge at beginning of long highway cut. Debark. (Buses proceed north to parking lot at Scenic Area).

STOP 8A. NORTHBOUND I-81 CUT NEAR DELANO: STRATIGRAPHY AND SEDIMENTOLOGY OF THE UPPER MEMBER OF THE MAUCH CHUNK FORMATION AND THE POTTSVILLE FORMATION (PART 1)

LEADERS: Jon D. Inners and Leonard J. Lentz

The deep cut on the northbound lane of I-81 northeast of Delano (Figure 63) is situated at the east end of the Western Middle Anthracite field between the Delano anticline to the north and the complexly faulted Mahanoy syncline to the south (Wood and Arndt, 1973). It exposes a continuous section from the uppermost part of the upper member of the Mauch Chunk Formation to the lower part of the Schuylkill Member.

A few of the questions we will try to address at this STOP include:

1. What depositional environments are represented by the four main packets of rocks exhibited here?
2. What type of events - climatic, tectonic, etc. - do the prominent conglomeratic beds represent?
3. How much consideration should be given to "mapability" in defining formations and members at well exposed stratigraphic sections?

Because of the traffic hazard, we will not be crossing to the west side of the interstate where the section was actually measured. This should create no great problem because most of the features of interest can be found on the east side (albeit not at exactly the same stratigraphic positions) and some of the larger ones are best viewed from a distance anyway. BE EXTREMELY CAREFUL!

The stratigraphic succession in the Delano cut is shown in Figure 64. Appendix A gives the detailed description on which this column is based. Figure

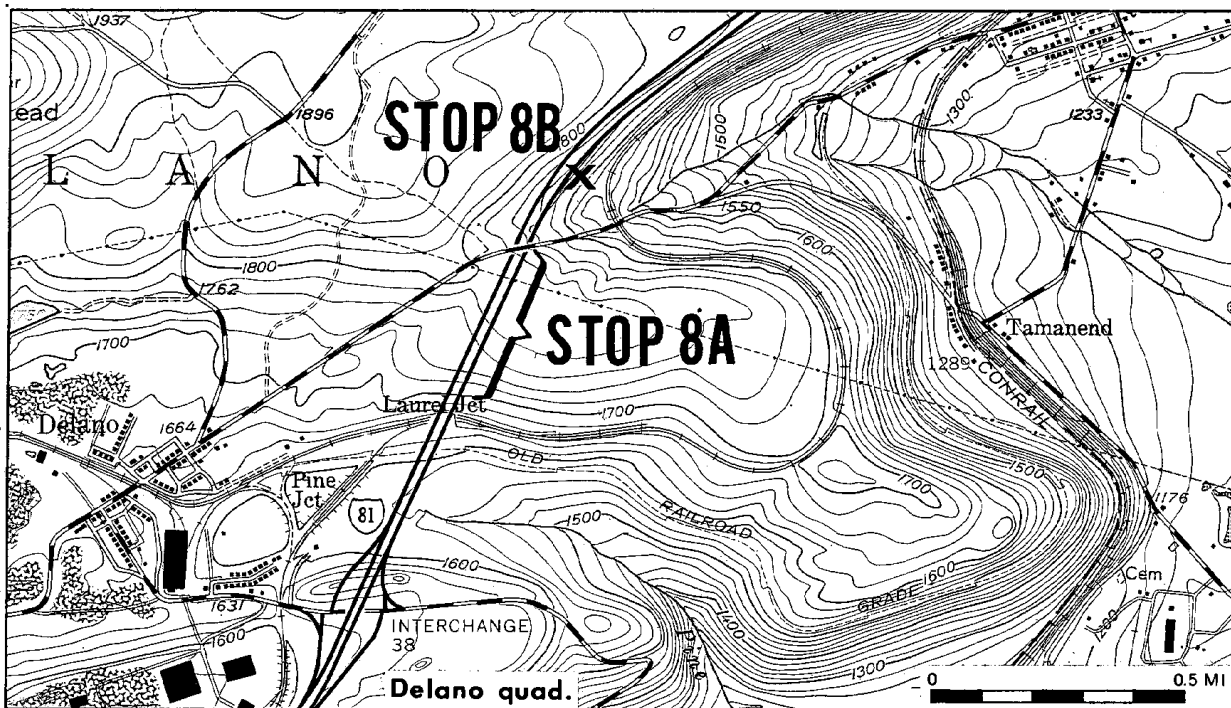
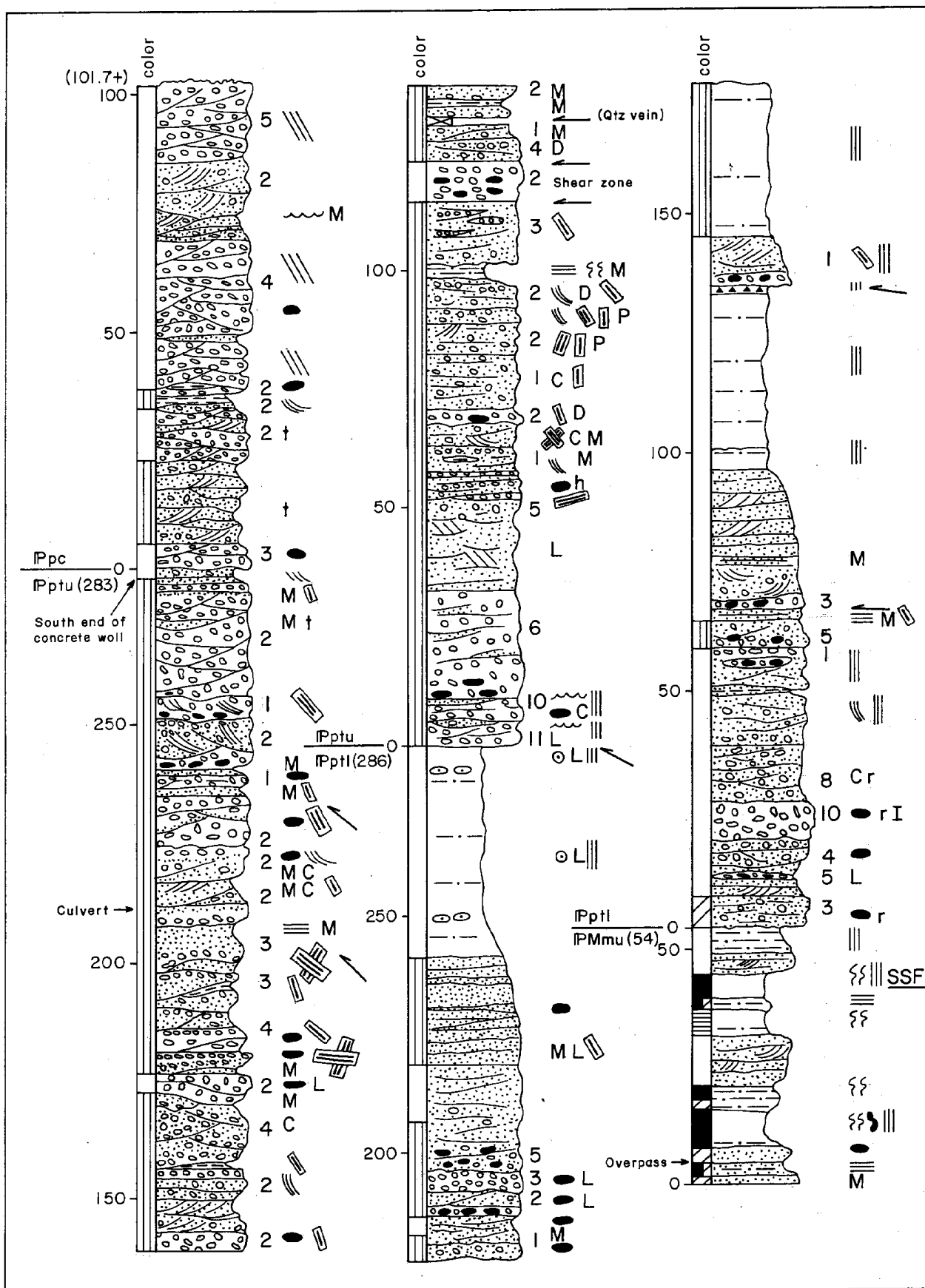


Figure 63. Location map for STOPS 8A and 8B.



65 is a sampling of thin section photomicrographs made from rocks in the cut. For logistic and time-saving reasons, we will examine the section from top to bottom.

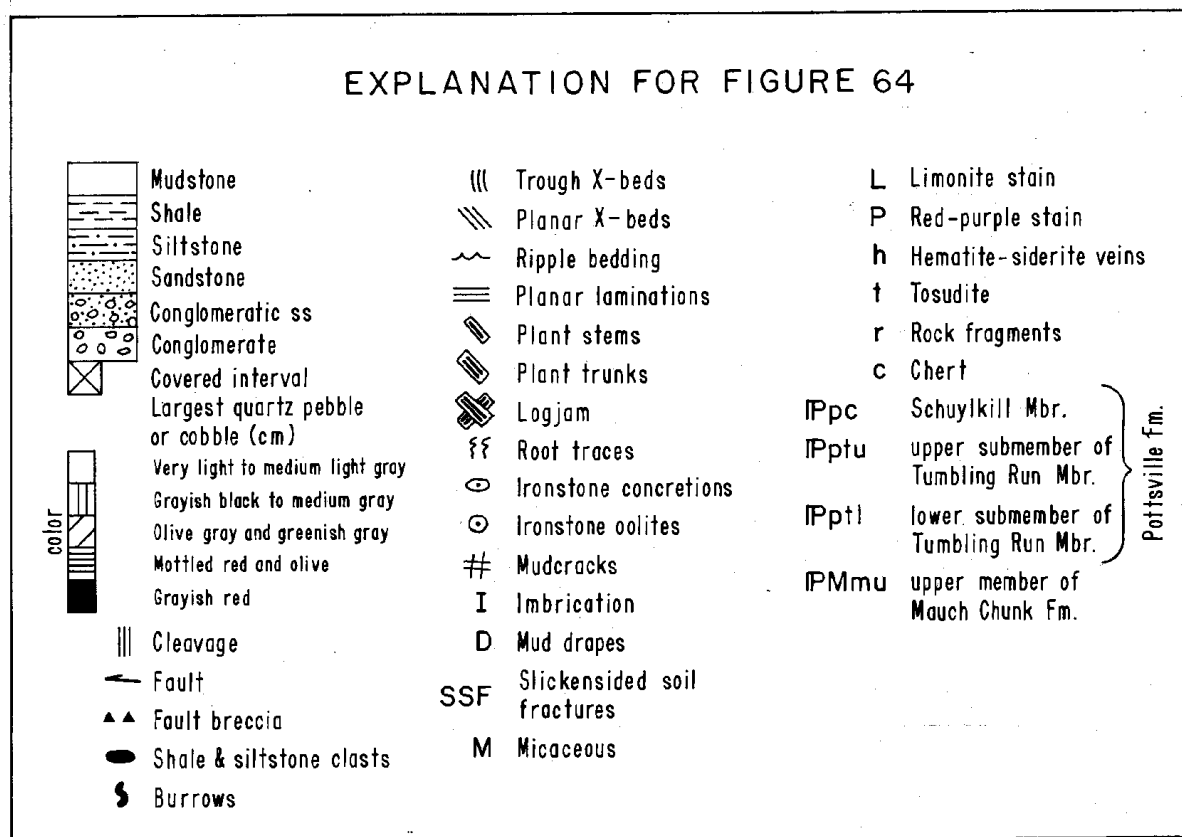
## POTTSVILLE FORMATION (part)

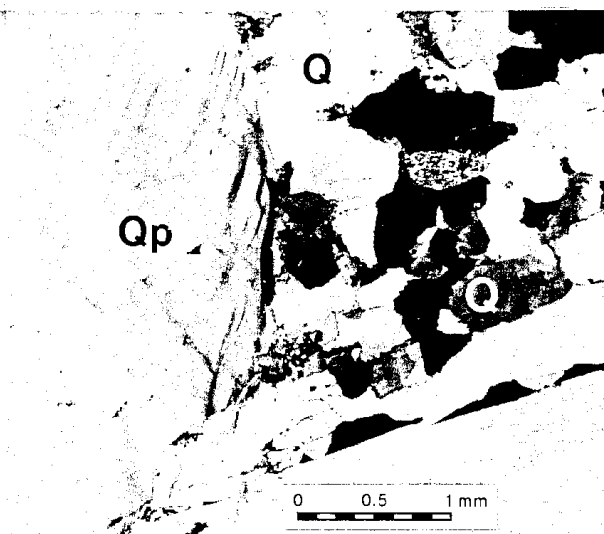
According to Wood and Arndt (1973), the Pottsville Formation in the Delano quadrangle is approximately 800 feet thick. On a composite stratigraphic section diagram, they indicate the following thicknesses for the three members: Tumbling Run, 460 feet; Schuylkill, 245 feet; and Sharp Mountain, 95 feet. Presumably these members are defined in the same manner as at their type section at Pottsville (Wood and others, 1956). Through detailed measurement of this section and reconnaissance work elsewhere in the vicinity of Delano, however, we have found that the U.S.G.S. workers were not as consistent as they claimed to be in placing the base of the Pottsville at the top of the highest redbed in the Mauch Chunk. The problems to which this gives rise are discussed in some detail below and again at Stop 12.

## Schuylkill Member (part)

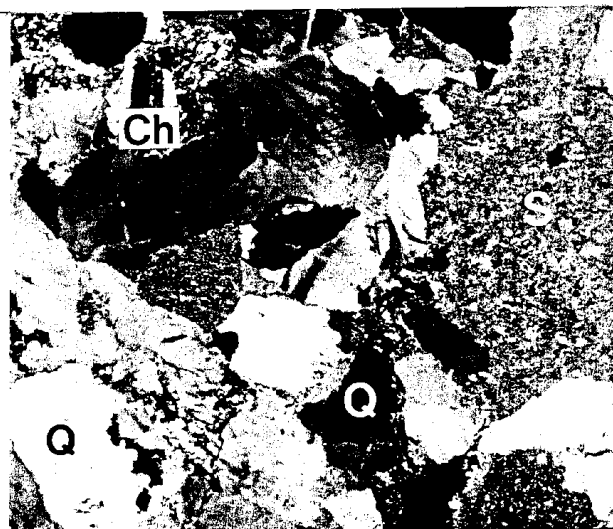
Wood and Arndt (1973) indicate that the average thickness of the Schuylkill Member in this area is about 245 feet. It is reportedly separated from the overlying Sharp Mountain Member (95 feet thick) by a "goose-egg" conglomerate

◀ Figure 64. Stratigraphic column of the uppermost Mauch Chunk and lower Pottsville Formations as exposed at STOP 8A.

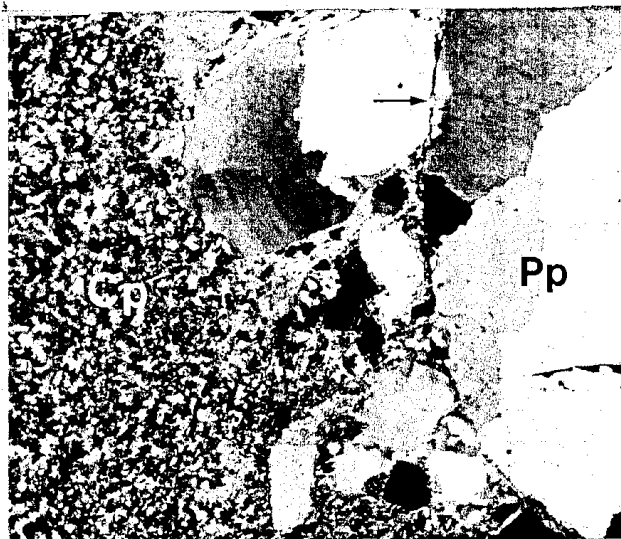




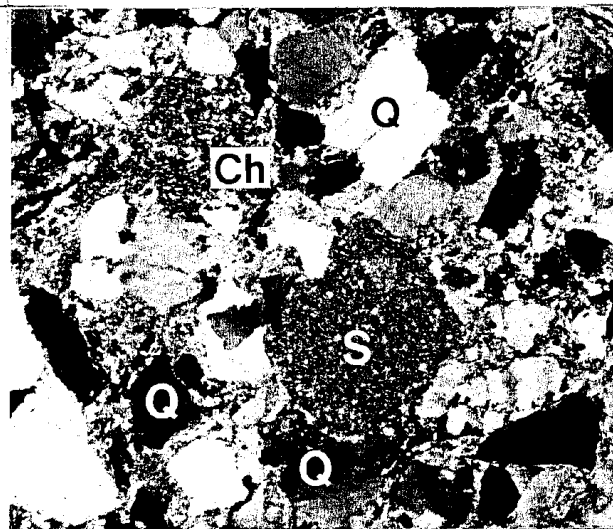
a



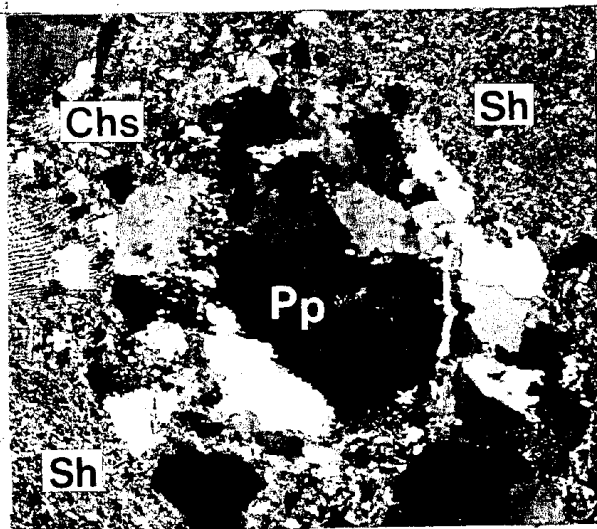
b



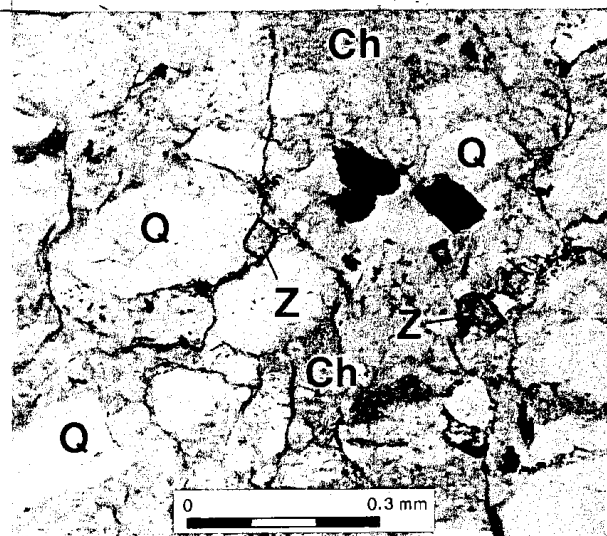
c



d



e



f

having cobbles to 10 cm in diameter. Somewhat less than half of the total thickness of the Schuylkill is exposed in the Delano cut.

The Schuylkill (and the overlying Sharp Mountain) formed on a vast braidplain that spread northward and northwestward from tectonic highlands in what is now the southeastern Pennsylvania Piedmont (Meckel, 1967). The mineralogical maturity of these rocks is probably due mainly to a deeply weathered, quartz-rich sourceland. Their "whiteness" and relative paucity of fine carbonaceous material, when compared to the same rocks in the Pottsville area, probably reflects the same paleoenvironmental influence that caused a decrease in the number of sub-Buck Mountain coal seams to the north and northeast.

102 to 0 feet

The bulk of the lower Schuylkill consists of medium- to thick-bedded, moderately sorted, light-gray, oligomict quartz-pebble conglomerate. Most of the pebbles are rounded to well rounded and 2 cm or less in diameter. The overwhelming percentage of pebbles are white vein-quartz, but a few are dark gray chert, quartzite, or shale.

The conglomerates and conglomeratic sandstones are organized into half-a-dozen fining-upward bar or channel sequences 15 to 25 feet thick. At the base of each "cycle" is a distinct erosion surface. The cycle between 22 and 35 feet is disconformably draped by dark gray shale, presumably the remnant of car-

- ◀ Figure 65. Photomicrographs of thin sections from STOP 8A (b, c, d, and e same scale as a).
- a. Oligomict conglomerate from the top of the upper submember of the Tumbling Run (unit 86 of Appendix A), showing angular to subangular monocrystalline quartz grains (Q) and rounded, "cleaved" quartz pebble (Qp). Note sparse illite matrix (i). Crossed nicols.
  - b. Conglomeratic quartz-lithic arenite from the upper submember of the Tumbling Run (unit 70), showing monocrystalline quartz grains (Q), siltstone grains (S), and chlorite (Ch). Crossed nicols.
  - c. Polymict conglomerate from the upper submember of the Tumbling Run (unit 43), showing polycrystalline quartz (Pp) and silty claystone (Cp) pebbles. Note sutured grain boundary at top right (arrow). Crossed nicols.
  - d. Lithic-quartz arenite from the lower submember of the Tumbling Run (unit 21), showing monocrystalline quartz grains (Q), burrowed or rooted(?) siltstone clast (S), and interstitial chlorite (Ch). Crossed nicols.
  - e. Polymict conglomerate from the lower submember of the Tumbling Run (unit 14), showing polycrystalline quartz pebble (Pp), silty shale clasts (Sh), and matrix of chlorite and silt (ChS). Note fracture filling of quartz pebble and stretched appearance of composite grains. Crossed nicols.
  - f. Quartz-lithic wacke from the upper member of the Mauch Chunk (unit 6), showing monocrystalline quartz grains (Q) and heavy minerals (opaques and zircon [Z]) in a matrix of chlorite (Ch). Plane-polarized light.

bonaceous mud deposited in a cut-off "anabranch" or on top of a bar during a falling-water stage (Smith, 1970).

Crossbedding style is closely related to grain size. Wedge-shaped, dominantly planar sets 5 to 10 feet thick characterize the thick conglomerate units and were probably formed by downcurrent addition of sediment of the slip faces of migrating transverse bars (Smith, 1971). Trough-crossbed sets to 1.5 feet thick in sandstone and conglomeratic sandstone may represent the migration of trains of irregularly crested dunes in swales and on the surfaces of longitudinal bars (Smith, 1970).

Tosudite (see Smith and Barnes, this volume) is a peculiar mineralogical constituent of the Schuylkill. It occurs as (intermittently) bluish blebs in the matrix of several conglomerate beds in the lower 30 feet (and also in a conglomerate about 10 feet below the top of the upper Tumbling Run).

### Tumbling Run Member

The Tumbling Run Member is 569 feet thick at the I-81 cut and is readily divisible into an upper, dominantly carbonaceous conglomerate interval (283 + feet thick) and a lower olive-gray conglomerate, sandstone, and mudstone interval (286 + feet). Wood and Arndt (1973) mapped the upper part only as Tumbling Run, the lower part being included in the upper member of the Mauch Chunk Formation. Although this is contrary to their oft-stated stratigraphic definition of the Pottsville Formation and the Tumbling Run Member (Wood and others, 1956; Wood and others, 1969), the widespread, gray cobble conglomerate at the base of the upper interval is a much more consistent and readily mappable contact than the highest redbed in the transition zone.

### Upper Submember

Except for its higher "carbon" content and generally lower quartz content, the upper half of the Tumbling Run Member is similar to the Schuylkill Member. Both are dominantly braided river deposits, the former having accumulated under slightly higher, more erratic streamflow conditions.

### 283 to 155 feet

The upper 127 feet of the upper Tumbling Run consists of numerous fining- or coarsening-upward conglomeratic channel and bar sequences 10 to 25 feet thick. Many of these "cycles" have thin, quartz-pebble lag deposits at the top and dark-gray-shale intraclasts at the base.

The conglomerates and sandstones in the upper few feet of this interval are considerably more quartz-rich than the rest of the unit (Figure 65a). (In fact these rocks might better be included in the Schuylkill.) The bulk of this upper part of the upper Tumbling Run is composed of polymict conglomerates and quartz-lithic sandstones (Figure 65b). Polycrystalline quartz grains are common, and many of the monocrystalline grains are strained (Figure 65b) or exhibit closely spaced microfractures (Figure 65a). Mica and siltstone clasts are common in the "dirtier" rocks.

Bedding within the depositional sequences is dominantly planar, but lenticular. Trough crossbedding similar to that in the overlying Schuylkill is

fairly common toward the tops of some of the sandier units, but the spectacular planar crossbeds seem to be absent (Wood and others, 1969).

Plant stems and trunks are common throughout this interval. Most occur as thin carbonaceous films on the surfaces of limonite- (yellowish-brown) or hematite- (purplish) stained casts. Prominent log jams can be seen at about 176 and 200 feet.

Subhedral to euhedral, pale-yellow stained, quartz crystals to 3 cm long coat tensional joints at about 238 and 233 feet.

#### 155 to 101 feet

This interval is depositionally similar to the overlying one, but contains two dark-gray, fossiliferous (plants) silty shale beds (155 and 135 feet). Neither appears to be rootworked, so correlation with any particular coal horizon is unwarranted.

Several bed-parallel, silicified faults (e.g., 131 feet) and a prominent quartz-mineralized shear zone (114 to 123 feet) may mark the position of the North Park Place fault of Wood and Arndt (1973).

#### 101 to 98 feet

This prominent carbonaceous shale interval may be at the position of the Lykens Valley No. 5 coalbed. Strap-root fragments are common in the root-worked zone at the top.

#### 98 to 52 feet

The most notable characteristic of these beds is the abundance of carbonaceous, iron-stained stem and trunk impressions. A log jam several feet thick occurs at about 63 feet.

Trough crossbeds are especially well developed at 64 feet and between about 94 and 98 feet.

#### 52 to 0 feet

The basal polymict conglomerate zone of the upper Tumbling Run is the coarsest interval in the I-81 cut and one of the coarsest in the entire Pottsville Formation of the Delano area (Wood and Arndt, 1973). Quartz, quartzite, sandstone and chert cobbles to 10 cm are common in the basal 10 feet (Figure 66). The upper 42 feet consists of a thick fining-upward sequence capped by a much thinner coarsening-upward zone that grades into the carbonaceous beds above 52 feet; the conglomerate at the base of this interval is composed predominantly of polycrystalline quartz and sedimentary-rock clasts (Figure 65c) and contains several dark-gray shale or argillite clasts to 15 cm in diameter.

Ripples with a wave length of 3 cm and a wave height of about 2 mm can be seen in the lenticular sandstone beds that are fused to the two basal 5-foot-conglomerates of this interval. The crests trend about N60E.

A coarse fracture cleavage perpendicular to bedding cuts the basal conglomerate units (Figure 67). At the top of the sandstone drapes, the bedding-

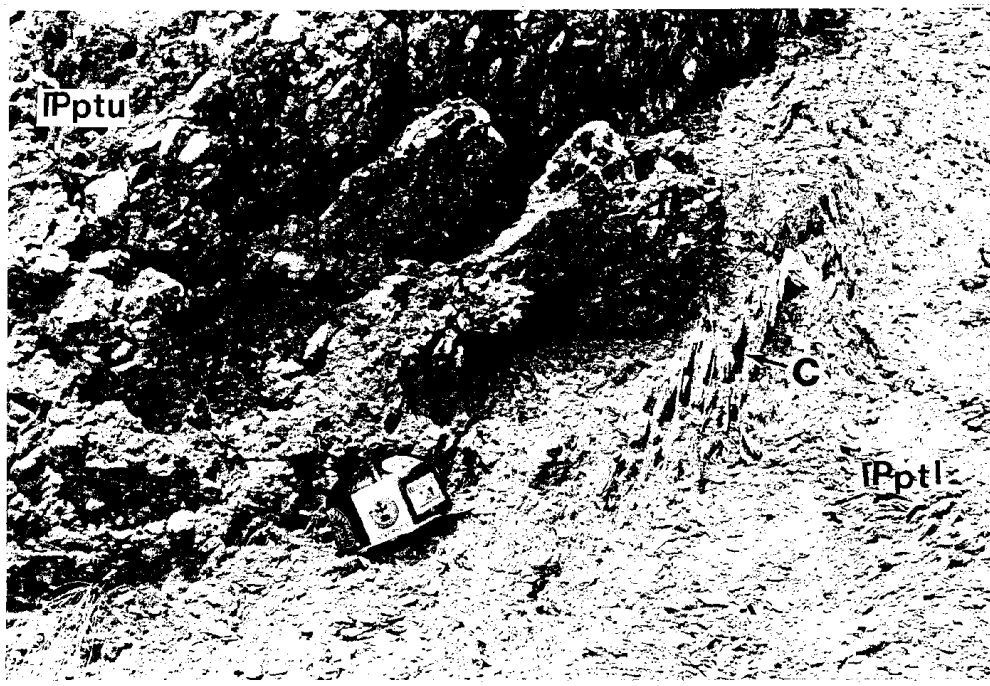


Figure 66. Cobble conglomerate and unconformity at the base of the upper Tumbling Run (unit 39). Note cleavage (c) in the mudstone underlying the conglomerate.

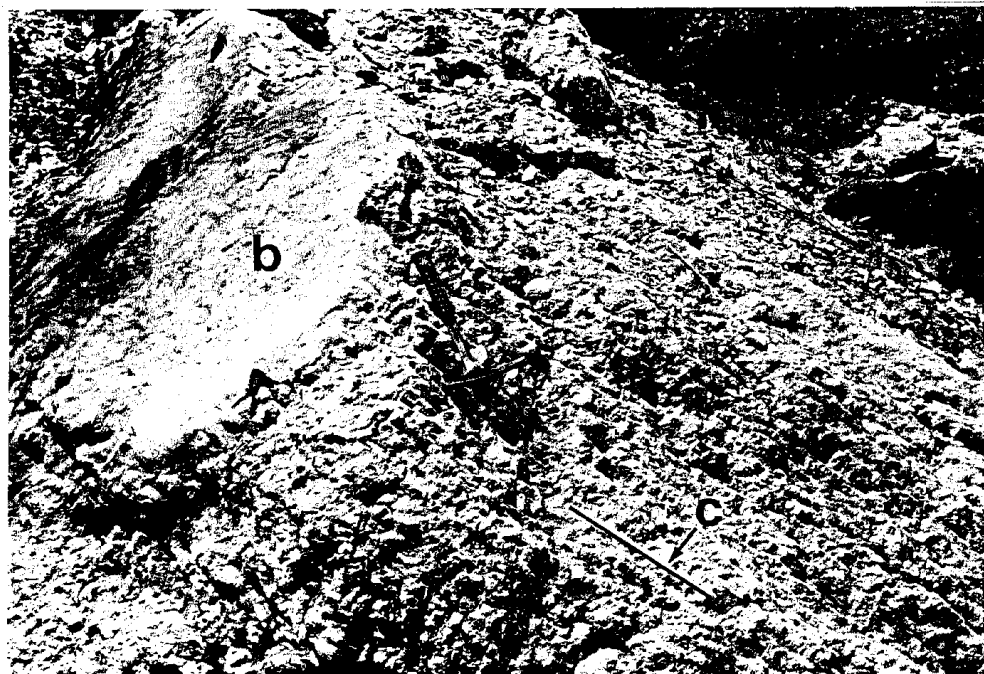


Figure 67. Fracture (pressure-solution?) cleavage in conglomerate of the upper submember of the Tumbling Run (unit 39). Note (rippled) sandstone drape at top. Hammer is 11 inches long.

cleavage intersections are locally parallel to the ripple crests noted above.

By all appearances, the basal contact of the upper Tumbling Run is an unconformity (Figure 66). If this is the same unconformity that can be seen at Stop 12 (and at several localities between here and there), then the upper Tumbling Run wedges out above it.

#### Lower Submember

The lower half of the Tumbling Run is apparently more closely related to the Mauch Chunk than to the Pottsville, and except for the fact that previous workers have included similar rocks with the Pottsville at the type and reference sections (White, 1900; Wood and others, 1956), this interval would be assigned to the underlying formation. Indeed, as noted above, Wood and Arndt (1973) did map our lower Tumbling Run as part of their upper member of the Mauch Chunk Formation. Because redbeds do appear intermittently in equivalent rocks from Interchange 39 (McAdoo) north along I-81, we include these beds in the Mauch Chunk from that point north (see Figure 82).

The sandstones and conglomerates in this lower submember (and the exposed sandstones in the uppermost Mauch Chunk) are less textually mature than are overlying rocks. An abundance of chlorite in the matrix may account for the pronounced olive-gray weathering cast of the coarser clastics. Heavy minerals (e.g. zircon and tourmaline) are much more common than in the upper Tumbling Run and Schuylkill. The gray to olive-gray mudstones and siltstones are similar to the fine-grained clastics of the upper Mauch Chunk and seem to differ from the latter mainly in never reaching a "ferric" oxidation state.

These rocks probably represent deposition on a high-gradient alluvial plain traversed by rivers intermediate between low-sinuosity meandering and braided. Reconnaissance investigation of nearby sections indicates that some of the conglomerates are widespread and can be correlated over many square miles. This suggests that the coarse-grained units may be tectonically or climatically controlled braided river deposits, rather than the basal parts of true fining-upward meandering river cycles.

#### 286 to 195 feet

A thick fining-upward alluvial cycle (?) constitutes the upper part of the lower Tumbling Run. The basal conglomeratic sandstone contains a few 5-cm quartz pebbles and many 1-cm, dark-gray shale clasts. Within the upper silty mudstone and claystone, bands of grayish-black ironstone (siderite-hematite-quartz) concretions occur at 249 and 281 feet. One-mm oolites of similar composition are scattered through this 44 ( $\pm$ )-foot, fine-grained sequence.

Several veins composed of milky quartz and grayish-black siderite-hematite-quartz (R. C. Smith, II, personal communication, 1987) cut the lower sandstone.

#### 195 to 177 feet

This is a prominent, limonite-stained conglomeratic interval containing a profusion of dark-gray shale intraclasts. The 2.4-foot bed at 187 feet contains flattened, randomly oriented shale clasts ranging from 2 to 30 cm in diameter. Some of the shale clasts between 177 and 181 feet are burrowed and contain quartz pebbles.

These beds probably represent several thin, stacked channel and bar sequences in a thalweg that persisted into the distinctly fining-upward interval above 195 feet.

#### 177 to 67 feet

This interval contains two thick fining-upward alluvial cycles (?). Both grade from quartz-pebble conglomerate containing large (8 to 14 cm) shale intraclasts through trough-crossbedded, medium-grained to pebbly sandstone into medium-gray, light-olive-weathering, intensely cleaved mudstone. A 1.5-foot thick fault zone composed of brecciated mudstone cemented by quartz separates the two cycles (at 136 feet). The basal contact of the lower cycle is also a fault surface.

#### 67 to 0 feet

At the base of the lower Tumbling Run is a thick sequence of medium-light-gray, light-olive-gray weathering, polymict conglomerates and conglomeratic sandstones containing a prominent cobbly bed (clasts to 10 cm) between 19 and 26 feet. Pebble and cobble lithologies include vein quartz, black chert, jasper, dark-gray quartzite, and siltstone. Dark-gray shale intraclasts to 8 cm or more are common in the lower 25 and upper 15 feet.

The conglomerates and sandstones in this interval are poorly sorted and contain abundant lithic clasts (Figures 65d and 65e). Chlorite is common in the matrix and accounts for the olive-gray weathering color.

A distinctive lens of quartz-intraclast conglomerate at 11 feet may contain fragments (to 15 cm) of hard, light gray argillite that resembles the "flint clays" of the bituminous fields. Some of the larger argillite masses may be "sedimentary diapirs" squeezed into the bed during loading.

The contact with the upper member of the Mauch Chunk is unconformable and may have as much as 5 feet of erosional relief. Unlike the unconformity at the base of the upper Tumbling Run, however, this hiatus seems to be of only local significance and represents merely erosion beneath a typical high-gradient alluvial cycle.

#### Mauch Chunk Formation (part)

The top of the Mauch Chunk Formations is here drawn at the base of the massive lower Tumbling Run conglomerate in near conformity with its position at the Pottsville type and reference sections where the contact is defined as the top of the highest redbed (White, 1900; Wood and others, 1956). At this stop the first redbed occurs 5 to 10 feet below this lower Tumbling Run conglomerate, but to the north redbeds appear almost haphazardly within the interval here called lower Tumbling Run (Figure 82), sometimes occurring less than 50 feet below the upper Tumbling Run conglomerate and at other times considerably lower in the section. This alone indicates that use of a color boundary to define mappable formations and members in the Mauch Chunk-Pottsville transition is untenable.

## Upper member (part)

The upper member of the Mauch Chunk, as mapped by Wood and Kehn (1973), is approximately 500 feet thick and contains two cobble conglomerate zones, one at the base and the other in the middle. Since they included what is here called the lower submember of the Tumbling Run in the Mauch Chunk, it is unclear just exactly how thick the "Mauch Chunk part" of the transition zone really is in this area. Presumably the middle cobble-conglomerate shown on the "composite stratigraphic section" of Wood and Arndt (1973) equates with the basal conglomerate of the lower Tumbling Run as defined here. This would mean that there remains only 200 to 250 feet of the upper member below what is exposed in the I-81 cut.

The rocks of the upper member are arranged in distinct fining-upward cycles that probably formed from the deposits of meandering rivers.

54 to 0 feet

The uppermost part of the Mauch Chunk Formation here consists of three fining-upward alluvial cycles (each 10 to 20 feet thick), only the middle one being complete. The basal channel (or bar) part of each cycle is very fine-to fine-grained, light-olive-gray to grayish-green sandstone, and the upper over-bank part is typically grayish-red, rootworked mudstone. The complete cycle that begins at 21 feet has 2 to 3 feet of erosional relief at the base.

The Mauch Chunk sandstones, like those in the lower Tumbling Run, are characterized by a high chlorite content, submaturity, and a relatively high heavy mineral content (Figure 65f). They range from quartz-lithic arenites to lithic wackes.

Slickensided-soil-fractures (Gray, 1984) are well developed in the red mudstone between 44 and 39 feet. These structures are presumably slip surfaces that formed in seasonally wet/dry vertisols by differential expansion of clays.

At conclusion of STOP 8A, continue walking north along I-81, to Scenic Area parking lot.

**STOP 8B. I-81 SCENIC AREA: PHYSIOGRAPHY AND GLACIAL GEOLOGY  
BETWEEN THE WESTERN MIDDLE AND SOUTHERN ANTHRACITE FIELDS,  
NORTH OF TAMAQUA**

**LEADER: Duane D. Braun**

This Scenic Area affords a splendid view southeastward from the rim of the Western Middle field across the Quakake Valley toward Broad Mountain and the bounding ridges along the north side of the Southern Anthracite field (Figure 68).

## Physiography

The Little Schuylkill lowland (Quakake Valley) immediately below the overlook is eroded from the Mauch Chunk redbeds as they wrap around the plunging nose of the Broad Mountain anticlinal ridge. Broad Mountain is underlain by resistant sandstone and conglomerate of the Pocono Formation and the upper mem-

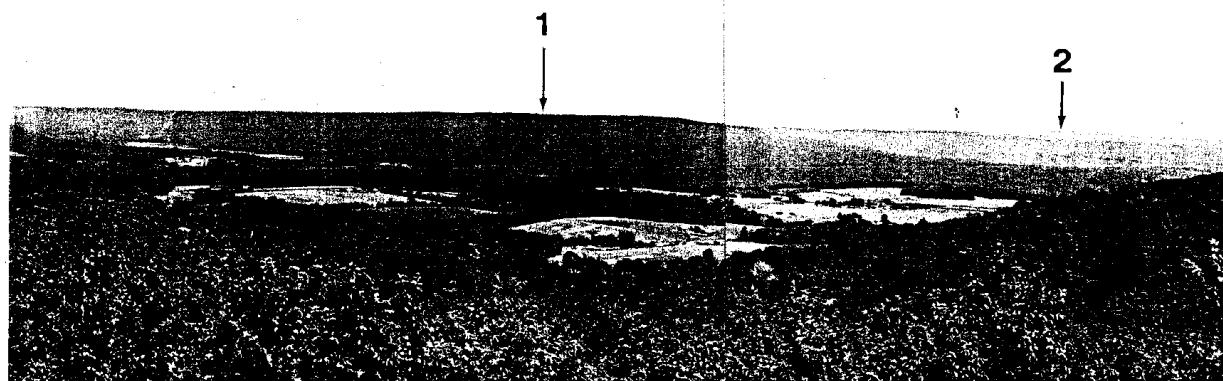


Figure 68. View southeastward from the scenic overlook at STOP 8B. 1 = Broad Mountain; 2 = Locust-Nesquehoning Mountain.

bers of the Catskill Formation. Across the lowland is the scarp face and knobby crest of homoclinal Locust-Nesquehoning Mountain. That ridge is underlain by the Pottsville conglomerate on the northwest limb of the Southern Anthracite synclinorium.

#### Glacial geology

The limit of pre-Illinoian glaciation is placed at about this site. Ice wrapped around the ridge on which we stand, burying the Ringtown lowland to the northwest and the Little Schuylkill lowland immediately below (Figures 1 and 2). Till and outwash mark the margin at Delano 1 mile (1.6 km) southwest of here. Ice impounded a lake in the western most end of the Little Schuylkill lowland. The lake drained south over a 1,400-foot (427 m) col across Locust Mountain and into the Southern Anthracite field. Glacial lake clays have been recovered from a borehole in the lowland to the north of the col. The margin of the ice is marked by a local drainage derangement of Locust Creek where 65+ feet (20+ m) of sand and gravel blocked the preglacial course of the creek. The pre-Illinoian margin crosses Locust Mountain a few miles west of Tamaqua and reached to Tuscarora in the Southern Anthracite field. Outwash extends from there down the Schuylkill River valley towards Pottsville.

- |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-----|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.6 | 16.4 | LEAVE STOP 8B.                                                                                                                                                                                                                                                                                                                                                                                                               |
| 0.1 | 16.5 | MERGE with I-81 North and retrace route back to Interchange 41.                                                                                                                                                                                                                                                                                                                                                              |
| 0.3 | 16.8 | Tumbling Run Member of Pottsville Formation exposed on both sides of road.                                                                                                                                                                                                                                                                                                                                                   |
| 0.4 | 17.2 | Another view of NEPCO cogeneration plant in distance to right.                                                                                                                                                                                                                                                                                                                                                               |
| 0.1 | 17.3 | Long cut in Tumbling Run Member of Pottsville Formation (Station 2 of Figure 82).                                                                                                                                                                                                                                                                                                                                            |
| 1.1 | 18.4 | Beginning of long cut exposing folded and faulted Pottsville/Mauch Chunk transition strata to right. The massive conglomerate at the south end is the same unit that occurs in the middle of the Tumbling Run (base of upper submember) at Stop 8. The siltstone-and-mudstone-bearing sequence below is equivalent to the lower submember of the Tumbling Run, but here it contains red mudstones. (Station 3 of Figure 82). |

|     |      |                                                                                                                                                                                                                                                                                                                                             |
|-----|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.8 | 19.2 | Conglomerates at north end of same cut (to right) are equivalent to those in the lower Tumbling Run at Stop 8A, but lie below the highest red bed of the Mauch Chunk Formation.                                                                                                                                                             |
| 0.5 | 19.7 | Spring Mountain cut.                                                                                                                                                                                                                                                                                                                        |
| 1.4 | 21.1 | Enter Luzerne County.                                                                                                                                                                                                                                                                                                                       |
| 1.2 | 22.3 | To the right is the fine coal preparation plant of the Beaver Brook Coal Company. Old strippings are in the northern part of the Honeybrook basin.                                                                                                                                                                                          |
| 0.4 | 22.7 | Upper member of Mauch Chunk Formation exposed at hinge of Pismire Ridge anticline.                                                                                                                                                                                                                                                          |
| 1.6 | 24.3 | Pass under PA Route 924 at Interchange 40.                                                                                                                                                                                                                                                                                                  |
| 0.2 | 24.5 | Cut through dark-gray rocks of the Llewellyn Formation.                                                                                                                                                                                                                                                                                     |
| 1.2 | 25.7 | Valmont Industrial Park (CAN DO) to right.                                                                                                                                                                                                                                                                                                  |
| 0.5 | 26.2 | Cross Black Creek.                                                                                                                                                                                                                                                                                                                          |
| 0.5 | 26.7 | BEAR RIGHT onto exit ramp at Interchange 41 (West Hazleton).                                                                                                                                                                                                                                                                                |
| 0.2 | 26.9 | Pottsville/Mauch Chunk contact to right (Stop 12).                                                                                                                                                                                                                                                                                          |
| 0.1 | 27.0 | STOP SIGN. TURN LEFT onto PA Route 93.                                                                                                                                                                                                                                                                                                      |
| 0.1 | 27.1 | TURN LEFT onto SR 3020 after crossing overpass.                                                                                                                                                                                                                                                                                             |
| 0.7 | 27.8 | On the left are extensive old strippings on lower Llewellyn coals in the area of the old Black Ridge Colliery (East Black Creek Basin). Pre-Illinoian till and stratified drift lie on a striated bedrock pavement in strippings just south of the road.                                                                                    |
| 0.1 | 27.9 | Entrance to the former Sugarloaf Landfill, closed in 1984 after condemnation by DER.                                                                                                                                                                                                                                                        |
| 0.5 | 28.4 | Typical boulder colluvium developed from the Pottsville Formation to the right. The housing development sits on thin colluvium overlying pre-Illinoian till.                                                                                                                                                                                |
| 1.0 | 29.4 | Massive, south-dipping Pottsville conglomerate crops out beneath the powerline to right.                                                                                                                                                                                                                                                    |
| 0.6 | 30.0 | Enter Tomhickon, another former "patch town." To left are strip-pings over the deep workings of the Tomhickon Colliery.                                                                                                                                                                                                                     |
| 0.3 | 30.3 | Intersection with Prospect Road. CONTINUE STRAIGHT AHEAD on SR 3020.                                                                                                                                                                                                                                                                        |
| 0.1 | 30.4 | South-dipping Pottsville conglomerate on right.                                                                                                                                                                                                                                                                                             |
| 0.5 | 30.9 | More exposures of south-dipping Pottsville conglomerate on right.                                                                                                                                                                                                                                                                           |
| 1.0 | 31.9 | Strippings on both sides of road over the old Derringer Colliery workings.                                                                                                                                                                                                                                                                  |
| 0.5 | 32.4 | Trough-crossbedded, plant-bearing conglomerate and sandstone of the Pottsville Formation on right at road bend.                                                                                                                                                                                                                             |
| 0.7 | 33.1 | Cross Black Creek.                                                                                                                                                                                                                                                                                                                          |
| 0.1 | 33.2 | Enter village of Derringer, former site of the Derringer Colliery.                                                                                                                                                                                                                                                                          |
| 0.4 | 33.6 | Enter Fern Glen, named for the former summer home of the Coxe family.                                                                                                                                                                                                                                                                       |
| 0.6 | 34.2 | Y-junction with Twp. Route 305. CONTINUE AHEAD on SR 3020 (right fork).                                                                                                                                                                                                                                                                     |
| 0.9 | 35.1 | TURN LEFT at entrance to Gowen Mine of Coal Contractors, Inc. The mine takes its name from Franklin B. Gowen (1836-1889), President of the Reading Railroad (and its subsidiary, the Philadelphia and Reading Coal and Iron Company) from 1870 to 1884. He was instrumental in crushing the Molly Maguires after the "Long Strike" of 1875. |

At this point, Black Creek (which from its headwaters near Eckley has been flowing mostly parallel to strike) turns a

right-angle bend and leaves the Roberts Run basin through a narrow water gap in the Pottsville conglomerate ridge.  
0.3 35.4 Office and breaker of the Gowen Mine. Buses follow haul road for approximately 1.75 miles to active operations in western part of property.

**STOP 9. GOWEN OPEN-PIT MINE: BEDROCK, SURFICIAL, AND ECONOMIC GEOLOGY**

**LEADERS: William E. Edmunds and Duane D. Braun**

The Coal Contractor's operation at Gowen is of interest both as an example of a rather novel open-pit method of mining anthracite and as the locality where the first thick section of pre-Wisconsinan glacial drift in the Eastern Middle field was discovered (Edmunds and Eggleston, 1984).

**Anthracite geology**

The Gowen Mine lies in the Roberts Run basin between Buck Mountain and South Buck Mountain at the northwest corner of the Eastern Middle field. The structure is relatively simple, consisting of a syncline cut at a low angle to its axis by a north-dipping, high-angle thrust fault (Figure 69).

The cross-sectional shape of the syncline varies considerably along the 2.5-mile (4.0-km) length of the mine. At the eastern end, it is a symmetrical, broad, open structure. Continuing west, the syncline becomes more V-shaped with an oversteepened south limb. This, in turn, changes into a wide, flat-bottomed syncline with abruptly upturned flanks. Locally, the flat bottom is split by a low anticlinal bulge. Near the west end, the syncline becomes fairly tight and oversteepened on the north side. Throughout the length of the syncline, the beds appear to flatten out away from the tighter core of the structure.

The south side of the syncline is cut by a north-dipping, high-angle thrust fault which trends at a low angle to the direction of the synclinal axis. The lowest coal mined in the main part of the syncline is repeated on the south side of the fault. Displacement along this fault plane is approximately 250 feet (75 m).

Surface bedrock in the valley of the Gowen Mine is Pennsylvanian-age Sharp Mountain Member of the Pottsville Formation overlain by Llewellyn Formation. The Sharp Mountain is about 200 feet (60 m) thick and consists mostly of conglomerate and sandstone. It contains a single coal seam, the Alpha, which is mined in the southeast corner of the property. At its thickest point, only the lower 450 feet (137 m) of the Llewellyn Formation is present. The Llewellyn is predominantly conglomeratic sandstone, sandstone, siltstone, and hard shale with about 10 to 15 percent coal. In the main mine, all coals belong to the Llewellyn, with the Buck Mountain seam, by definition, the base of the formation.

Coal seams of the main operation are the Buck Mountain (No. 5), Gamma or Seven-foot (No. 6), Wharton or Skidmore (No. 7), Bottom Mammoth (No. 8), Middle Mammoth (No. 8 1/2) and Top Mammoth (No. 9). Coal seam thicknesses vary considerably, as do intervals between. The Buck Mountain is mostly 7 to 15 feet (2 to 4.5 m) thick. One or more of the members of the Mammoth complex is always present and, in places, they collectively may provide up to 30 feet (9 m) of coal.

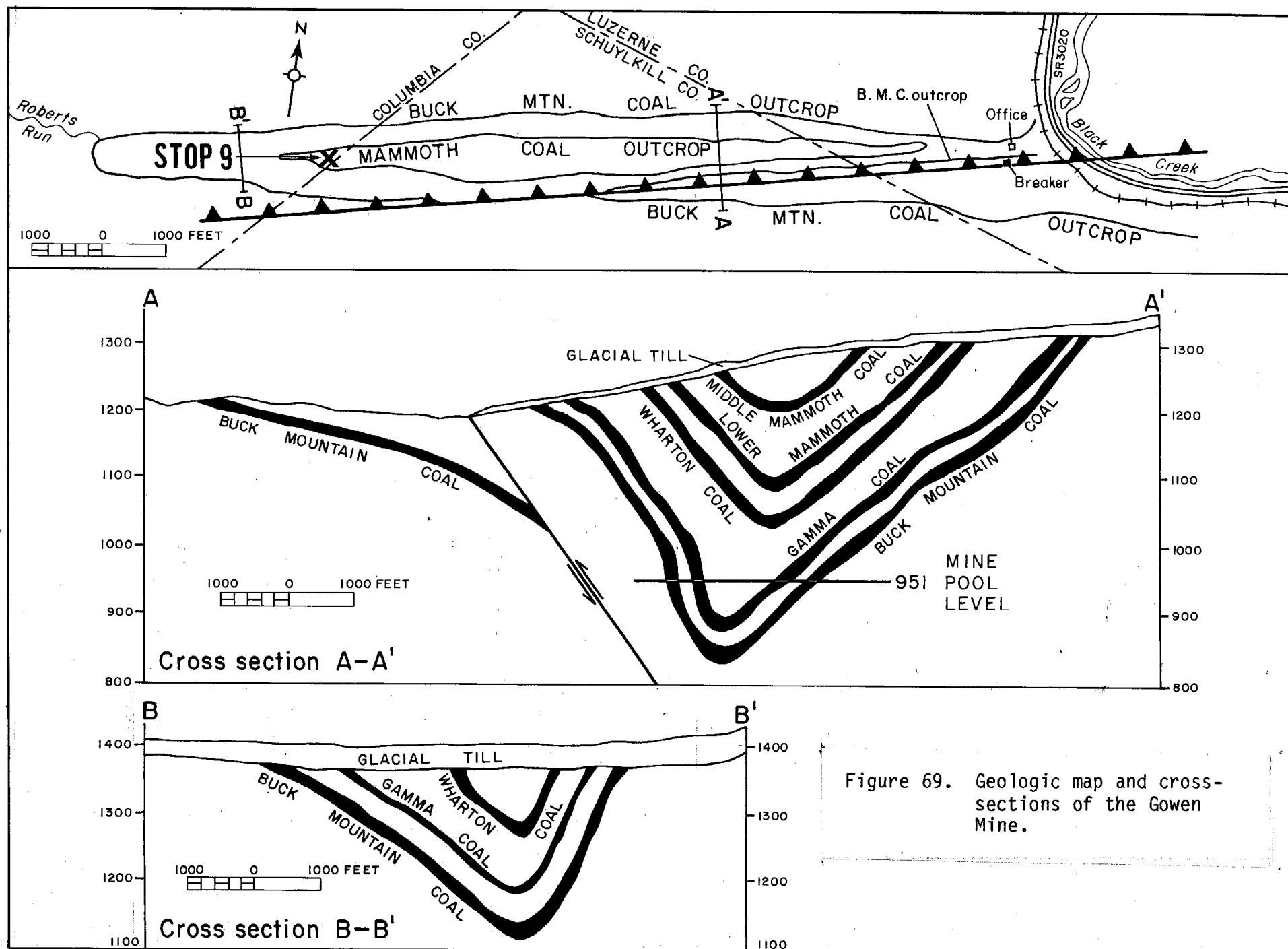


Figure 69. Geologic map and cross-sections of the Gowen Mine.

The effects of tectonic stress upon the relatively incompetent coal was well displayed in the earlier stages of the development of the mine: mass flow of the Buck Mountain seam produced a wedge of coal up to 65 feet (20 m) thick in the bottom of the syncline west of current operations.

The entire basin was deep-mined in the past, although there have been no underground operations for many years. The previous owner stripped out most of the Mammoth complex from the center of the basin as well as some of the Buck Mountain along the flanks. Coal Contractors commenced their mining in late 1982. The present operation began with an initial box cut to the base of the Buck Mountain near the west end of the basin, followed by progressive development east along the synclinal axis.

Coal Contractor's mine is a truck-and-shovel operation in which most overburden removal is done by a Demag hydraulic excavator and carried out of the pit by 80-ton trucks. The coal itself is extracted by smaller equipment. Unlike most anthracite surface mines, where a drag line is used for overburden removal (Stop 11), this piece of equipment is used here mainly for spoil pile redistribution and other specialty purposes. The Gowen mine is one of the most efficiently engineered and operated facilities in the Anthracite area. Production in 1986 was 133,000 tons.

### Glacial geology

The active pit is in the up-plunge southwest end of a topographic and structural basin. As ice retreated northeast across the area, a proglacial lake was impounded between a 1,478-foot-(448-m-) notch near the nose of the syncline and the retreating ice front (Figure 70). The bedrock valley floor is at about 1,300 feet (396 m) near the west end and declines to 1,000 feet (300 m) at Black Creek gap, providing a lake basin 170-470 feet (52-143 m) deep. The lake mostly drained when the ice retreat opened a 1,200-foot- (366-m-) sluice in the col across South Buck Mountain at Nuremburg (Figure 70). Complete drainage occurred when ice recession opened the Black Creek water gap. The basin partly filled with lake sands, outwash, and till from the oscillatory ice front retreat (Figure 71). The deposits are as thick as 100 feet (30 m) in the western half of the valley and thin eastward to nothing at Black Creek gap. The thinning is primarily a result of postglacial erosion working headward from Black Creek gap.

The glacial material is considered to be pre-Illinoian in age for two reasons. First, the margin lies a few miles south (outside) of the late Illinoian border (Figure 70). The late Illinoian margin loops around the Conyngham Valley, 2 miles (3 km) to the north. That margin partly dammed Black Creek at the mouth of the gap at elevation of 960 feet (293 m). This elevation is too low to cause any deposition at the east end of the Gowen strippings. Secondly, the ridges to either side of the basin have been stripped of glacial material and tors have been weathered out of the Pottsville. This degree of weathering and erosion implies more than just Sangamonian weathering.

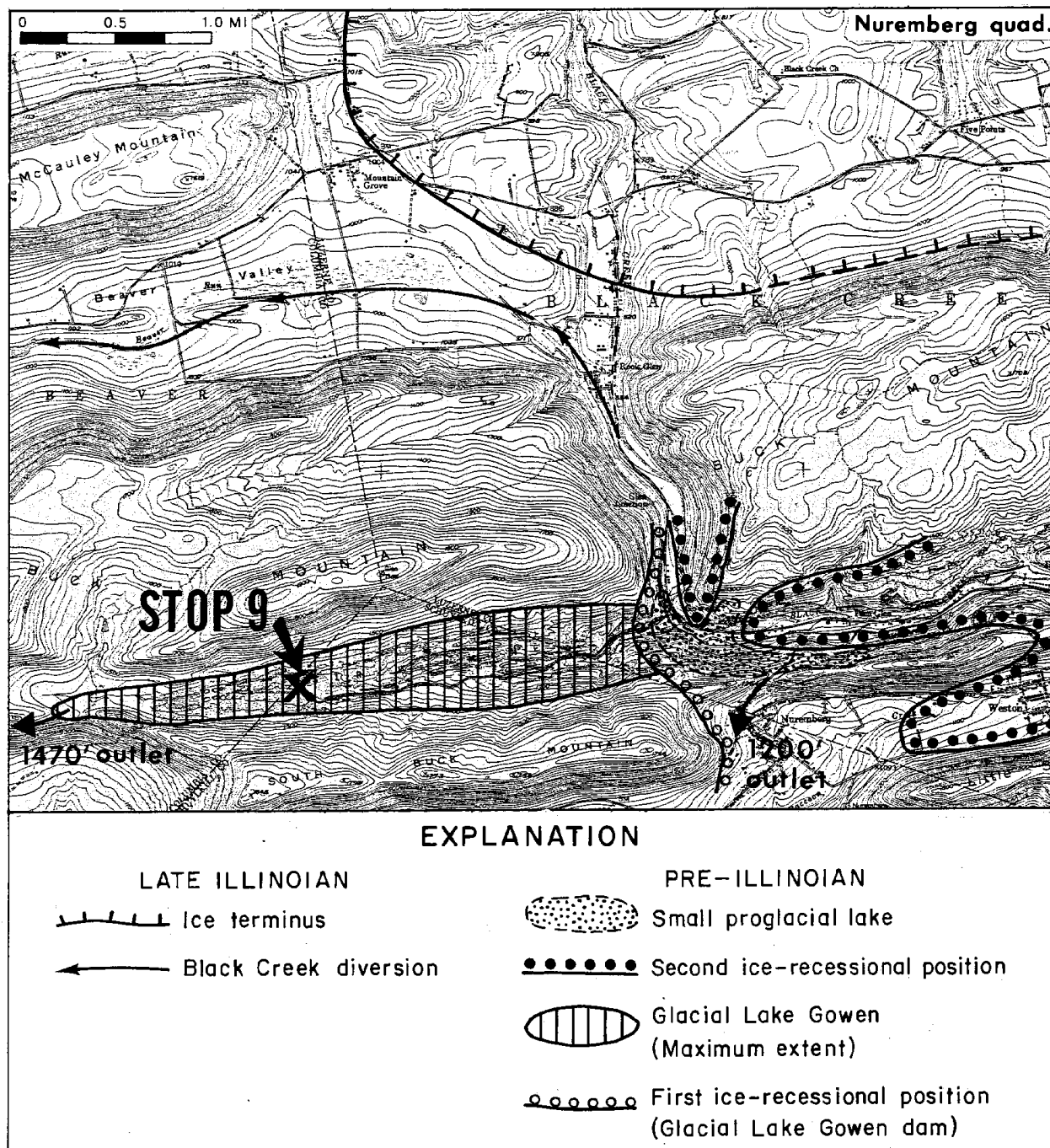


Figure 70. Ice margins and proglacial lakes in the vicinity of the Gowen Mine.

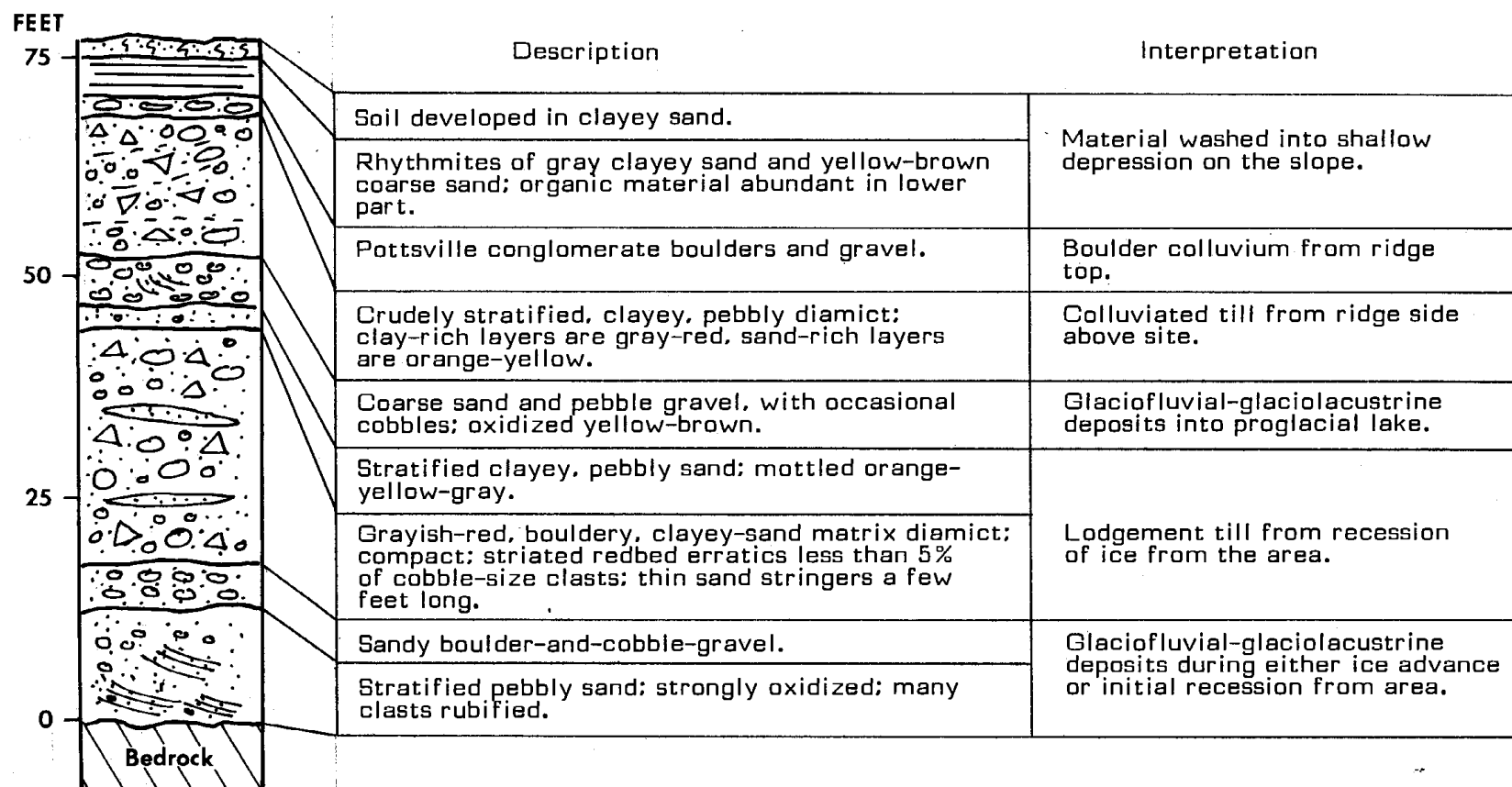


Figure 71. Generalized stratigraphic section of the pre-Illinoian glacial deposits at STOP 9.

|     |      |                                                                                                                                                                                                                                                                                                                                                                                                |
|-----|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |      | LEAVE STOP 9. Restart mileage at mine office.                                                                                                                                                                                                                                                                                                                                                  |
| 0.3 | 35.7 | STOP SIGN. TURN RIGHT onto SR 3020 and retrace route to PA Route 93.                                                                                                                                                                                                                                                                                                                           |
| 4.7 | 40.4 | Road intersection in Tomhickon. CONTINUE STRAIGHT AHEAD.                                                                                                                                                                                                                                                                                                                                       |
| 1.7 | 42.1 | Sugarloaf Landfill to right.                                                                                                                                                                                                                                                                                                                                                                   |
| 1.4 | 43.5 | STOP SIGN. TURN RIGHT onto PA Route 93.                                                                                                                                                                                                                                                                                                                                                        |
| 0.7 | 44.2 | TRAFFIC LIGHT. TURN LEFT onto SR 3026..                                                                                                                                                                                                                                                                                                                                                        |
| 2.3 | 46.5 | TRAFFIC LIGHT. TURN RIGHT onto US. Route 309 (south).                                                                                                                                                                                                                                                                                                                                          |
| 0.5 | 47.0 | Genetti Motor Lodge to left.                                                                                                                                                                                                                                                                                                                                                                   |
| 0.4 | 47.4 | TURN LEFT onto street just before McDonald's restaurant.                                                                                                                                                                                                                                                                                                                                       |
| 0.2 | 47.6 | STOP SIGN. CONTINUE STRAIGHT AHEAD, now on PA Route 940.                                                                                                                                                                                                                                                                                                                                       |
| 0.1 | 47.7 | Enter village of Harleigh.                                                                                                                                                                                                                                                                                                                                                                     |
| 0.2 | 47.9 | Harleigh Breaker of the Jeddo-Highland Coal Company and refuse banks to right. From here to Eckley, we will be passing through the Big Black Creek basin.                                                                                                                                                                                                                                      |
| 1.4 | 49.3 | To right is the village of Ebervale.                                                                                                                                                                                                                                                                                                                                                           |
| 0.2 | 49.5 | Abandoned headframe of Ebervale No. 24 Slope (Jeddo-Highland) to right.                                                                                                                                                                                                                                                                                                                        |
| 0.8 | 50.3 | Intersection with Stockton Road. CONTINUE STRAIGHT AHEAD on PA Route 940.                                                                                                                                                                                                                                                                                                                      |
| 0.1 | 50.4 | Enter contiguous villages of Oakdale (west) and Japan (middle) and Jeddo (east). Jeddo, originally founded by the Union Improvement Company in the 1850's, was expanded by George B. Markle into the "patch town" for his Jeddo Colliery in the 1860's. The houses were in coal company hands for more than 80 years and were finally sold off in 1946.                                        |
| 1.0 | 51.4 | Y-intersection. BEAR RIGHT onto road to Eckley.                                                                                                                                                                                                                                                                                                                                                |
| 0.4 | 51.8 | Village of "Jeddo borough".                                                                                                                                                                                                                                                                                                                                                                    |
| 0.7 | 52.5 | To left is the site of the Jeddo No. 5 Slope and the Highland No. 5 Breaker (Jeddo-Highland). The ruins of the power plant and breaker were removed in the winter of 1987-88 as part of an OSM reclamation project. On the right is the edge of a great mass of silt and coarse breaker refuse from this operation. Pagnotti Enterprises is currently processing the waste bank for fine coal. |
| 0.5 | 53.0 | STOP SIGN. TURN RIGHT onto SR 2051. Immediately to left after turning is a waste bank of pre-Illinoian glacial till.                                                                                                                                                                                                                                                                           |
| 0.3 | 53.3 | Cross silt-choked valley of Black Creek.                                                                                                                                                                                                                                                                                                                                                       |
| 0.3 | 53.6 | Replica of mule barn (Eckley Miners' Village) to right.                                                                                                                                                                                                                                                                                                                                        |
| 0.5 | 54.1 | Massive rusty-weathering lithic sandstone of the Llewellyn Formation in remnant of old stripping to right.                                                                                                                                                                                                                                                                                     |
| 0.3 | 54.4 | TURN RIGHT into parking lot of Visitors' Center at Eckley Miners' Village. Debark. (Buses proceed to Mule Barn parking area at opposite end of village).                                                                                                                                                                                                                                       |
|     |      | STOP 10 AND LUNCH. ECKLEY MINERS' VILLAGE: THE "PARAGON" OF MINING TOWNS                                                                                                                                                                                                                                                                                                                       |

LEADER: Mary Ann Landis

Eckley Miners' Village is among the earliest coal-company-owned towns in the Eastern Middle field of Pennsylvania's Anthracite region. Today it remains as the only anthracite mining town owned by one landlord -- the Commonwealth of Pennsylvania (Figure 72).

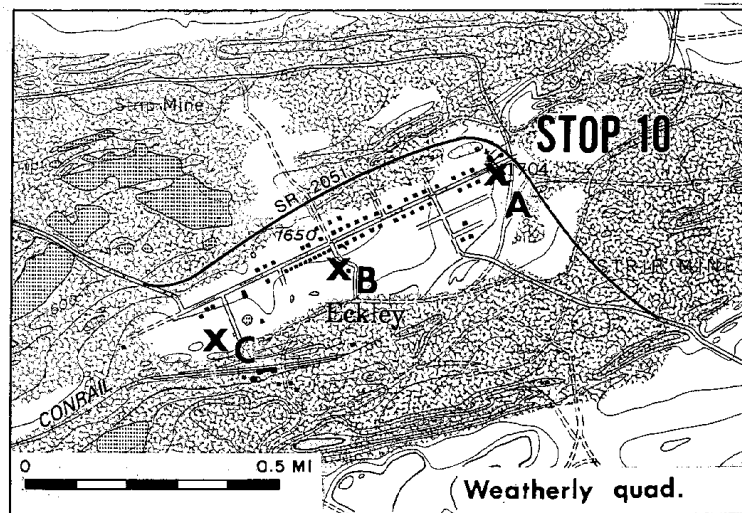


Figure 72. Location map for STOP 10. (A = Visitors' Center; B = "Molly Maguire Breaker"; C = Beltrami Breaker).

Eckley, first named Fillmore, was founded in 1854 by Sharpe, Leisenring and Company to supply housing for the company's workers at their adjacent Council Ridge Colliery. Like most nineteenth-century anthracite collieries and "patch towns", Eckley and the Council Ridge Colliery seemed to spring up over night. A lengthy newspaper account in the November 8, 1855, edition of the Mauch Chunk Gazette gives an excellent account of the year-old mining operations (Anonymous, 1855):

To a person acquainted with the location, as it appeared two years ago, the first emotions, on approaching Fillmore, are those of surprise, that where was then a dense forest, unreclaimed by the hand of man and [rarely] echoing to the sound of civilization, --save occasionally the report of the hunter's rifle and the baying of his hounds in pursuit of the Red Deer, -- so large a town has sprung up as if by magic; and the solitude of the forest has been superseded [sic] by the hum of machinery, the puffing of Engines, and the busy stir of a population of five hundred souls...

In April, 1854, Sharpe, Leisenring & Co., composed of Messrs. Richard Sharpe, George Belford, Francis Weiss, A. L. Foster, and William Reed [and John Leisenring], have procured of Chas. S. Coxe, Esq., of Philadelphia, a lease of land, comprising a body of about 1500 acres, situated on the headwaters of Black Creek, about seven miles Eastward of Hazleton and one and a half miles Westward of the new openings of the Buck Mountain Mines -- commenced exploration to ascertain the location of the several veins of coal on the land, preparatory to the erection of the necessary machinery for the raising and preparing of coal for market...

The land leased by Sharpe, Leisenring & Co. at the Eastern end of the Black Creek coal basin, it has been ascertained by geological developments, made principally under the direction of Mr. A. L. Foster, con-

tains the Buck Mountain and other veins, long known in the market as producing superior quality of coal. The average width of the coal measures [is] three quarters of a mile, and they extend East and West through all the land embraced in the lease, a distance of about one and a half miles. -- Within this area, it has been ascertained, there exists four distinct coal basins, side by side, so located that they may be advantageously worked by six slopes, each having a range of the whole length of the tracts -- an advantage not usually enjoyed in other operations.

In locating the two openings from which the coal is presently raised, the Lessees selected a point on the anticlinal axis of the two basins, from which a slope is driven North and South into each basin; the coal from both passing through the same Breaker and Screens to a common series of pockets or deposits. Slope number one, dipping South at an angle of fifteen degrees, has been driven one hundred and seventy yards, a distance sufficient for two "Lifts" or ranges of work. Slope number two, dipping North at an angle of thirty-five degrees, has been driven one hundred yards. The Bottom of the basin has not been reached by either slope...

Daddow (in Daddow and Bannon, 1866) described the geological formations at the Council Ridge Colliery as follows:

Here the basin of Big Black Creek is three-quarters of a mile wide and divided into four synclinal troughs, or undulations, which increase in breadth and depth from the south to the north side of the basin. The mines at Eckley are located in the "saddle," or anticlinal, between the two first or southern basins or synclinals, and consist of two slopes, one in each basin. That in the first basin is on the south dip, with an angle of 30 degrees, and that in the second basin is on the north dip, with an angle of 20 degrees. Each is 200 yards deep, and the basins they penetrate are, respectively, 125 feet vertical in No. 1, and 275 feet in No. 2--the vertical depth varying with the undulations of the surface...The capacity of these mines is about 125,000 tons annually.

To meet the production potential of the colliery, the company had to attract skilled workers to its operation and consequently found it necessary to provide reasonably comfortable and convenient housing to do so. Eckley was then, as it is now, relatively isolated; Jeddo was the only sizeable nearby community. South Heberton, now part of Freeland, and Hazleton were too far away to make efficient use of a miner's time and energy, much of which would be lost in traveling to work on foot. Within a year of its founding, Sharpe, Leisenring and Company had constructed fifty houses for the workers and their families, a total of about five hundred persons. Five years later, the number of houses and residents had trebled; and coal production reached 122,388 tons.

Apparently the village was highly regarded, in its early days, for its organized plan and its working class housing (Figure 73); one reporter called it the "paragon" of mining communities.

Early in its history, M. S. Henry (1860) described the evolution of the village and its plan:

As soon as they [the company] were satisfied that the coal was sufficiently abundant to warrant the erection of dwellings for miners, and other buildings necessary for mining purposes, they built a saw-mill, considering it the first requisite for turning the pines and hemlocks of the forest into dwellings. Since that time they have erected over one hundred and fifty tenements, and five neat cottages for the accommodation of the resident partners. They have also erected in that time three commodious school-houses, two churches (Episcopal and Presbyterian), a store, and a fine hotel. The general arrangement of the place is perhaps the most complete of any mining town in the State. The location of the houses is divided into four sections or divisions, each section occupied according to grade, viz., the cottages of the proprietors in one section, the boss laborers and contractors in another, the miners in a third, and second class miners and slate pickers in another. As the dwellings are all owned by the lessees, the cost of each has been according to its location. Considerable attention has been given to make them convenient within, and with their projecting eaves and gables and uniform appearance, present a very neat and picturesque appearance without. The tenements are in blocks of two houses each, on lots of fifty feet front by two hundred feet deep, and gives to each tenant a fine garden, which many have ornamented with considerable taste.

After 134 years, the uniformity of the houses is still apparent (Figure 74). The town plan and its occupational stratification can be seen in the changes in house size as one walks from east to west, even though South Street and its houses are gone. The smaller laborers', or what Henry called "second class miners and slate pickers," houses are located at the eastern end of the village. First-class miners lived in the larger double homes nearer the center of town. Bosses and contract miners inhabited larger single houses near the west end of town, and the mine owners lived at the westernmost edge of the village.

This imposed occupational stratification also resulted, although probably coincidentally, in stratification according to ethnic background and religion. During the first decade of Eckley's history, a large number of Irish immigrants moved to the Anthracite region seeking employment, primarily as a result of the potato famines. Because most of these immigrants were farmers in Ireland, they had no experience working in the mines. They made up the unskilled labor force and, as a result, lived at the east end of town.

At the opposite end of the occupational ladder were those miners who had experience working in mines in Europe or in the United States. These immigrant and native miners, at least in the years prior to the Civil War, were chiefly of Welsh, English, and German stock. Since they had mining skills and experience, and were valuable to the company, they were given the more commodious houses located at the center and near the west end of town.

The ethnic and religious division is seen most clearly in the location of the churches in the village. Since most of the Irish were Catholic and lived at the eastern end of Eckley, it was logical to build the Catholic Church near their homes. The Church of the Immaculate Conception was built in 1861 at a time when 25 percent of the villagers were Irish. By contrast the two Protestant churches in the village, Presbyterian and Episcopalian, were built in

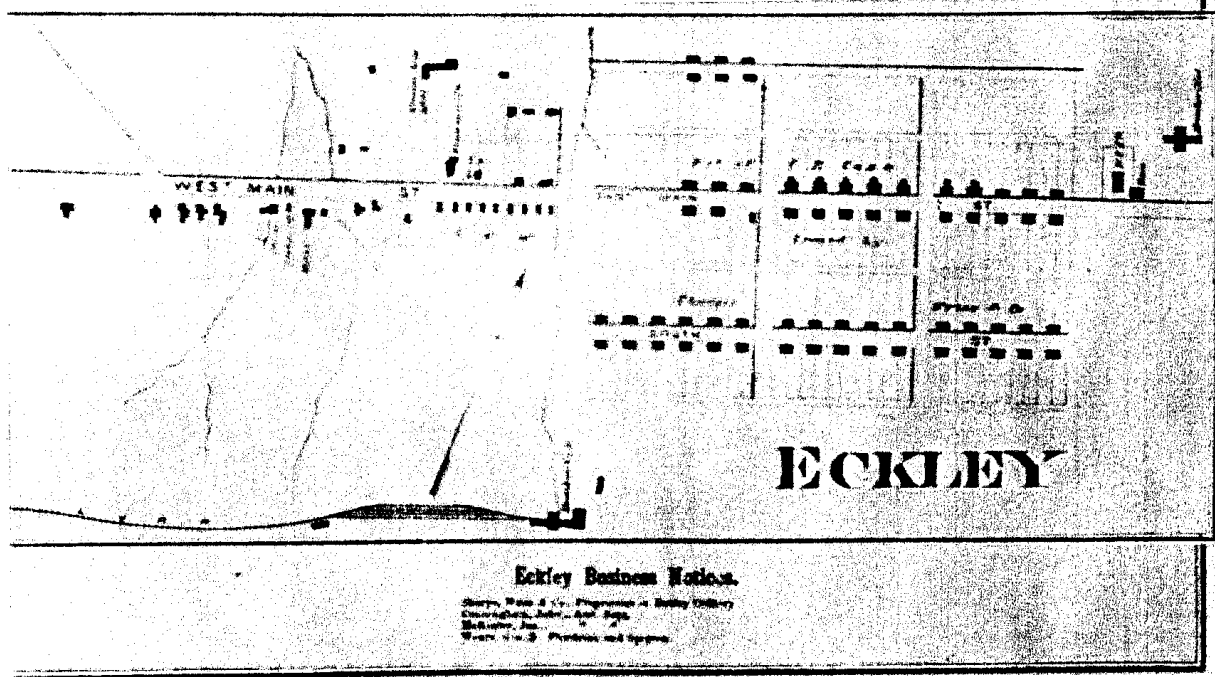


Figure 73. Town plan of Eckley in the 1860's.



Figure 74. View west down Main Street in Eckley Miners' Village in the summer of 1987. The "Molly Maguire Breaker" stands behind the houses to the extreme left.

1859 at the western end of the village nearer the homes of the Welsh, English, and Germans who would have worshipped there. It should be noted that the two main Protestant sects shared their churches with groups of German Lutherans, Welsh Baptists, and Welsh Methodists.

The change in Eckley's ethnic make-up over a period of 100 years also can be seen in the history of the three churches. By 1925 the Presbyterian Church was removed. In 1938 the Episcopal Church was torn down; only one Episcopalian family remained in town, and they lived across the street from the church. However, the Catholic church was in use until the mid-1960's. Although it was considered to be an Irish church, villagers of other ethnic backgrounds worshipped there as well. Usually the newer immigrants, who began arriving from Eastern Europe in the 1880's and became the new unskilled labor force, worshipped in their own ethnic churches in Freeland and Hazleton. However, when convenience was of primary importance, they worshipped in Eckley. Therefore, the church remained.

The village and the Council Ridge Colliery changed, not only physically but in terms of ownership, over a period of 97 years. In 1874 Sharpe, Leisenring/Weiss, and Company's lease ran out with the Coxe Estate. John Leisenring, independent of his old partners, took over the lease for the land and operated the business until his death in 1884; his son-in-law ran the operation until 1886 in his stead. In 1886, the Coxe Estate assumed control of the colliery and village under the name of Coxe Brothers Coal Company; it was headed by Eckley B. Coxe, the gentleman for whom the town Fillmore was renamed in 1857.

The Coxe Estate operated the colliery until 1905 when it was taken over by the Lehigh Valley Railroad, although the operation retained the Coxe name. In 1954 the Jeddo-Highland Coal Company assumed ownership and continued to operate the mines until 1962 when the property was sold to George Huss.

It was Huss who owned Eckley when Paramount Studios chose the site to film the movie "The Molly Maguires." Because the village houses had never been sold to the tenants, the structures had changed little over the years, making Eckley a prime location for filming in 1968. A breaker, company store, and mule barn were reconstructed and the houses and streets were made to look as they would have in the 1870's. At the conclusion of the filming, a group of Hazleton businessmen formed the Anthracite Historic Site and Museum, Inc., to attempt to preserve the town as an historic site. They purchased the village from George Huss and, in 1971, turned it over to the Pennsylvania Historical and Museum Commission (PHMC).

One of the first tasks undertaken by the PHMC was the compilation of oral histories from the two hundred and fifty residents, many of whom had lived in the town for over seventy years. Today, of that number, only thirty residents remain.

In 1974, the PHMC was given St. Paul's Protestant Episcopal Church of White Haven, Eckley's sister church. Both structures were built by the same carpenter and had the same first rector, Peter Russell, a brother-in-law of Richard Sharpe. The church was very similar to Eckley's St. James. Today the church contains a collection of nineteenth- and early twentieth-century stained glass windows, gothic revival chancel furniture, and a rare Beman tracker-action organ, purchased in 1891. The present church stands on the site of St. James, which was removed in 1938.

In 1978 the commission began restoration work on the Church of the Immaculate Conception. The project was a major one requiring the rebuilding of the foundation, jacking and restructuring of the frame, and the replastering, repainting, restenciling, and regraining of the interior. Unfortunately, all original furniture and statuary, except the altar, were missing from the sanctuary. But a church in Berwick, of the same name, donated their old church's furnishings when they moved into a modern building. Today the interior of the Catholic Church reflects the period of the 1920's.

In 1980 the Villages' Visitor's Center was opened to the public. The permanent exhibits reflect the daily and seasonal activities of the anthracite miner's family. The traditional work week of household chores is illustrated through artifacts, photos, graphics, and quotes taken from the oral histories, as are the seasonal chores and the social, religious, and educational activities of patch-town residents. A miners' double house has been restored in the Village to illustrate the period of 1880-1890, showing living conditions of the immigrant miner, his family and boarders, and the improvements these workers would have made in their environment as they continued to work for the coal company.

Presently the PHMC is undertaking a major restoration project at the west end of the Village. The mine owner's house, built in 1860, is being restored to the period of 1873 to reflect the Richard Sharpe family's residence; the Sharpes lived there from 1860 until 1874. Another major project, presently in the planning stages, is the restoration of the company-doctor's office which will be interpreted to show company medical practice in the 1870's.

Eckley is being preserved as an example of the hundreds of anthracite "patch towns" that sprang up in the region in the nineteenth century and which now are rapidly disappearing. The Miner's Village tells the story of the men, women, and children who worked to supply nineteenth-century America with the fuel to fire the Industrial Revolution.

- 0.6 55.0 LEAVE STOP 10 from parking lot at Mule Barn. To left is Eckley Breaker of Beltrami Enterprises.
- 0.2 55.2 STOP SIGN. CONTINUE STRAIGHT AHEAD, now on SR 2051.
- 0.2 55.4 Fine-coal preparation plant of Pagnotti Enterprises ahead to left.
- 0.3 55.7 TURN LEFT onto road to Jeddo.
- 1.6 57.3 STOP SIGN at Y-intersection. CONTINUE STRAIGHT AHEAD on Route 940 through Jeddo-Japan-Oakdale.
- 1.0 58.3 To the left pre-Illinoian till and stratified drift crop out in the highwalls of old strippings. On the south side of the basin, 13 to 23 feet of red till, dominated by Mauch Chunk redbed clasts, is overlain by 10 to 26 feet of Pottsville-rich colluvium and is underlain by weathered old colluvium or deeply bright-orange weathered saprolite. On the north side interbedded "redbed" till and rubified quartz-lithic ("non-redbed") sand and gravel was formerly exposed in the area now covered by relocated Stockton road.
- 0.1 58.4 Stockton road (SR 3019) to left. CONTINUE STRAIGHT.
- 0.8 59.2 TURN LEFT onto access road, crossing railroad tracks.
- 0.1 59.3 Ebervale office of the Jeddo-Highland Coal Company (adjacent to ruins of Ebervale No. 24 Slope). Buses follow haul road

approximately 0.4 mile to vicinity of active stripping operations.

**STOP 11. EBERVALE OPEN-PIT MINE OF JEDDO-HIGHLAND COAL COMPANY:  
BEDROCK AND MINING GEOLOGY**

**LEADER:** Jon D. Inners (with additional comments by Christopher Wnuk, U.S. Geological Survey, and George Senick, Jeddo-Highland Coal Company [retired]).

The Ebervale open-pit mine is situated near the middle of the 7-mile-long Big Black Creek basin between the villages of Ebervale and Oakdale (Figure 75). The basin occupies a broad valley drained by west-flowing Black Creek and is bounded by Black Creek Ridge on the north and Council Ridge on the south. We will briefly examine the fossiliferous seatrock (*Stigmaria*, *Neuropteris*) exposed near the debarkation point and then walk down into the pit to view the mining operation.

Bedrock at the Ebervale mine belongs to the Middle Pennsylvanian (Westphalian)-age part of the Llewellyn Formation (Oleksyshyn, 1984; Berg and others, 1986). The highwall at the east end exposes interbedded dark-gray sandstones, siltstones, and "slates" between the Little Orchard (top) and Mammoth (bottom) seams. Dark-gray, hackly, rootworked and fossiliferous claystone that represents the seatrock of the Mammoth bed forms the inclined footwalls along the north and south edges.

Of the several seams mined at Ebervale, the Mammoth is by far the most important. It is 25 to 28 feet thick and of excellent quality. According to Smith (1895), the Mammoth coalbed in the Big Black Creek basin is "divided

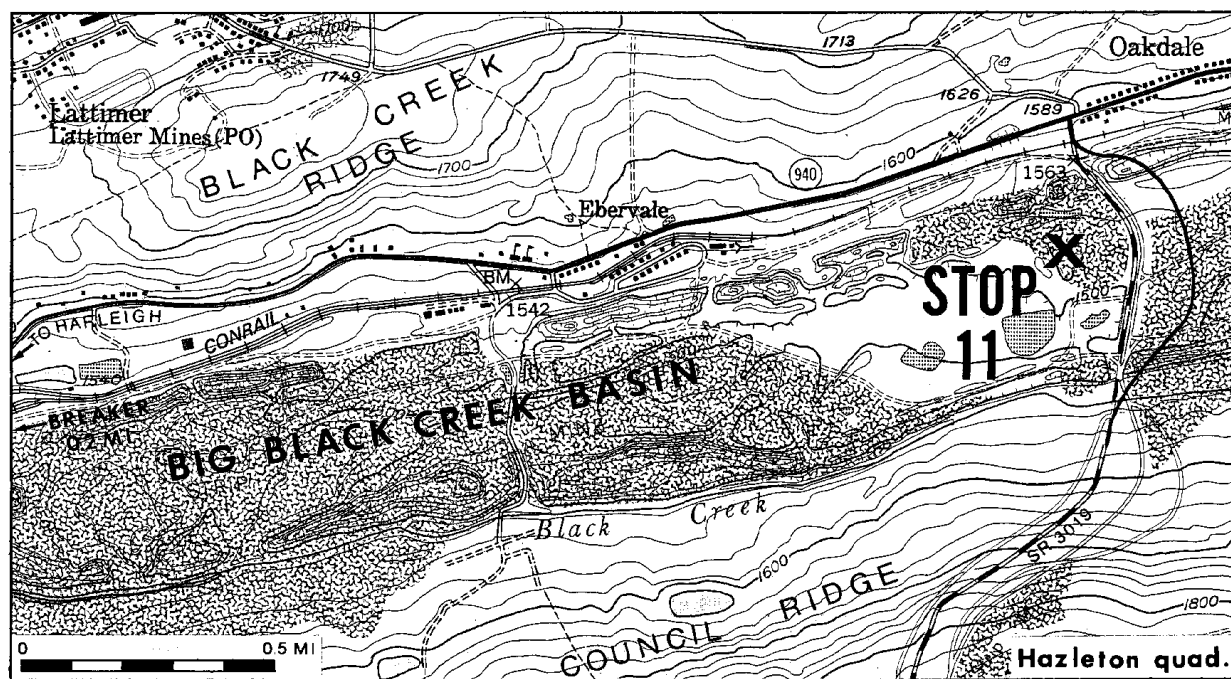


Figure 75. Location map of STOP 11.

mostly into large 6' and 7' benches of solid coal and carries in all a fairly small percentage of refuse." The Primrose and Orchard seams range from 2 to 3 feet and 3 to 5 feet thick, respectively; the Little Orchard is 1.5 to 3.5 feet thick and contains at least 50 percent coaly shale.

The Big Black Creek basin in the vicinity of the Ebervale mine is an asymmetrical, flat-bottom syncline with the steep limb on the south (Figure 76). A disharmonic, third-order anticline deforms the gentler north limb in the active transverse face. This fold dies out about 1,000 feet to the east and rises westward to take on a box-like configuration. The top split of the Buck Mountain (No. 5) coalbed, the deepest coal formerly mined to any significant extent, lies at a depth of about 500 feet (altitude 1,000 feet) in the middle of the basin.

Deep mining in this part of the Big Black Creek basin commenced in 1858, when George B. Markle opened the Jeddo colliery. By 1885, G. B. Markle and Company had developed extensive workings on the Mammoth seam east and west of the Stockton road and on the Buck Mountain seam in the vicinity of Jeddo. Surface mining of the Mammoth and underground mining of the other coalbeds probably began about the turn of the century. In 1921 the Jeddo-Highland Coal Company took over the Markle mining interests and continued operation of the deep mines until the late 1950's or early 1960's (Figure 77). Pagnotti Enterprises, a firm with large holdings in the Pittston area of the Northern field, absorbed Jeddo-Highland in 1964.

The current surface mine activities were initiated in 1966 after Jeddo-Highland interests acquired drag-lines big enough to go after the pillars of Mammoth coal remaining in the underground workings at the center of the basin (Figure 78). The first box-cut was taken at the Jeddo No. 7 Breaker in Harleigh in June of 1966. Work has progressed eastward to the existing pit by making successive cuts from north to south or south to north across the basin, depending on conditions. With the moving of the Stockton Road (SR 3019) this past summer, mining can now continue eastward toward Jeddo. Current production probably averages 1,500 to 2,000 tons/day, nearly all from the Mammoth.

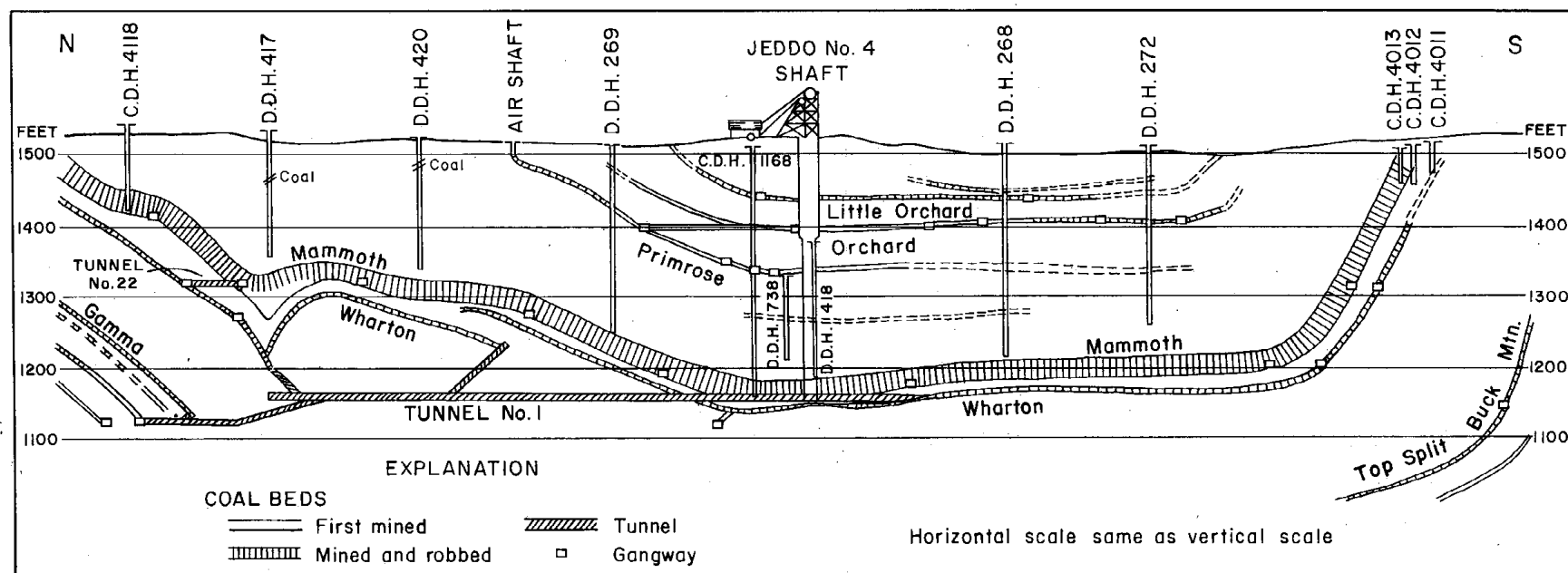


Figure 76. Geologic cross section of the Ebervale mine at the site of the currently active face.



Figure 77. Ruins of Jeddo Shaft No. 4 just prior to removal in the summer of 1985. This shaft was probably sunk about the turn of the century. It hoisted its last coal on August 22, 1941.

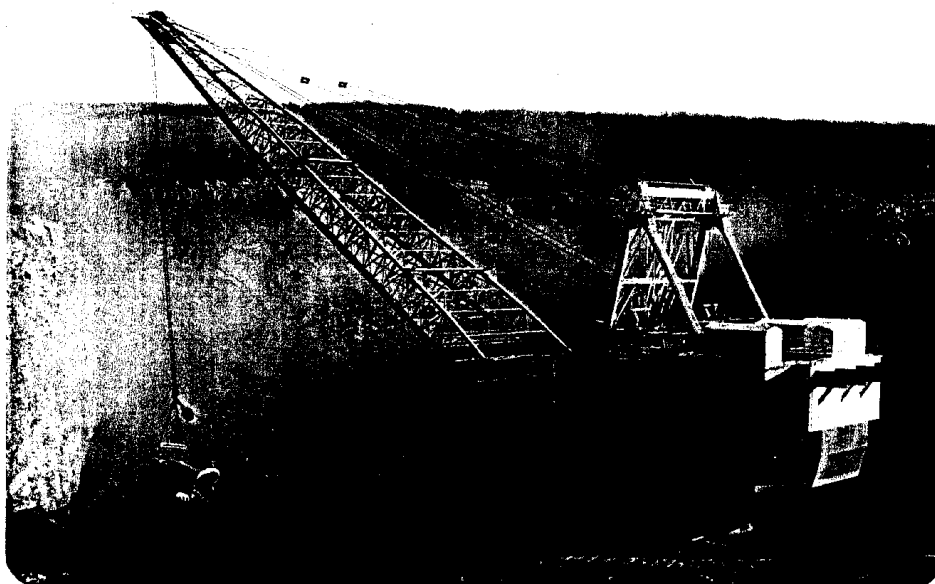


Figure 78. Marion 8,700 85-yd<sup>3</sup> walking dragline in action (March, 1982). The bucket is capable of lifting about 128 tons of earth. Boom length is 300 feet.

LEAVE STOP 11. Restart mileage at company office.

|     |      |                                                                                                                                                                                                                   |
|-----|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.1 | 59.4 | STOP SIGN. TURN LEFT onto PA Route 940.                                                                                                                                                                           |
| 1.9 | 61.3 | STOP SIGN at west end of Harleigh. CONTINUE STRAIGHT.                                                                                                                                                             |
| 0.2 | 61.5 | STOP SIGN. TURN RIGHT onto US. Route 309 (north).                                                                                                                                                                 |
| 0.3 | 61.8 | Genetti Motor Lodge to right.                                                                                                                                                                                     |
| 0.6 | 62.4 | TRAFFIC LIGHT. TURN LEFT onto SR 3026.                                                                                                                                                                            |
| 2.3 | 64.7 | TRAFFIC LIGHT. TURN RIGHT onto PA Route 93.                                                                                                                                                                       |
| 0.4 | 65.1 | BEAR RIGHT onto entrance ramp of I-81 North.                                                                                                                                                                      |
| 0.1 | 65.2 | Stop buses part-way down ramp. Debark. (Buses continue on I-81 to Interchange 42 [I-80], loop around and return to Interchange 41; then park on south side of PA Route 93 [facing Hazleton] to await passengers). |

STOP 12. INTERCHANGE 41 CUT AT WEST HAZLETON; STRATIGRAPHY AND SEDIMENTOLOGY OF THE UPPER MEMBER OF THE MAUCH CHUNK FORMATION AND THE POTTSVILLE FORMATION (PART 2)

LEADERS: Jon D. Inners and Leonard J. Lentz

This series of outcrops exposes the upper Mauch Chunk Formation and part of the Pottsville Formation on Butler Mountain at the north edge of the Eastern Middle Anthracite field (Figure 79). We will examine the section in ascending stratigraphic order, starting along the northbound entrance ramp north of PA Route 93 and then crossing that highway to look at the rocks on the northbound exit ramp. TRAFFIC IS FAIRLY HEAVY HERE, SO BE CAREFUL. BECAUSE OF THE BROKEN AND UNSTABLE ROCK CUT-SLOPE, HARDHATS SHOULD BE WORN!

The primary purpose of this STOP is to examine the stratigraphic changes that take place in the Mauch Chunk-Pottsville interval northward from Delano (Stop 8A) to West Hazleton, with special emphasis on the development of a sub- or mid-Pottsville disconformity. We will also expand somewhat on the inferences concerning depositional environments that were made at Stop 8A. The same stratigraphic problems involving the Mauch Chunk-Pottsville boundary that were discussed at Stop 8A are present here, but they will not be dealt with beyond the bearing that they have on interpretation of the "sub-Pottsville" disconformity.

The upper Mauch Chunk-Pottsville succession at Stop 12 is shown in Figure 80. Note that it differs markedly from the section exposed at Stop 8A. Not only is the redbed-bearing part of the upper Mauch Chunk much more conglomeratic (similar beds may be covered or below road level at Delano), but the upper submember of the Tumbling Run Member of the Pottsville Formation is absent. Interbedded conglomerates and olive-gray mudstones identical to the lower submember of the Tumbling Run at Stop 8A are here included in the upper member of the Mauch Chunk (Schasse and others, in press). The member assignment of the "white" Pottsville conglomerate at the south end of the section is unclear: Inners and Lentz believe, on local stratigraphic evidence, that these beds represent the Schuylkill Member, while Edmunds shows elsewhere in this volume that regional considerations dictate that it be Sharp Mountain.

Appendix B gives a detailed description of the rocks at STOP 12, and Figure 81 shows representative photomicrographs of thin sections from the cut. Figure 82 illustrates our interpretation of the development of the "sub-Pottsville" unconformity northward from Stop 8A.

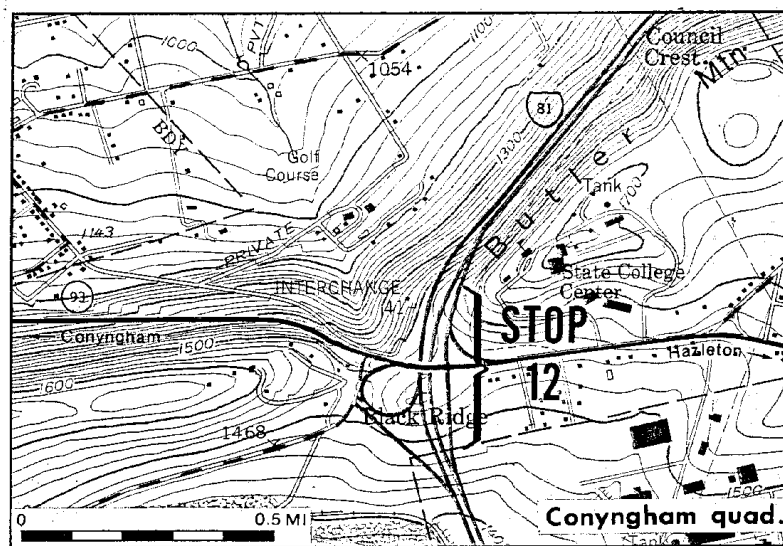


Figure 79. Location map for STOP 12.

## MAUCH CHUNK FORMATION (part)

### Upper member (part)

Approximately 557 feet of the upper member of the Mauch Chunk Formation are exposed in the cuts at Interchange 41. Total thickness of the member in this area is presumed to be about 600 feet (Schasse and others, in press). The member is readily divisible into a lower redbed and conglomerate sequence and an upper conglomerate and olive-gray mudstone sequence ("lower Tumbling Run equivalent").

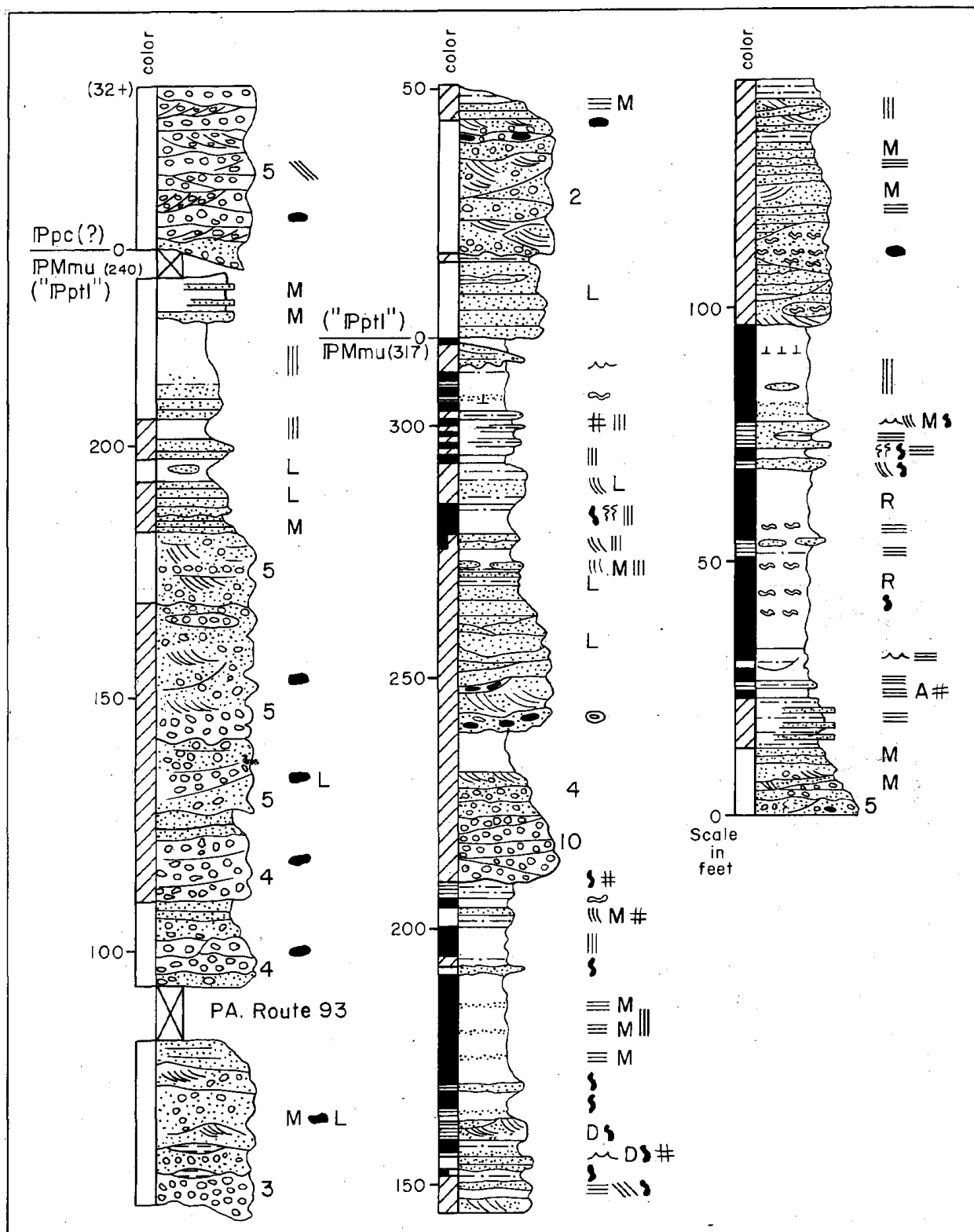
### Redbed and conglomerate sequence

The redbed-bearing part of the upper Mauch Chunk is somewhat more than 317 feet thick. The basal conglomerate of the upper member is not exposed, but it presumably lies less than 100 feet below the base of the section shown in Figure 80.

The pebbly nature of the coarse clastics, well-developed fining-upward cycles, and locally abundant carbonate nodules ("caliche") (especially in the lower two-thirds) all point to a high gradient, meandering, semi-arid alluvial plain origin for these rocks.

### 0 to 97 feet

The lower 40± feet of the section represents the upper part of a fining-upward alluvial cycle, the basal part of which is exposed on the north side of the southbound lane of the highway. The thick, red mudstones above this are probably overbank flood deposits (with local crevasse-splay sandstones), although the abundance of disrupted parallel laminations is suggestive of playa-lake or mudflat sedimentation.



In-situ carbonate nodules are especially common within red mudstones between 40 and 60 feet above the base. The larger, nodules (>1 cm) are probably inorganic "caliche" formed through the evaporation of soil water near the ground surface. Smaller, somewhat "ropy" masses, on the other hand, may be partly biogenic, having originated as calcitic coatings on rootlets (Figure 81a).

#### 97 to 141 feet

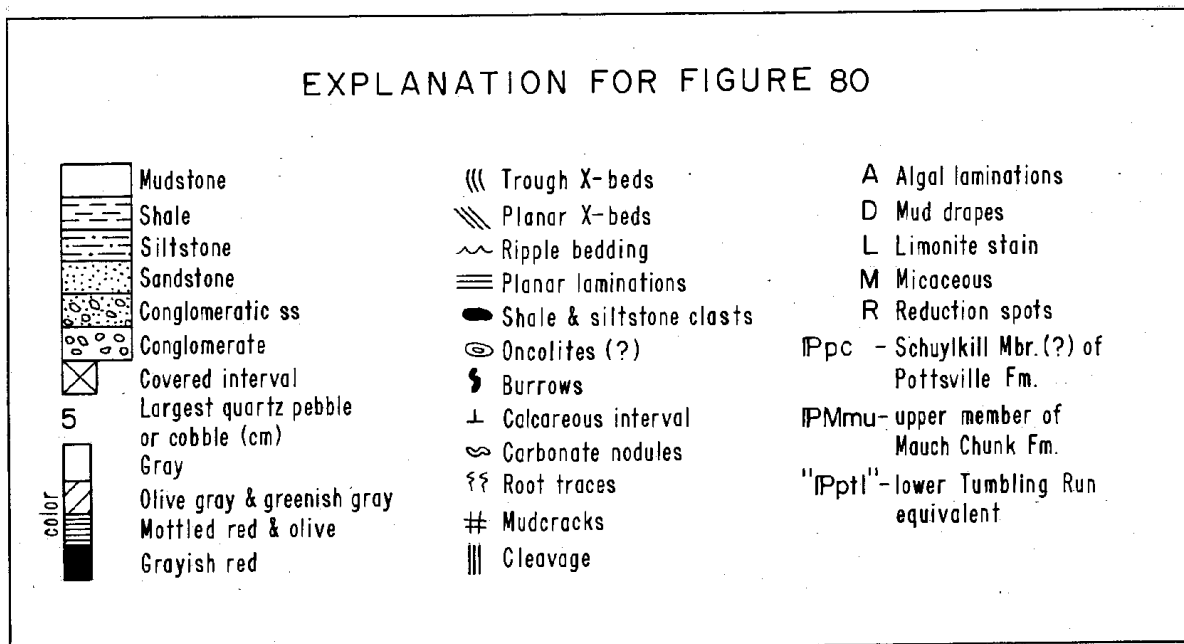
This interval is predominantly dark-greenish-gray to light-olive-gray, fine-grained sandstone that contains lenses (to 10 feet thick) of calcareous breccia between 97 and 112 feet. The limy clasts are probably "caliche" nodules eroded from the floodbasin(?) muds and redeposited on channel bars. Thin sections of these nodular beds show intense development of pressure solution cleavage (Figure 81b).

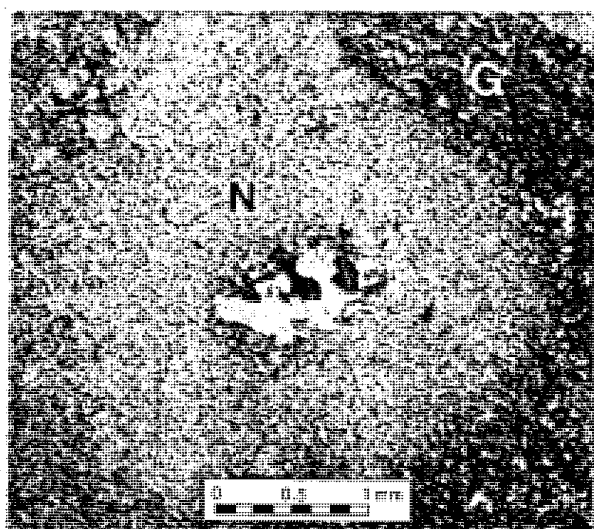
The sandstones above the breccia interval are predominantly fine grained, micaceous, and planar laminated to trough crossbedded. They represent the upper channel or bar part of a fining-upward alluvial cycle.

#### 141 to 209 feet

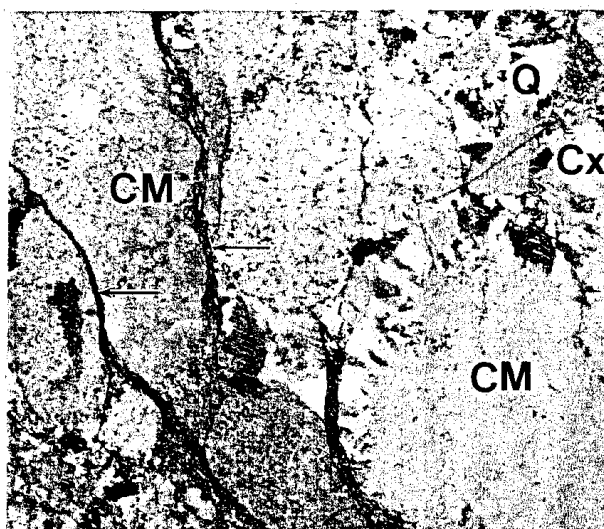
This fine-grained interval consists mainly of grayish-red, overbank mudstones, containing intermittent gray, sandy crevasse-splay (?) deposits. Burrows are abundant, especially in the sandstones between 150 and 170 feet where they appear as red streaks and blotches on light-olive-gray weathered surfaces. The dominantly gray siltstones between 200 and 209 feet contain red, downward-directed flame structures that appear to be filled desiccation cracks. Intense cleavage has destroyed any sedimentary structures that might have existed in the dominant grayish-red mudstones. At 205 feet is one of only two occurrences of caliche nodules above those at 58 feet.

◀ Figure 80. Stratigraphic column of the upper Mauch Chunk and lowermost Pottsville Formations at STOP 12.

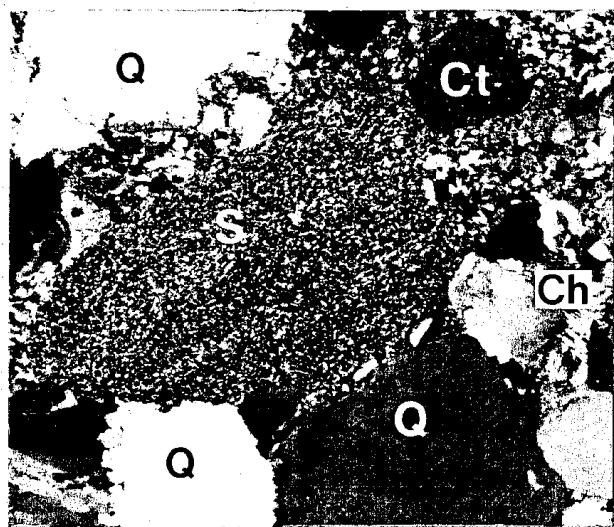




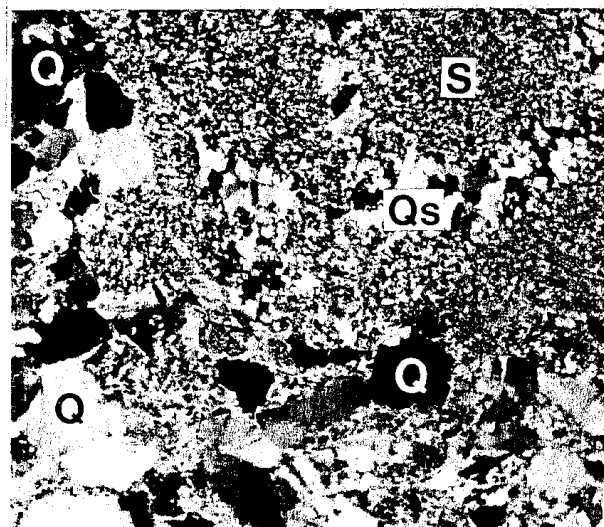
a



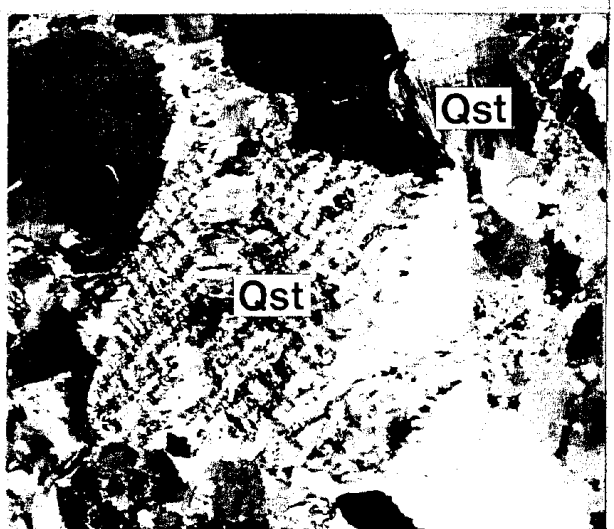
b



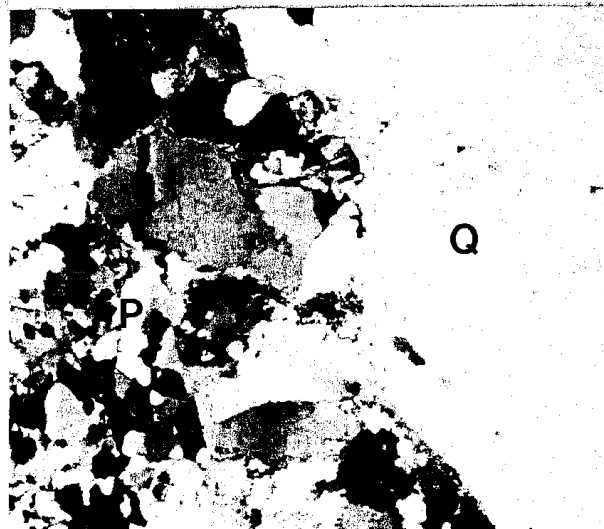
c



d



e



f

## 209 to 239 feet

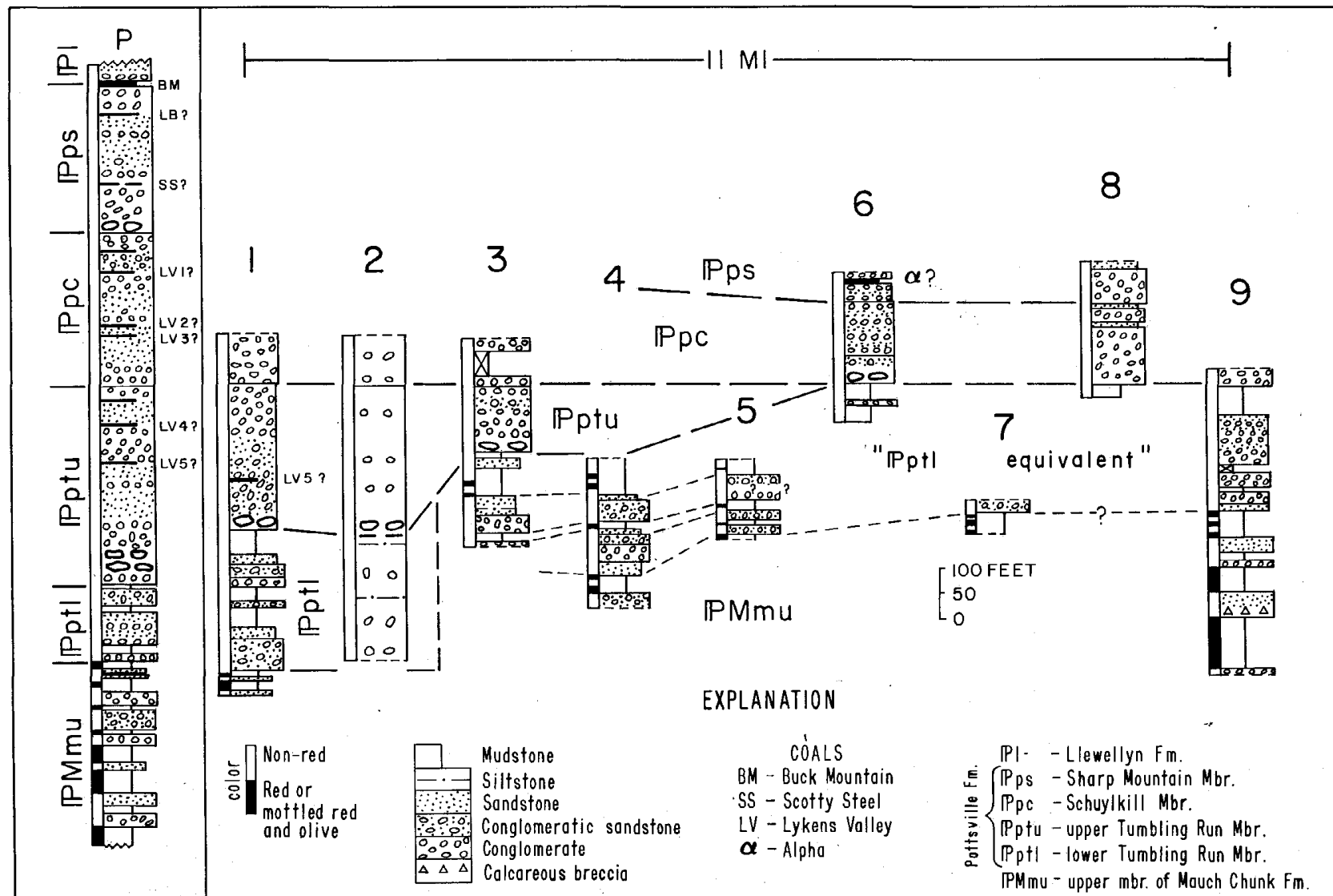
A prominent quartz-conglomeratic unit overlain by light-olive-gray mudstone occupies this interval. Rounded quartz, quartzite, chert, and siltstone pebbles to 10 cm (average 2 to 4 cm) compose a rather poorly sorted, clast-supported conglomerate in the lower 13 feet (4 m) (Figures 83 and 81c), and interbedded sandstone, conglomeratic sandstone, and conglomerate (with well-developed trough crosslamination at the top) make up the next 9 feet. Many of the quartz pebbles exhibit a distinctive "rose" staining. Because this unit caps Sugarloaf Mountain, an isolated synclinal knob in the center of the Conyngham Valley to the north (Figure 84), it is informally known as the "Sugarloaf Mountain conglomerate." Its total areal extent is unknown, and its relationship to conglomerates in the lower Tumbling Run to the south is uncertain. The coarseness and lithologies of the clasts, however, is suggestive of the conglomerate at the base of the lower Tumbling Run at Stop 8A.

## 239 to 317 feet

In the lower part of this interval is a 50+-foot thick fining-upward cycle that begins with a coarse-grained sandstone containing prominent lenses of shale-clast conglomerate. Rounded, yellowish-weathered (sideritic?), concentrically laminated nodules at 240 feet may be algal oncolites that were flushed from a pond on the flood basin during high water (see Berg, 1981). Very-fine-grained, trough-crossbedded sandstones at 270 and 277 feet are probably crevasse-splay deposits.

The upper 25 feet is dominantly grayish-red and olive-gray overbank siltstone and mudstone, but a small sandstone channel comes in at about 312 feet. The highest calcareous zone in the section is at 305 feet.

- ◀ Figure 81. Photomicrographs of thin sections from STOP 12. (All same scale).
- Calcareous (red) mudstone from the upper member of the Mauch Chunk Formation (unit 8 of Appendix B), showing calcareous nodule (N) with rootlet void filled with sparry calcite (Cx) in a groundmass (G) of silt, clay, and chlorite. Crossed nicols.
  - Calcareous breccia from the upper member of the Mauch Chunk (unit 18), showing clay-micrite nodules (CM) with sparry calcite (Cx) as rims on nodules or fillings of root voids and quartz grains (Q) in matrix. Note intense pressure-solution cleavage with carbon residue (arrows). Crossed nicols.
  - Polymict conglomerate from upper member of the Mauch Chunk (unit 37), showing rounded siltstone clast (S), monocrystalline quartz (Q) and chert (Ct), and chlorite (Ch). Crossed nicols.
  - Conglomeratic quartz-lithic sandstone from the upper member of the Mauch Chunk (unit 65), showing rounded, burrowed siltstone clast (S) and monocrystalline quartz grains (Q). The burrow is filled with quartz silt (Qs). Crossed nicols.
  - Intensely strained quartz grains (Qst) in conglomeratic quartz-lithic sandstone in the upper member of the Mauch Chunk (unit 65). Crossed nicols.
  - Oligomict quartz conglomerate from the Schuylkill Member of the Pottsville Formation (unit 77), showing monocrystalline (Q) and polycrystalline (P) quartz pebbles and clast-supported fabric. Note minor interstitial illite or chlorite (i). Crossed nicols.



The paucity of caliche and calcareous mudstone in the part of the section from 58 to 305 feet reflects a more gradual change from calcareous to non-calcareous mudstone than that which occurs rather abruptly at 393 feet above the base in the upper member of the Mauch Chunk at the Pottsville reference section (see Levine and Slingerland, 1987).

#### "Lower Tumbling Run equivalent"

The 240-foot non-red interval at the top of the Mauch Chunk is stratigraphically continuous with the lower submember of the Tumbling Run Member of the Pottsville Formation at Stop 8A (Figure 82). The gross internal organization and color of these rocks indicate that they probably formed on a high-gradient, meandering alluvial plain under rather humid conditions.

#### 0 to 183 feet

The lower 100+ feet of this interval consists predominantly of stacked, conglomeratic channel and bar deposits. Good "sandstone-to-mudstone" cycles can be observed only from 0 to 18 feet and 18 to 50 feet. The coarse clastics exhibit the same light-olive-gray to grayish-orange weathering colors and abundance of olive-gray shale and siltstone clasts as those in the lower Tumbling Run at Stop 8A. Lenticular, intraformational shale-clast conglomerates are particularly evident at about 40 feet.

The sandstones and conglomerates are composed predominantly of quartz and lithic grains (Figure 81d). Many of the quartz grains are intensely strained (Figure 81e), probably as a result of Alleghanian deformation.

#### 183 to 240 feet

These beds are apparently correlative with the finer grained interval at the top of the lower Tumbling Run at Stop 8A (Figure 64), as well as at the top of the upper member of the Mauch Chunk at Interchange 39 (Stations 3 and 4 of Figure 82). If this is the case, very little erosion has taken place at the disconformity beneath the upper Tumbling Run/Schuylkill Members of the Pottsville Formation.

As at Stop 8A, this interval basically fines upward from mostly medium-grained sandstone at the base to mudstone and siltstone at the top (fining-upward alluvial cycle?).

- ◀ Figure 82. Correlation diagram of stratigraphic sections between Delano (Stop 8A) and West Hazleton (STOP 12). 1 = Stop 8A; 2 = cut on west side of northbound lane of I-81, 2 miles north of Interchange 38; 3 = south end of cut on east side of northbound lane of I-81 at Interchange 39; 4 = north end of cut at Interchange 39; 5 = cut on west side of US Route 309 at south end of McAdoo; 6 = cut on west side of southbound lane of I-81, 0.5 mile north of Luzerne-Schuylkill County line; 7 = composite of Pismire Ridge cuts on I-81; 8 = cut on west side of southbound lane of I-81, 0.7 mile south of Interchange 41; 9 = STOP 12.

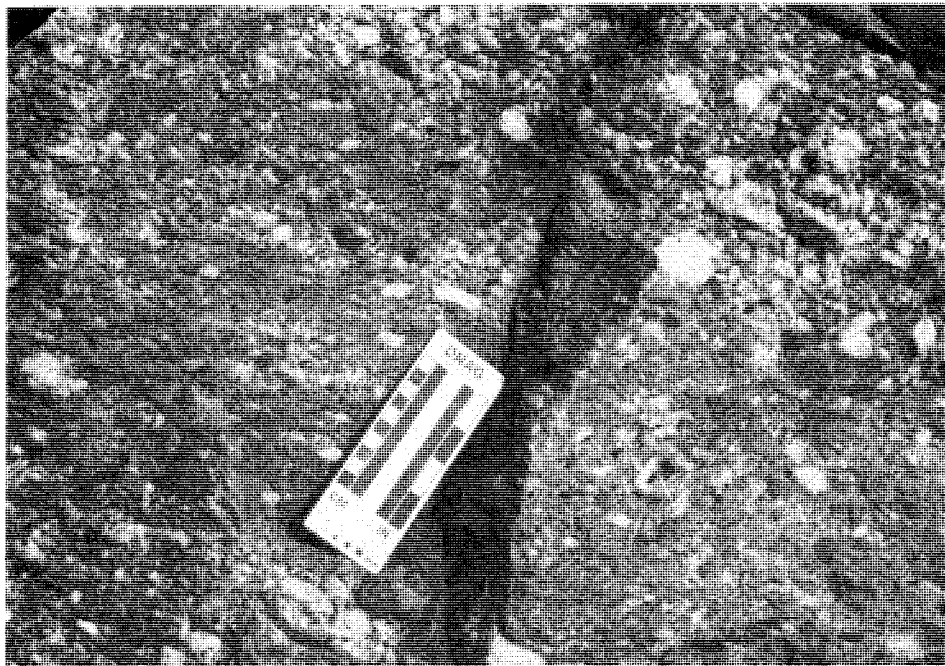


Figure 83. "Sugarloaf Mountain conglomerate" (unit 37) at STOP 12 (loose block). Note the relatively poor sorting and the abundance of white vein-quartz and dark lithic clasts.

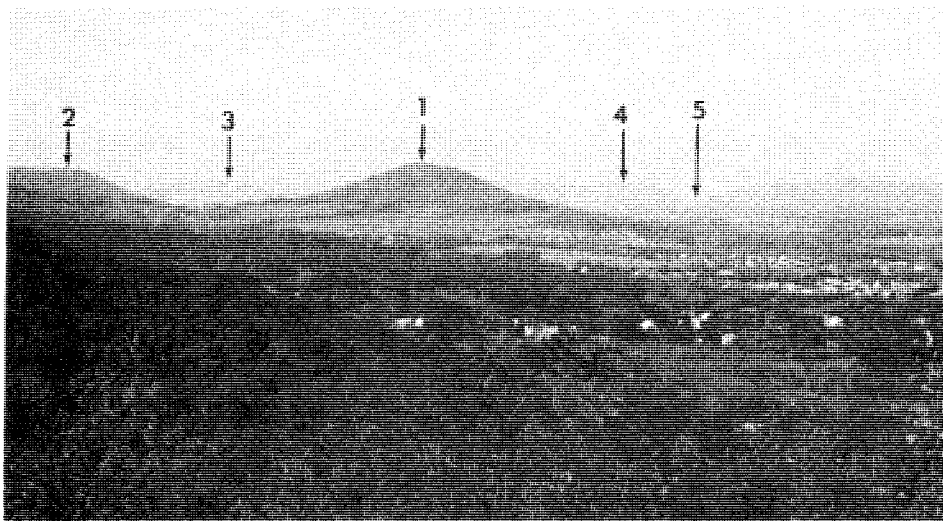


Figure 84. Sugarloaf Mountain (1) as seen from STOP 12. Other features marked are: 2 = Buck Mountain; 3 = McCauley Mountain; 4 = Nescopeck Mountain; 5 = Nescopeck Creek gap.

## POTTSVILLE FORMATION (part)

Only the lowermost part of the 250 feet of Pottsville Formation believed to be present in this area crops out at STOP 12. Based on stratigraphic tracing (Figure 82) and the probable correlation of tosudite-bearing rocks at Stop 8A with those near the base of the Pottsville near Tomhickon (see Smith and Barnes, this volume), we include this interval in the Schuylkill Member of Wood and others, 1969.

A disconformity at the base of the Schuylkill Member first becomes conspicuous along I-81 about 5 miles south of STOP 12 (Station 6 of Figure 82). At that point up to 18 feet of clast-supported (in part) oligomict conglomerate containing vein-quartz and quartzite cobbles to 15 cm in diameter abruptly overlies dusky-yellow weathered siltstone typical of the "lower Tumbling Run equivalent." Similarly, at the Humboldt Reservoir 3.5 miles southwest of STOP 12, abundant quartz and a few gneiss cobbles (to 10 cm in diameter) occur in the Schuylkill Member where it overlies olive-gray sandstone of the "lower Tumbling Run equivalent."

## Schuylkill Member (part)

From exposures along I-81, 0.7 mile south of here (Station 8 of Figure 82), we interpret the Schuylkill Member to be about 150 feet thick. It appears to include the coarsest beds in the Pottsville Formation of this area.

0 to 32 feet

Aside from the lowermost 1 to 5 feet which is pebbly, quartzose sandstone, the entire exposed thickness of the Schuylkill is quartz-rich oligomict conglomerate composed almost entirely of rounded, 1- to 5-cm, white vein-quartz pebbles (Figure 81f). The lenticular bedding units, dominance of horizontal stratification, and the lack of preserved fine-grained interbeds indicate that these conglomerates are braided river deposits.

The horizontally stratified conglomerates that make up the bulk of the exposed Schuylkill probably formed by vertical accretion on longitudinal bars (Rust and Koster, 1984); these coarse, clast-supported deposits probably represent high-flow deposits. Also conspicuous are the 1- to 2-foot trough crossbeds and, somewhat less so, the 3- to 10-foot planar crossbeds observed at Stop 8A (see Smith, 1970, 1971).

The numerous dark-gray shale clasts (largest of which is 41 cm long) in the lower part of the member were eroded from ephemeral carbonaceous mud beds deposited in "cut-offs," on bar tops, or in restricted overbank areas (Smith, 1970).

LEAVE STOP 12 from south side of PA Route 93, resuming mileage from this point.

|     |      |                                                      |
|-----|------|------------------------------------------------------|
| 0.4 | 65.6 | TRAFFIC LIGHT. TURN LEFT onto SR 3026.               |
| 2.3 | 67.9 | TRAFFIC LIGHT. TURN RIGHT onto US Route 309 (south). |
| 0.5 | 68.4 | TURN LEFT into parking lot of Genetti Motor Lodge.   |

END OF 2ND DAY.

# REFERENCES CITED IN ROAD LOG AND STOP DESCRIPTIONS

- Anonymous, 1855, A visit to Fillmore: Mauch Chunk Gazette, November 8.
- Ash, S. H., 1950, Buried valley of the Susquehanna River: U.S. Bureau of Mines Bulletin 494, 27 p.
- Berg, T. M., 1981, Stop 6. Huntley Mountain Formation, pisolite locality, in Berg, T. M., and others, leaders, Geology of Tioga and Bradford Counties, Pennsylvania: Annual Field Conference of Pennsylvania Geologists, 46th, Wellsboro, PA, Guidebook, p. 131-133.
- Berg, T. M., McInerney, M. K., Way, J. H., and MacLachlan, D. B., 1986, Stratigraphic correlation chart of Pennsylvania (2nd printing, revised): Pennsylvania Geological Survey, 4th ser., General Geology Report 75.
- Brasch, W. M., 1982 Columbia County place names: Orangeville, PA, Columbia County Historical Society, 253 p.
- Braun, D. D., Gillmeister, N. M., and Inners, J. D., 1988, in press, Postglacial and historic dip-slope rockslides in the Valley and Ridge of northeastern Pennsylvania (abs.): Geological Society of America Abstracts with Programs, v. 20, p. 10.
- \_\_\_\_\_, in press, Post glacial to historic dipslope rock block slides in the Valley and Ridge of northeastern Pennsylvania: Geological Society of America Special Paper.
- Braun, D. D., Miller, D. S., Miller, J. C., and Inners, J. D., 1984, Abandoned valley of the North Branch Susquehanna River at Mifflinville, Pennsylvania: Evidence for a pre-late Wisconsinan ice margin: Geological Society of America Abstracts with Programs, v. 15, p. 5.
- Braun, D. D., Wilshusen, J. P., and Inners, J. D., 1987, The Nanticoke rockslide of March 20, 1986: Pennsylvania Geology, v. 18, no. 2, p. 2-6.
- Budel, J., 1982, Climatic geomorphology: Princeton, NJ, Princeton University Press, 443 p.
- Campbell, M. R., 1903, Geographic development of northern Pennsylvania and southern New York: Geological Society of America Bulletin, v. 14, p. 277-296.
- Carmer, C., 1955, The Susquehanna: New York, David McKay, 493 p.
- Cotter, J. F. P., 1983, The minimum age of the Woodfordian deglaciation of northeastern Pennsylvania and northwestern New Jersey: unpublished Ph.D. dissertation, Lehigh University, 151 p.
- Cotter, J. F. P., Ridge, J. H., Evenson, E. B., Sevon, W. D., Sirkin, L., and Stuckenrath, S., 1985, The Wisconsinan history of the Great Valley, Pennsylvania and New Jersey, and the age of the "Terminal Moraine": In Evenson, E. B. (ed.), Friends of the Pleistocene Field Conference, 48th, Guidebook, p. 1-59.
- Daddow, S. H., and Bannon, B., 1866, Coal, iron, and oil; or the practical American miner: Philadelphia, Lippincott, p. 196.
- Davis, W. M., 1889, The rivers and valleys of Pennsylvania: The National Geographic Magazine, v. 1, no. 3, p. 183-253.
- Davis, W. M., and Wood, J. W., 1890, The geographic development of Northern New Jersey: Boston Society of Natural History Proceedings, v. 24, p. 365-423.
- Edmunds, W. E., and Eggleston, J. R., 1984, Field guide to the Pennsylvania Anthracite region: 63 p.
- Gray, M. B., 1984, Slickensided soil fractures -- indicators of strain and deformation processes in the Bloomsburg Formation, central Pennsylvania (abs.): Geological Society of America Abstracts with Programs, v. 16, p. 19.
- Groshong, R. H., 1975, Strain, fractures, and pressure solution in natural single-layer folds: Geological Society of America Bulletin, v. 75, p. 863-900.
- Hack, J. T., 1960, Interpretation of erosional topography in humid temperate regions: American Journal of Science, v. 258-A, p. 80-97.
- \_\_\_\_\_, 1965, Geomorphology of the Shenandoah Valley, Virginia and West Virginia and Origin of the residual ore deposits: U.S. Geological Survey Professional Paper 484, 84 p.
- \_\_\_\_\_, 1975, Dynamic equilibrium and landscape evolution, in Melhorn, W. N. and Fernald, R. C. (eds.), Theories of landform development: Binghamton, NY, Publications in Geomorphology, p. 87-102.
- Henry, M. S., 1860, History of the Lehigh Valley: p. 367-369.
- Hewett, D. F., 1917, Some manganese mines in Virginia and Maryland, in Ransome, F. L. and Gale, H. S., Contributions to economic geology, 1916, Part I: U.S. Geological Survey Bulletin 640, p. 37-71.

- Hoskins, D. M., J. D. Inners, and J. A. Harper, 1983, Fossil collecting in Pennsylvania (3rd edition): Pennsylvania Geological Survey, 4th Ser., General Geology Report 40, 215 p.
- Inners, J. D., 1978, Geology and mineral resources of the Berwick quadrangle, Luzerne and Columbia Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 174c, 34 p.
- \_\_\_\_\_, 1980, Meltwater erosion in Salem Creek valley, Luzerne County, Pennsylvania: Pennsylvania Geology, v. 11, no. 6, p. 5-11.
- \_\_\_\_\_, 1981, Geology and mineral resources of the Bloomsburg and Mifflinville quadrangles and part of the Catawissa quadrangle, Columbia County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 164cd, 152 p.
- Inners, J. D., Braun, D. D., and Gilmeister, N. M., 1988, "Danger -- falling rocks": the Chulasky rockslide: Pennsylvania Geology, v. 19, no. 3, p. 7-12.
- Inners, J. D., and Way, J. H., 1979, The Light Street thrust fault, northeastern Pennsylvania (abs.): Geological Society of America Abstracts with Programs, v. 11, p. 17.
- Inners, J. D., and Williams, J. H., 1983, Clinton Iron-ore mines of the Danville-Bloomsburg area, Pennsylvania: their geology, history, and present-day environmental effects, in Nickelsen, R. P., and Cotter, E., leaders, Silurian depositional history and Alleghanian deformation in the Pennsylvania Valley and Ridge: Annual Field Conference of Pennsylvania Geologists, 48th, Danville, PA, Guidebook, p. 53-63.
- King, P. B., 1950, Geology of the Elkton area, Virginia: U.S. Geological Survey Professional Paper 230, 82 p.
- Lesley, J. P., 1859, The iron manufacturer's guide: New York, John Wiley, 766 p.
- Levine, J. R., and Slingerland, R., 1987, Upper Mississippian to Middle Pennsylvanian stratigraphic section, Pottsville, Pennsylvania, in Roy, D. C. (ed.), Northeast Section: Geological Society of America Centennial Field Guide, v. 5, p. 59-63.
- Meckel, L. D., 1967, Origin of Pottsville conglomerates (Pennsylvanian) in the central Appalachians: Geological Society of America Bulletin, v. 78, p. 223-258.
- Moore, R. C., Lalicker, C. G., and Fischer, A. G., 1952, Invertebrate fossils: New York, McGraw-Hill, Inc., 766 p.
- Oleksyshyn, J., 1982, Fossil plants from the Anthracite Coal fields of eastern Pennsylvania: Pennsylvania Geological Survey, 4th ser., General Geology Report 72, 157 p.
- Peltier, L., 1949, Pleistocene terraces of the Susquehanna River, Pennsylvania: Pennsylvania Geological Survey, 4th ser., General Geology Report 23, 158 p.
- Pennsylvania Power and Light Co. [1975], Susquehanna Steam Electric Station, Units 1 and 2: Preliminary Safety Analysis Report, v. 1, p. (2.5)1D(2.5)24.
- Petrillo, F. C., 1986, Anthracite and slackwater: the North Branch Canal 1828-1901: Easton, PA, Center of Canal History and Technology, 280 p.
- Pierce, K. L., 1966, Bedrock and surficial geology of the McConnellsburg quadrangle, Pennsylvania: Pennsylvania Geological Survey, 4th series, Atlas 109a, 111 p.
- Powell, H. B., 1978, Philadelphia's first fuel crisis: University Park, The Pennsylvania State University Press, 167 p.
- Rispoli, R., 1981, Stress fields about strike-slip faults inferred from stylolites and tension gashes: Tectonophysics, v. 75, p. 29-36.
- Rust, B. R., and Koster, E. H., 1984, Coarse alluvial deposits, in Walker, R. G. (ed.), Facies Models (2nd ed.): Geoscience Canada, Reprint Series 1, p. 53-69.
- Schasse, H. W., Inners, J. D., and MacLachlan, D. B., in press, Geology and mineral resources of the Conyngham quadrangle, Luzerne and Schuylkill Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 175b.
- Sevon, W. D., 1985, Pennsylvania's polygenetic landscape: Annual Field Trip of the Harrisburg Area Geological Society, 4th, Guidebook, 55 p.
- Schultz, A. P., 1986, Ancient, giant rockslides, Sinking Creek Mountain, Southern Appalachians, Virginia: Geology, v. 14, p. 11-14.
- Smith, A. D. W., 1895, Report on the Anthracite region, in Lesley, J. P., and others, A summary description of the geology of Pennsylvania: Pennsylvania Geological Survey, 2nd ser., Final Report, v. 3, pt. 1, p. 1916-2152.

- Smith, N. D., 1970, The braided stream depositional environment: comparison of the Platte River with some Silurian clastic rocks, north-central Appalachians: Geological Society of America, v. 81, p. 2993-3014.
- \_\_\_\_\_, 1971, Transverse bars and braiding in the lower Platte River, Nebraska: Geological Society of America Bulletin, v. 82, p. 3407-3420.
- Varnes, D. J., 1978, Slope movement types and processes, in Schuster, R. L., and Krizek, R. J. (eds.), Landslides -- Analysis and control: National Academy of Sciences Special Report 176, p. 11-33.
- Watts, W. A., 1983, Vegetational history of the eastern United States, 25,000 to 10,000 years ago, in Wright, H. E. (ed.), Late-Quaternary environments of the United States: Minneapolis, University of Minnesota Press, v. 1, p. 306-307.
- Way, J. H., in press, Geology and mineral resources of the Millville and Washingtonville quadrangles, Montour, Columbia, and Northumberland Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 154cd.
- White, C. D., 1900, The stratigraphic succession of the fossil floras of the Pottsville Formation in the Southern Anthracite Coal Field, Pennsylvania: U.S. Geological Survey, 20th Annual Report, p. 743-953.
- White, I. C., 1883, Geology of the Susquehanna River region in the six counties of Wyoming, Lackawanna, Luzerne, Columbia, Montour, and Northumberland: Pennsylvania Geological Survey, 2nd ser., Report G7, 464 p.
- Williams, J. H., and Eckhardt, D. A., 1987, Groundwater resources of the Berwick-Bloomsburg-Danville area, east-central Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 61, 76 p.
- Wood, G. H., Jr., and Kehn, T. M., 1973, Geologic map of the Delano quadrangle, Schuylkill County, Pennsylvania: U.S. Geological Survey Geologic Quadrangle Map GQ-1054.
- Wood, G. H., Jr., Trexler, J. P., Arndt, H. H., Yelenosky, A., and Soren, J., 1956, Subdivision of the Pottsville Formation in Southern Anthracite Field, Pennsylvania: American Association of Petroleum Geologists Bulletin, v. 40, p. 2669-2688.
- Wood, G. H., Jr., Trexler, J. P., and Kehn, T. M., 1969, Geology of the west-central part of the Southern Anthracite field and adjoining areas: U.S. Geological Survey Professional Paper 602, 150 p.

## APPENDIX A

### DESCRIPTION OF SECTION MEASURED ON INTERSTATE ROUTE 81 NEAR DELANO, SCHUYLKILL COUNTY, PENNSYLVANIA (STOP 8A)

The measured section is located on the west side of the northbound lanes of I-81, 0.5 mile north-northeast of Interchange 38 and 0.75 mile northeast of Delano village. A continuous rock succession beginning in the middle of the upper member of the Mauch Chunk Formation and ending in the lower part of the Schuylkill Member of the Pottsville Formation is exposed between 40°50'45"N/76°03'26"W (north end) and 40°50'30"N/76°03'35"W (south end). Bedding dips 25 to 50 degrees south-southeastward into the complexly faulted Mahanoy syncline of Wood and Arndt (1973).

Description by J. D. Inners and L. J. Lentz (August, 1987).

| UNIT                            | THICKNESS<br>FEET | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                     |
|---------------------------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>POTTSVILLE FORMATION</b>     |                   |                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Schuylkill Member (part)</b> |                   |                                                                                                                                                                                                                                                                                                                                                                                                 |
| Concealed above.                |                   |                                                                                                                                                                                                                                                                                                                                                                                                 |
| 101                             | 16.7              | Conglomerate, medium to thick bedded, medium light gray (N6), quartzitic, coarse-grained sandy matrix, rounded quartz pebbles to 5 cm (average 1 cm); composed of wedge-shaped crossbed sets, 5 to 10 ft thick, that fine upward into pods of medium-dark-gray, coarse-grained to conglomeratic sandstone. Bottom contact sharp.                                                                |
| 100                             | 10.7              | Sandstone, medium bedded, light gray (N7) and dark gray (N3) current-laminated, medium to coarse grained, locally contains rounded quartz pebbles to 2 cm, quartzitic; well developed trough crossbeds in 0.5 ft sets; unit composed of broadly lenticular units forming stacked "channels" that interfinger with and cut out unit 99 above road level. Lower contact gradational to erosional. |
| 99                              | 5.5               | Interbedded sandstone and conglomerate, medium bedded, medium (light) gray (N5.5), fine grained to pebbly, rounded quartz pebbles 0.5 to 2 cm in conglomerate beds; bedding is lenticular. At top is 3.1 ft of platy fine- to medium-grained, micaceous sandstone, planar at the base and rippled at the top. Lower contact is gradational.                                                     |
| 98                              | 19.5              | Conglomerate, medium bedded, medium light gray (N6), quartzitic, bimodal (coarse grained sandy matrix and dominant pebble size of 1 cm); pebbles, rounded, mostly vein quartz to 4 cm, but a few carbonaceous shale; composed of wedge-shaped crossbed sets to 5 ft thick. Sharp, but welded contact with underlying unit.                                                                      |
| 97                              | 0-0.9             | Sandstone, light gray (N7), medium grained, well sorted, quartzitic. Sharp lower contact.                                                                                                                                                                                                                                                                                                       |
| 96                              | 10.5              | Conglomerate, similar to unit 98, but wedge-shaped crossbed sets are up to 10 ft thick; quartz pebbles mostly 1 to 2 cm, up to 4 cm. Grain size decreases upward within each individual bed of cross bed sets. Pebbles are dominantly vein quartz, but also dark gray quartzite and chert. Erosional lower contact.                                                                             |

|                                        |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|----------------------------------------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 95                                     | 1.7   | Sandstone, medium bedded, medium dark gray (N4), quartzitic, fine grained to pebbly (fines upward), moderately sorted, pebbles to 1 cm; well developed trough crossbeds in sets 0.25 to 0.5 ft thick. Wedge shaped unit that thickens higher on cut. Sharp lower contact.                                                                                                                                                                                                                                                   |
| 94                                     | 0-0.2 | Clay shale, medium gray (N5), subfissile. Lower contact sharp.                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 93                                     | 0.4±  | Conglomerate, medium bedded, dark gray (N3), moderately sorted, fine to coarse grained sandy matrix, quartz pebbles to 2 cm and dark gray shale clasts to 15 cm. Lower contact sharp.                                                                                                                                                                                                                                                                                                                                       |
| 92                                     | 0.6   | Clay shale, medium gray, subfissile, containing thin lenticular, quartzitic conglomerate bed in middle. Sharp lower contact.                                                                                                                                                                                                                                                                                                                                                                                                |
| 91                                     | 1.3±  | Sandstone, conglomeratic, quartzitic, medium bedded, medium dark gray (N4), fine grained to pebbly, scattered pebbles to 2 cm (mostly 1 cm or less). Banded; trough crossbeds in 1.3 ft sets. Dark gray (N3) shale clasts to 8 cm at top. Lower contact sharp.                                                                                                                                                                                                                                                              |
| 90                                     | 11.7  | Conglomerate, medium bedded, very light gray (N8), quartzitic, medium to coarse sandy matrix; composed mostly of rounded quartz pebbles to 2 cm, but also contains dark gray shale clasts to 3 cm scattered throughout and to 10 cm concentrated at base. Trough crossbedded. A coarse-sandy unit 4.0 ft from the top exhibits bimodal trough crossbedding in 1 ft sets. Few bluish tosudite blebs in matrix. Scoured, erosional lower contact.                                                                             |
| 89                                     | 16.6  | Sandstone, medium to thick bedded, medium gray (N5), quartzitic; mostly medium to coarse grained and well sorted, but with some lenticular, granular to pebbly bands (to 1 cm) ranging up to 0.6 ft thick (as at base) that fine upward into sandstone. Planar bedding dominant, but a few internal trough crossbeds evident; color banded medium gray (N5) to medium light gray (N6) at top and bottom. 1- to 2-in sandstone drape occurs 2.3 ft from top. Scattered bluish tosudite blebs in matrix. Sharp lower contact. |
| 88                                     | 5.4   | Conglomerate, medium bedded, very light gray (N8), quartzitic; rounded quartz pebbles to 3 cm, mostly 0.5 to 1 cm; also contains a few small dark gray shale pebbles; somewhat finer grained at top. Bedding is lenticular. Scoured, erosional lower contact.<br>Exposed thickness of Schuylkill Member = 102 ± ft                                                                                                                                                                                                          |
| Upper submember of Tumbling Run Member |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 87                                     | 0.65  | Sandstone, conglomeratic, planar bedded, medium light gray (N6), coarse grained to pebbly, quartzitic; rounded quartz pebbles to 1 cm. Weathering pale purplish red ("rose"). Sharp lower contact.                                                                                                                                                                                                                                                                                                                          |
| 86                                     | 1.4   | Sandstone, thin to medium bedded (laminated at top), light gray (N7), fining upward from pebbly at base to fine grained at top. Rounded quartz pebble to 2 cm. Laminated sandstone at top is trough crossbedded. Sharp lower contact. [South end of concrete wall].                                                                                                                                                                                                                                                         |

|    |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|----|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 85 | 1.3  | Sandstone, thin to medium bedded, medium dark gray (N4), predominantly medium grained, but containing a few quartz granules. Trough crossbedded. Sharp lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 84 | 1.2  | Conglomerate, medium gray (N5), moderately sorted, quartzitic; pebbles to 1 cm. Sharp lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 83 | 22.3 | Conglomerate, thick bedded, medium gray (N5), yellowish brown weathered, quartzitic; moderately sorted, subangular to subrounded quartz pebbles to 2 cm (mostly 1 cm), also some dark-gray shale clasts. Composed of wedge-shaped crossbed sets 3 to 6 ft thick; about 6 ft below top is a 1 ft-deep and 6 ft-wide channel fill of fine to medium-grained, micaceous quartz sandstone. At top is a 3-in drape of yellowish-brown weathered, shaly, fine-grained, micaceous sandstone, containing plant stems (recess in cut). Scattered blebs of bluish tosudite about 6 ft below top. Erosional lower contact.                                             |
| 82 | 3.9  | Conglomerate, medium bedded, medium gray (N5), quartzitic; moderately sorted, subangular to subrounded quartz pebbles to 1 cm, also dark gray shale clasts common in lower part. Internally trough crossbedded. Yellowish-brown weathered trunk casts are common, especially at top. Within this relatively thin interval, three wedge-shaped bar sequences occur between bottom and top of cut. Erosional lower contact.                                                                                                                                                                                                                                   |
| 81 | 12.1 | Sandstone, conglomeratic, medium to thick bedded, medium gray (bottom) to medium dark gray (top), argillaceous; medium grained to pebbly, subangular to rounded quartz to 2 cm (mostly 1 cm or less); dark gray shale pebbles (1 to 3 cm in diameter) common in lower 3 ft, but rare higher in unit. Grayish-red-purple (5RP4/2) stained bedding surfaces are common. Planar to trough crossbedded (small scale) internally. Composed of large (?) wedge-shaped crossbed sets that are bounded by distinct partings; thin (to 1 in) conglomerate lags are fused to top of crossbed sets. Unit thins as it is cut out above road level. Sharp lower contact. |
| 80 | 0.3  | Sandstone, medium gray (N5), argillaceous, fine grained but containing a few narrow bands of 1 cm+-rounded quartz pebbles, micaceous. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 79 | 2.0  | Conglomerate, medium bedded, light-brownish-gray (5YR6/1) matrix, rounded quartz pebbles 0.5 to 1 cm; lenticular band of 5 to 15-cm, dark-gray shale clasts at base. Undulatory bedding surfaces and possible trough crossbeds. Unit fines slightly upward. Contains casts of plant stems and small trunks. Rock exhibits distinctive grayish-red-purple weathering stain. Conspicuous quartz mineralization (including euhedral, iron-stained crystals to 2.5 cm long) on joint and fault surfaces. Sharp lower contact.                                                                                                                                   |
| 78 | 1.1  | Sandstone, medium bedded, medium dark gray (N4), medium to coarse grained, somewhat argillaceous, very micaceous. Planar bedded. Carbonized plant stems at top. Sharp lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 77 | 11.8 | Conglomerate, medium bedded, medium gray (N5), quartzitic, moderately sorted (fine grained to pebbly); pebbles to 2 cm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

|    |          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |          | at base, 0.5 to 1 cm in bulk of unit. Contains black coaly fragments, as well as dark-gray shale clasts. Mostly planar bedded, but a few wedge-shaped crossbed sets are present; contains a few lenses of coarse-grained sandstone 0.5 to 1-ft in thickness. One large, purplish-stained bark impression stands out. Some joints exhibit small, euhedral to subhedral quartz crystals. Prominent transverse fault surface cuts unit. Undulatory, erosional lower contact.                                                                                                                |
| 76 | 5.0-8.0  | Interbedded sandstone and conglomerate, medium to thick bedded, dark gray (N3) (lower part) to medium dark gray (N4) (upper part); coarsens upward from medium grained and micaceous at base to pebbly at top; carbonaceous. Conglomerate beds contain quartz pebbles to 2 cm and dark-gray shale clasts to 3 cm. Lenticular and planar bedded at base, trough crossbedded at top. Erosional lower contact.                                                                                                                                                                              |
| 75 | 9.3      | Sandstone, medium to thick bedded, medium dark gray (N4); in general, unit fines upward from coarse grained and granular at base to fine grained and micaceous at top; but at road level a sandstone wedge coarsens upward to a 3-in thick conglomerate with quartz pebbles and dark-gray shale clasts to 2 cm in diameter. Unit contains much carbonized plant debris, especially at top. Small trough crossbeds in upper shaly, micaceous sandstone. There is another, laterally equivalent bar sequence higher on cut. Erosional lower contact. [Culvert].                            |
| 74 | 5.0-10.7 | Predominantly sandstone, medium to thick bedded, medium dark gray (N4); medium grained; conglomeratic at base, containing rounded quartz pebbles to 3 cm., and fining upward. Sandy part of unit is micaceous and has vague parallel laminations. Partially cut out by superjacent channel higher on cut. Erosional lower contact.                                                                                                                                                                                                                                                       |
| 73 | 0-3.0    | Sandstone, poorly bedded and lenticular, medium dark gray (N4), coarse grained, quartzitic; contains abundant, randomly oriented, casts of small trunks (5 to 8 cm wide) ("log jam"). A curved fault surface locally forms top of unit. Erosional lower contact.                                                                                                                                                                                                                                                                                                                         |
| 72 | 12.0±    | Sandstone, locally conglomeratic, medium bedded, medium gray (N5) to medium dark gray (N4); predominantly fine to coarse grained (in distinct color and textural bands), but containing some quartz granules in lower and medial part and a lag of quartz pebbles (to 3 cm) about 3 in thick at top. Unit is composed of at least three coarsening-upward bar sets; at the top of the lowest set (3 ft above base of unit) is a faulted layer with abundant carbonized bark impressions; below upper bar set is a 0.5 ft lens of dark gray, silty clay shale. Gradational lower contact. |
| 71 | 4.9      | Conglomerate, medium bedded, medium dark gray (N4); rather poorly sorted, quartz pebbles and dark-gray shale clasts (to 2 cm) forming crude bands; pebble lag at top of unit contains pebbles to 4 cm. Some carbonized plant stems occur at the top. Strike joints are conspicuously quartz mineralized. Erosional lower contact.                                                                                                                                                                                                                                                        |
| 70 | 4.3      | Conglomeratic sandstone grading up into conglomerate, medium bedded, medium dark gray (N4; fine grained to pebbly                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

|    |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|----|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |       | in lower half and granular to pebbly in upper half (pebbles mostly 1 to 3 cm). 1 to 1.6 ft above base is a "log jam" of small carbonized plant trunks. Dark-gray siltstone clasts are common below the concentration of trunks. Pebbly lag layer 0.3 to 0.5 ft thick occurs at very top of unit. Pebbles in upper part have a purplish surficial stain. Strike joints are quartz mineralized. Sharp lower contact.                                                                                                                                      |
| 69 | 0-0.7 | Sandstone, thin bedded, medium gray (N5), medium grained, well sorted, quartzose and micaceous. Flaggy bedded. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                               |
| 68 | 4.0   | Conglomerate, very thick bedded, medium light gray (N6); 1-2 cm rounded quartz and dark-gray clay-shale pebbles in a medium to coarse-grained sandy matrix. Relatively planar bedded. Unit has a distinctive olive-gray and rusty orange weathering color. Erosional lower contact.                                                                                                                                                                                                                                                                     |
| 67 | 0-3.3 | Sandstone, medium bedded, dark gray (N3), medium grained and only moderately sorted, containing numerous subrounded quartz granules, argillaceous and micaceous. Bedding is planar but broadly undulating, except at base where there is a small channel developed. Locally cut out completely by overlying conglomerate. Unit also present high on cut where it is up to 10 ft thick. Erosional lower contact.                                                                                                                                         |
| 66 | 13.4  | Conglomerate, medium to thick bedded, medium gray (N5); moderately well sorted, composed of subrounded to rounded quartz pebbles to 4 cm (mostly 2 cm or less) and coarse to very coarse sand. Unit consists of stacked, lenticular, fining-upward channel units in which individual beds are largely planar. Carbonaceous coating on many pebbles. Erosional lower contact.                                                                                                                                                                            |
| 65 | 0-0.5 | Silty clay shale, dark gray (N3), subfissile; fossiliferous, containing carbonized plant stems (common). Polished and slickensided locally. Unit fills 5-ft $\pm$ long pocket that is cut out by overlying unit. Sharp lower contact.                                                                                                                                                                                                                                                                                                                   |
| 64 | 5.7   | Sandstone, conglomeratic, medium bedded (1-2 ft beds), dark gray (N3), dominantly medium grained; moderately sorted, containing many bands of subangular to rounded quartz and lithic pebbles mostly 1 cm or less. At the top is a 0.6 ft conglomerate-lag with clasts to 2.5 cm. Bedding is predominantly planar, but a few vague wedged-shaped crossbeds are present. Oblique joints are quartz mineralized; locally well developed spaced cleavage or strike joints. Bedding partings have a rusty-brown to purplish-red stain. Sharp lower contact. |
| 63 | 7.2   | Sandstone, medium bedded, dark gray (N3), fine to medium grained (fining upward); contains scattered quartz pebbles, especially in lower 2 ft. Unit composed of large scale trough crossbeds. Sharp lower contact.                                                                                                                                                                                                                                                                                                                                      |
| 62 | 4.4   | Conglomerate, sandy, very thick bedded, medium gray (N5), moderately sorted; composed of rounded quartz, dark-gray shale, and siderite pebbles to 2 cm and coarse- to very-coarse sand. Coarsens upward. Contains carbonaceous plant stems (common). Gradational lower contact.                                                                                                                                                                                                                                                                         |
| 61 | 2.7   | Sandstone, thin bedded; dark gray (N3), except medium dark gray (N4) at top; coarsens upward from dominantly fine                                                                                                                                                                                                                                                                                                                                                                                                                                       |

|    |         |                                                                                                                                                                                                                                                                                                                                                                                                                     |
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|    |         | grained at base to coarse grained at top; micaceous. Contains a few scattered quartz pebbles to 2 cm in basal 1 in. Planar bedded. Sharp lower contact.                                                                                                                                                                                                                                                             |
| 60 | 1.1     | Sandy silt shale, subfissile to laminated, grayish black (N2), micaceous; contains a 0.5 ft-thick lens of poorly sorted conglomerate near middle (quartz pebbles to 1 cm). Undulatory bedding. Large carbonized plant stems are common. Sharp lower contact.                                                                                                                                                        |
| 59 | 2.3     | Sandstone, thin bedded, medium dark gray (N4), medium to coarse grained; pebbly in lower 0.5 ft (rounded quartz pebbles 0.5 to 1 cm, rarely to 2 cm), then fines upward. Unit composed of large scale trough crossbeds. Rare carbonized plant fragments. Faulted lower contact.                                                                                                                                     |
| 58 | 1.0±    | Partially covered fault zone. Thick quartz vein occupies much of interval.                                                                                                                                                                                                                                                                                                                                          |
| 57 | 4.1     | Sandstone, medium bedded, dark gray (N3), medium grained, quartzose and micaceous. Few quartz pebbles to 1 cm. Gradational ? lower contact.                                                                                                                                                                                                                                                                         |
| 56 | 4.0     | Sandstone, conglomeratic, medium bedded, dark gray (N3), moderately sorted, fine grained to pebbly; rounded quartz pebbles to 4 cm occur in bands. Some carbonaceous shale drapes present. Faulted lower contact.                                                                                                                                                                                                   |
| 55 | 9.0     | Shear zone: conglomerate, medium to thick bedded, light gray (N7), moderately well sorted; mostly subrounded quartz pebbles to 1 cm (few 2 cm+). Carbonaceous zone 1.0 ft above base and some carbonaceous shale clasts scattered throughout. Injected by profusion of quartz veins. Faulted lower contact.                                                                                                         |
| 54 | 13.0    | Sandstone, conglomeratic, medium to thick bedded, dark gray (N3), coarse grained; subrounded quartz pebbles, mostly 1-2 cm (largest 2.5 cm), occur in lenses 0.2 to 2 ft thick. Plant stems and trunks concentrated along bedding, especially in conglomeratic pods. Faults common. Erosional, channelled contact with underlying unit.                                                                             |
| 53 | 3.4±    | Silt-clay-laminite shale, grayish black (N2), weathering (5YR2/1) and medium dark gray (N4), micaceous, rootworked at top (strap roots common). Unit becomes finer toward top. (Possible position of Lykens Valley No. 5 coalbed). Sharp lower contact.                                                                                                                                                             |
| 52 | 3.5-6.0 | Interbedded conglomerate and conglomeratic sandstone, medium bedded, medium dark gray (N4); sandy fraction is medium to coarse grained; subrounded quartz pebbles mostly 1 cm or less, few 2 cm. Irregularly trough crossbedded in sets 0.5 to 2 ft thick; crossbed sets are locally draped by dark gray (N4) plant-bearing, carbonaceous silt shale. Abundant carbonized plant debris at top. Sharp lower contact. |
| 51 | 2.6     | Sandstone, conglomeratic, thick bedded, banded light gray (N7) and dark gray (N3); moderately sorted, medium grained to pebbly, fining upward; subrounded quartz pebbles to 1 cm. Internally trough crossbedded, with dark gray, planar band at top. Contains numerous carbonized to purplish-(iron-) stained plant stems and trunks locally. Gradational lower contact.                                            |

- 50      6.7      Sandstone, conglomeratic, thick bedded, medium dark gray (N4); moderately sorted, medium grained to pebbly; sub-rounded quartz pebbles (to 2 cm) are scattered throughout and also form distinct bands, especially in lower part; also contains some hard black granules and pebbles; trough crossbedded at top. Grayish-red-purple (5RP5/2) stained casts of plant trunks and stems to 2.8 ft long and 0.7 ft wide) are common throughout unit; few carbonized stem clasts at top. Gradational lower contact.
- 49      12.0      Sandstone, locally conglomeratic, medium bedded (1-2 ft), medium dark gray (N4); coarse grained, scattered lenses of 0.5-1 cm quartz pebbles. Very carbonaceous, containing common carbonized plant fragments. Intensely fractured. Sharp lower contact.
- 48      3.2-6.2      Conglomerate, thick bedded to very thick bedded, dark gray (N3) to medium dark gray (N4); moderately well sorted, coarse sand matrix, quartz pebbles to 2 cm; also contains dark-gray shale clasts. Muddy drape with plant leaflets at top. Numerous large stem and trunk compressions and casts at base. Unit contains many quartz veins and slicken-sided surfaces. Erosional lower contact (relief of 3 ft).
- 47      2.0-5.0      Sandstone, medium bedded (disturbed in lower part), medium dark gray (N4), medium to coarse grained (some quartz granules), carbonaceous and micaceous. Trough crossbed sets to 0.5 ft thick at base. "Log jam": Abundant casts of plant trunks and branches, especially in lower part. Gradational lower contact.
- 46      4.9      Sandstone, medium bedded, medium dark gray (N4), medium grained, argillaceous and micaceous. Just below top are two gravel lenses, 0.3 to 0.5 m thick, containing quartz granules and pebbles to 1 cm. Squeezed pod of dark-gray carbonaceous shale 0.5 by 1.0 ft lies just below gravel lenses. Upper surface of unit is undulatory. Faint sedimentary banding evident locally. Wedge-shaped crossbeds in 1-2 ft sets at base. Numerous quartz veins cut unit. Gradational lower contact.
- 45      6.0      Interbedded conglomerate and sandstone, medium to thick bedded, medium dark gray (N4); sandstones are medium to coarse grained, containing a few granules, in relatively continuous beds 0.5 to 2.0 ft thick; conglomerates composed of rounded quartz pebbles and numerous dark gray shale clasts to 2 cm, in lenses 0.25 to 3 ft thick. 1.0± mm grains of shiny, red hematite are scattered throughout. At base is a 3-ft lens of quartz conglomerate containing numerous casts of plant trunks and stems. Gradational lower contact.
- 44      19.0      Sandstone, locally conglomeratic, medium to thick bedded, medium gray (N5) to light brownish gray (5YR6/1), limonite stained; predominantly coarse grained, scattered round quartz pebbles 1 to 5 cm in diameter in upper 4 ft of unit. Crossbedded (planar-tangential sets 1-2 ft thick). Quartz fracture-fillings, some parallel to joints, are common. Gradational lower contact.

- 43      23.0      Conglomerate, thick to very thick bedded, medium gray (N5); poorly sorted, medium to coarse grained sandy matrix, rounded quartz pebbles most commonly 1 to 2.5 cm (largest 6 cm); siliceous. Few dark-gray siliceous shale or argillite clasts to 15 cm; bent by loading, particularly in lower part of unit. Plane bedded; several very thin medium to coarse sandstone lenses, 0.1 ft or less in thickness, extending less than 1.0 m parallel to bedding. Sharp lower contact.
- 42      0-1.6      Sandstone, medium bedded, medium gray (N5); predominantly medium grained to coarse grained, siliceous. Lens shaped; plane bedded, possibly rippled at top (wave length 3 cm, wave height 2 mm). Coarsely cleaved (bedding-cleavage intersections parallel ripple crests locally). Sharp lower contact.
- 41      5.0      Conglomerate, very thick bedded, medium gray (N5); poorly sorted, medium grained to cobbly; pebbles and cobbles to 10 cm, 2-3 cm common, diverse lithologies (vein quartz, quartzite, chert, etc.). Dark gray shale clasts to 3 cm are common, few 6 to 9 cm. Planar bedded. Coarsely cleaved. Sharp lower contact.
- 40      0-0.4      Sandstone, thin to medium bedded, medium gray (N5), limonite stained; medium to coarse grained, few rounded quartz pebbles to 5 cm; siliceous. Lens-shaped; plane bedded, rippled at top (wave length 4 cm, intersections wave height 2 mm). Coarsely cleaved (bedding-cleavage intersections do not parallel ripple crests). Sharp lower contact.
- 39      5.2      Cobble conglomerate, very thick bedded, medium gray (N5); poorly sorted, medium grained to cobbly, clast supported; rounded quartz and quartzite pebbles and cobbles clasts to 6 cm are common (largest 11 cm); siliceous. Plane bedded. Limonite stained. Coarsely cleaved. Erosional and faulted lower contact.  
Thickness of upper submember of Tumbling Run Member = 283 ± ft
- 38      4.5      Lower submember of Tumbling Run Member  
Claystone, massive, light gray (N7), limonite stained; locally with ironstone oolites to 1 mm; cleaved and faulted. Deeply weathered, forms deep recess on slope. Sharp lower contact.
- 37      39.8      Mudstone, silty, massive, medium gray (N5), weathering light olive gray (5Y6/1) with limonite stain; contains two beds of grayish-black ironstone (siderite-hematite-quartz) concretions, 3.5 ft thick at 5 ft below top and 1 ft thick at 8 ft above base. One-mm ironstone ooids occur locally. Both concretions and ooids weather out to leave pits. Intensely cleaved. Sharp lower contact.
- 36      22.0      Sandstone, medium bedded; predominantly medium gray (N5), but locally "light and dark banded," small pocket of dark gray (N3) near base; fines upward from medium and coarse grained at base to fine grained at top; micaceous in lower part; also contains some medium-gray (N5) to light-olive-gray (5Y6/1) shale clasts to 1 cm. Possibly some macerated

|    |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
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|    |      | plant debris in lower part. Limonite stained. Badly fractured. Gradational contact at base.                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 35 | 23.0 | Sandstone, medium to thick bedded, medium gray (N5) (lower part) to medium light gray (N6) (upper part), fines upward from coarse and pebbly at base to medium at top, siliceous; numerous quartz pebbles to 1 cm (rarely to 5 cm) in lower part, fewer in upper part; abundant dark gray (N3) shale clasts to 1 cm in lower 5 ft; quartz and shale pebbles to 6 cm on upper bedding surface. Unit cut by many milky quartz and grayish-black siderite-hematite veins. Sharp lower contact.                                                                           |
| 34 | 4.0  | Conglomerate, medium bedded, medium dark gray (N4); poorly sorted, fine grained to pebbly; contains dark-gray, quartz-pebbly shale clasts to 27 cm and quartz pebbles to 3 cm. Very irregularly bedded. Limonite stained. Gradational lower contact.                                                                                                                                                                                                                                                                                                                  |
| 33 | 3.2  | Sandstone, conglomeratic, medium bedded, medium gray (N5); moderately sorted, coarse grained to pebbly; rounded quartz pebbles and dark-gray shale clasts to 2 cm; discontinuous dark gray shale partings may be shale-clast concentrations; siliceous. Limonite stained. Abundant quartz veins. Sharp lower contact.                                                                                                                                                                                                                                                 |
| 32 | 2.4  | Shale-clast conglomerate, unbedded, medium gray (N5) (matrix) to dark gray (N3) (clasts), matrix of coarse grained sand to pebbles; flattened shale clasts range from 2 to 30 cm in diameter, randomly oriented. In upper part is a 0.5 ft quartz pebble conglomerate lens. Abundant slickensides on irregular parting surfaces. Sharp lower contact.                                                                                                                                                                                                                 |
| 31 | 9.9  | Sandstone, medium to thick bedded, medium gray (N5) (lower part) to medium light gray (N6) (upper part); fines upward from coarse (scattered quartz pebbles to 1 cm) to fine grained; quartzose. Abundant dark gray shale clasts in lower 4.5 ft (range in size from 1 to 15 cm) and on top surface (0.5 to 4 cm); some shale clasts are pebbly and burrowed. Micaceous. Relatively planar bedded; vague planar crossbeds at top. Sharp lower contact.                                                                                                                |
| 30 | 32.5 | Mudstone, silty, massive bedded (irregular partings every 1 to 4 ft), medium gray (N5), weathered light olive gray (5Y6/2). Intensely cleaved; cleavage attitude varies from subvertical to steeply north-dipping. Gradational lower contact. [Culvert].                                                                                                                                                                                                                                                                                                              |
| 29 | 10.0 | Sandstone, medium bedded (1 to 2 ft beds), medium (light) gray (N5.5), weathered light olive gray (5Y6/2), fines upward from coarse to medium grained; few scattered quartz granules and pebbles to 1 cm; quartzose. In lower part are a few dark gray shale clasts to 8 cm+ as well as a pocket of such clasts that measures 3 ft along bedding. 1-ft (or less) tangential crossbed sets are locally developed. Macerated plant debris is common in the lower part. Coarsely cleaved; locally injected with quartz veins, especially at base. Faulted lower contact. |
| 28 | 1.5  | Fault gouge, weathers rusty red (5R4/4) and rusty orange; ranges from quartz-cemented mudstone chips to intensely                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

|    |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
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| 27 | 33.0  | cleaved mudstone. Zone thickens upward into 5-6 ft of cleaved mudstone like unit 29. Faulted lower contact. Mudstone, silty, medium bedded, light gray (N7); intensely cleaved (partings spaced 2-4 cm). Contains some 2-3 ft thick intervals of silty, more coarsely cleaved mudstone; at top is a small pocket (1.5 ft) of medium gray (N5) silty mudstone. Sharp lower contact.                                                                                                                                                                                                                                                              |
| 26 | 4.2+  | Mudstone, silty at top, massive, medium light gray (N6), weathered dusky yellow green (5GY5/2); intensely cleaved. Undulatory, yellow-brown stained bedding surface at top. Sharp lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 25 | 18.0  | Sandstone, medium to thick bedded, medium light gray (N6), weathered light olive gray (5Y6/2), fines upward from medium to fine grained, quartzose. Trough crossbedded; flaggy and micaceous at base. Smooth bedding surface at top. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                 |
| 24 | 11.5  | Sandstone, thick bedded, medium light gray (N6), weathered light olive gray (5Y6/2), coarse grained to pebbly, quartzose. Unit composed largely of trough-crossbed sets to 2 ft thick, with planar crossbeds internal to troughs. Planar bedded and micaceous at top. At base is a 3-ft conglomerate band containing 4-5 cm dark gray shale clasts and subangular quartz pebbles 0.5 to 3 cm in size; this grades up into crossbedded sandstone containing scattered pebble bands. Lower conglomerate also contains a few shale clasts to 14 cm in maximum dimension that are oriented subvertically to bedding. Sharp (faulted) lower contact. |
| 23 | 1.4±  | Sandstone, laminated to flaggy, light gray (N7), very fine grained, quartzose and micaceous. Contains abundant macerated plant debris. Unit appears to thicken and coarsen (to conglomeratic sandstone) laterally up cut. Sharp lower contact.                                                                                                                                                                                                                                                                                                                                                                                                  |
| 22 | 6.5   | Sandstone, conglomeratic, medium to thick bedded (in 1- to 3-ft beds), medium gray (N4); predominantly coarse grained, but fines upward; quartzose. Lower part contains abundant quartz, quartzite, and gray-shale pebbles to 5 cm (poorly sorted). Crudely cleaved and jointed, with vein quartz along partings and fractures. Unit weathers a distinctive yellow-orange-olive color. Sharp lower contact.                                                                                                                                                                                                                                     |
| 21 | 8.6   | Sandstone, medium bedded (in 1- to 2-ft beds), light gray (N7), predominantly medium grained but coarser at base and top, quartzose. In middle of unit is a 1.3 by 6 ft pod of shale-clast conglomerate, containing dark-gray shale pebbles to 2 cm. Upper 1 ft consists of a coarsening-upward bed with quartz pebbles to 2 cm at top. Cleaved and jointed. Sharp lower contact.                                                                                                                                                                                                                                                               |
| 20 | 0-1.0 | Clay shale, thinly laminated to fissile, weathered grayish orange (10YR6/4). Contains some thin, fine to medium grained sandstone interbeds. Unit pinches out toward top of cut. Sharp lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 19 | 12.0  | Sandstone, medium bedded, light gray (N7), fining upward from conglomeratic in basal 0.8 ft to medium grained (with scattered pebbles) in remainder of unit, quartzose. Pebbles mostly quartz, rounded to subrounded, and 1 cm or less in                                                                                                                                                                                                                                                                                                                                                                                                       |

- diameter (largest is 5 cm). Contains some vague trough crossbeds. A strong cleavage is developed perpendicular to bedding; quartz veins track cleavage partings. Gradational lower contact.
- 18      12.2      Sandstone, conglomeratic, thick bedded, light gray (N7), weathered yellowish orange (10YR7/6), medium grained to cobbly; overall unit appears to coarsen upward, but it contains numerous small fining-upward sequences. Contains a few rounded quartz cobbles to 8 cm, but dominant coarse clasts are rounded quartz and quartzite pebbles 0.5 to 2 cm in diameter. (Few chert and metamorphic rock clasts). Two discrete zones of flat-lying pebbles in middle of unit. Unit transected by quartz veins perpendicular to bedding. Gradational lower contact.
- 17      7.5      Cobble conglomerate, very thick bedded, medium light gray (N6), weathers yellowish orange; coarse sandy matrix, rounded cobbles and pebbles. Cobbles average 5 to 8 cm in diameter (some 10+ cm); vein quartz, gray and purple quartzite, black chert, jasper, dark gray shale and siltstone, etc. Cobble concentrations appear imbricated. Conglomerate thins laterally as it is replaced by sandstone. Sharp lower contact.
- 16      6.0      Conglomeratic sandstone and conglomerate, medium to thick bedded, light gray (N7), weathers dark yellow brown (10YR6/6); sandstone and matrix of conglomerates fine to coarse sand; unit fines upward overall, decrease in average pebble size upward; subrounded to rounded granules and pebbles. Pebbles range from 0.5 to 4 cm in diameter, mostly vein quartz, but considerable dark gray chert and gray shale. Conglomerate forms lenses 5 to 10 cm thick. Erosional lower contact (3+ ft of relief).
- 15      2.0      Sandstone, thick bedded, medium light gray (N6), weathered dusky yellow (5Y6/4), coarse grained to granular, quartzose. Unit pinches out toward top of outcrop due to erosion beneath overlying conglomerate. Sharp lower contact.
- 14      0-1.8      Conglomerate, medium light gray (N6), poorly sorted; numerous subrounded to rounded quartz pebbles 0.5 to 5 cm in diameter, as well as hard, light gray (N7) argillite clasts to 15 cm (flint clay?). Some large argillite masses may be "sedimentary diapirs" squeezed into conglomerate as a result of loading. Limonitic stain on fracture surfaces. Forms discontinuous lens having a sharp lower contact.
- 13      4.0      Sandstone, thin bedded, medium light gray (N6), weathered light olive gray (5Y5/2), fine grained, quartzose. Lower part, crossbedded; upper part, parallel laminated. Coarsely cleaved. Gradational lower contact.
- 12      6.5      Sandstone, conglomeratic, medium bedded (beds 1-2 ft), greenish gray (5G6/1), medium grained to pebbly. Pebbles are mostly vein quartz, but also jasper and metamorphic? rock fragments, up to 3 cm, subangular to rounded; also light-olive-gray shale clasts to 27 cm - possible sheared along fractures. Abundant quartz-filled veins perpendicular to bedding. Erosional contact with underlying unit. Thickness of lower submember of Tumbling Run Member = 286 ± ft

# MAUCH CHUNK FORMATION

|                                                                      |          |                                                                                                                                                                                                                                                                                                                                                                                                                             |
|----------------------------------------------------------------------|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Upper member (part)                                                  |          |                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 11                                                                   | 0-5.4    | Siltstone, massive, medium gray (N5), weathered medium olive gray (5Y6/2). Strongly cleaved. Upper part of fining-upward channel fill sequence. Gradational lower contact.                                                                                                                                                                                                                                                  |
| 10                                                                   | 4.6      | Sandstone, medium bedded, medium gray (N5), weathered medium olive gray (5Y6/2), very fine grained. Faintly trough crossbedded. Erosional lower contact.                                                                                                                                                                                                                                                                    |
| 9                                                                    | 5.0-10.0 | Mudstone, silty, massive, grayish red (5YR5/2), burrowed. Contains thin grayish horizontal and vertical streaks. Slickensided soil fractures well developed. Strongly cleaved and hackly. Thins to south. Gradational lower contact.                                                                                                                                                                                        |
| 8                                                                    | 2.0      | Siltstone and silty mudstone, laminated to medium bedded, medium gray (N5) (siltstone) and grayish red (5YR5/2) (mudstone); interbedded in upper 1 ft, lower 1 ft is reddish mottled, gray siltstone. Gradational lower contact.                                                                                                                                                                                            |
| 7                                                                    | 5.7      | Mudstone, silty, massive, grayish red (5YR4/2), mottled light olive gray (5Y6/1), few siltier bands 2-3 ft above base. Rootworked and hackly. Sharp lower contact.                                                                                                                                                                                                                                                          |
| 6                                                                    | 10.5     | Sandstone, medium bedded, grayish green (10GY5/2), weathered pale olive (10Y6/2), fine grained, planar-tangential cross-bedded. Erosional lower contact (relief up to 3 ft).                                                                                                                                                                                                                                                |
| 5                                                                    | 5.5      | Siltstone, thin to medium bedded in lower part, massive in upper part; dusky red (5R3/4), with some light olive (10Y5/4) bands in lower 2.5 ft; appears to fine upward and become more argillaceous at top. Intensely rootworked in upper 1 ft ("maroon" specks along roots). Olive bands are somewhat coarser, up to 0.4 ft thick. Grades laterally into overlying unit. Irregularly fractured. Gradational lower contact. |
| 4                                                                    | 7.6      | Mudstone, silty, massive, grayish red purple (5RP5/2), root-worked and burrowed; very silty in lower 0.3 ft. Highly cleaved; hackly to splintery. Gradational lower contact.                                                                                                                                                                                                                                                |
| 3                                                                    | 2.8      | Sandstone, massive, light olive gray (5Y6/1), very fine grained, crudely crossbedded. Contains numerous grayish red purple shale blebs. Gradational lower contact.                                                                                                                                                                                                                                                          |
| 2                                                                    | 3.5      | Sand-silt laminite, banded grayish red purple (5RP5/2) and medium gray (N5). Individual bands to 0.75 in thick. Gradational lower contact.                                                                                                                                                                                                                                                                                  |
| 1                                                                    | 1.2+     | Sandstone, massive, olive gray (5Y6/1), fine grained, micaceous. Mottled and rootworked. Covered lower contact. Concealed below.                                                                                                                                                                                                                                                                                            |
| Exposed thickness of upper member of Mauch Chunk Formation = 54 ± ft |          |                                                                                                                                                                                                                                                                                                                                                                                                                             |

## APPENDIX B

### DESCRIPTION OF SECTION MEASURED AT INTERCHANGE 41 OF INTERSTATE ROUTE 81 NEAR WEST HAZLETON, LUZERNE COUNTY, PENNSYLVANIA (STOP 12)

The measured section is located at Interchange 41 (PA Route 93) of I-81 at the edge of Butler Mountain, 1.75 miles northwest of West Hazleton borough. Approximately two-thirds of the thickness of the upper member of the Mauch Chunk Formation (units 1 to 59) is exposed on the southeast side of the northbound entrance ramp between 40°59'03"N/76°02'03"W (north end) and 40°58'52"N/76°02'00"W (south end). The remainder of the upper member of the Mauch Chunk and the lowermost part of the unconformably overlying Schuylkill (?) Member of the Pottsville Formation (units 61 to 77) is exposed along the northbound exit ramp south of Route 93 from 40°58'50"N/76°02'06"W to 40°58'44"N/76°02'06"N. The upper Mauch Chunk includes a thick, wholly non-red interval (units 53-75) that is equivalent to the lower submember of the Tumbling Run Member of the Pottsville Formation. Bedding dips 15° (north end) to 27° (south end) southward.

Description by H.W. Schasse (November, 1978) and J. D. Inners (April, 1988).

| UNIT                              | THICKNESS<br>FEET | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-----------------------------------|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>POTTSVILLE FORMATION</b>       |                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Schuylkill (?) Member (part)      |                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Concealed above.                  |                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 77                                | 30.0              | Conglomerate, medium to thick bedded, light gray (N7) to very light gray (N8), moderately sorted. Rounded pebbles 0.5 to 5 cm (average 1 to 2 cm), mostly white vein quartz, but dark-gray (N3) chert frequent; also fairly common are subangular, dark-greenish-gray to dark-gray silty-clay-shale clasts 2 to 14 cm in diameter (especially near base); one of the latter measures 41 cm long by 25 cm thick. Mostly tabular bedded; few large-scale planar-crossbed sets to 3 ft or more in thickness; also some trough-crossbed sets 1 to 2 ft thick in upper part of exposure (frost-rived ledges and tors on hillside above cut). Limonite stained at base. Erosional lower contact (slickensided). |
| 76                                | 0.5-<br>5.0       | Sandstone, medium bedded, very light gray (N8), coarse grained to pebbly, quartzose, friable. White, vein-quartz pebbles (mostly +1 cm) in local concentrations. Few 2-cm pebbles in uppermost part. Lower contact covered. Exposed thickness of Schuylkill (?) Member = 35 ± ft                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>MAUCH CHUNK FORMATION</b>      |                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Upper member                      |                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| ("Lower Tumbling Run equivalent") |                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 75                                | 4.9               | Covered interval.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 74                                | 6.2               | Interbedded very-fine-grained sandstone and silty clay shale, thin to medium bedded, medium gray (N5), weathered light olive gray (5Y5/2). Sandstones, tabular bedded and micaceous, mostly in beds 2 to 4 in thick. Shale beds 1 to 3 in thick. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 73                                | 1.3±              | Sandstone, medium bedded, medium light gray (N6), weathered light olive gray (5Y5/2), coarse to very fine grained (fin-                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

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|    |      | ing upward), micaceous. Mostly tabular bedded, but some trough crosslamination at base. Erosional lower contact (relief of 0.5 ft).                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 72 | 19.7 | Very fine-grained sandstone fining upward into silty mudstone, mostly medium bedded, medium light gray (N6), weathered light olive gray (5Y6/4); contains a few 1 to 3 in shaly zones; more thinly parted toward top. Possible south-dipping thrust fault in massive sandy siltstone 6.9 ft above base. Cleaved. Gradational lower contact.                                                                                                                                                                                                                                                           |
| 71 | 3.3  | Mudstone, massive, hackly, grayish orange (10YR7/4), silty to very fine sandy. Strongly cleaved and deeply weathered. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 70 | 3.3  | Sandstone, medium bedded, light olive gray (5Y5/2), very fine grained, micaceous. Tabular bedded. Brown, limonitic stain on fracture surfaces. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 69 | 5.0  | Mudstone, massive, hackly, medium light gray (N6); weathered light olive brown (5Y6/6), with numerous crusty, dark-yellowish-orange (10YR6/6), limonitic pods that may be weathered pyrite. Unit contains a few vaguely defined siltstone lenses to 5 cm thick. Gradational lower contact.                                                                                                                                                                                                                                                                                                            |
| 68 | 4.6  | Sandstone, medium bedded, light olive gray (5Y5/2), silty and very fine grained, crudely bedded. Brown, limonitic stain on weathered surfaces. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 67 | 1.6± | Sandstone, medium bedded, light olive gray (5Y5/2), pebbly to medium grained (fining upward), trough crosslaminated. Scattered white, vein-quartz pebbles to 1 cm at base. Erosional lower contact.                                                                                                                                                                                                                                                                                                                                                                                                   |
| 66 | 2.3  | Sandstone, thin to medium bedded, light olive brown (5Y5/6) weathered, very fine grained, micaceous, planar partings. Fractures weathered dark brown (limonitic). Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                          |
| 65 | 14.8 | Sandstone and conglomeratic sandstone, medium to thick bedded (thinner bedded at top), medium light gray (N6), weathered light olive gray (5Y7/2), coarse grained to pebbly, siliceous. Pebbles mostly vein quartz, subangular to rounded, 1 cm or less to 5 cm (rare); occur scattered in sandstone, as linear stringers, or as small lenses. Predominantly tabular bedded, but with some trough cross-stratification. Badly fractured. Gradational lower contact.                                                                                                                                   |
| 64 | 26.2 | Conglomerate and conglomeratic sandstone, medium to thick bedded, very light olive gray (5Y7/1), coarse grained to pebbly, moderately to poorly sorted. Lower part is conglomerate; also a 2 ft conglomerate pod about 2 ft from top. Pebbles mostly white vein-quartz, commonly iron-stained, but numerous olive-gray shale (to 4 cm) and dark-gray siltstone (to 3 cm) in lower conglomerate and profuse olive-gray shale clasts (1± cm) in upper conglomerate pod. Few low-angle trough cross-strata at base of some bedding units; some large-scale channelling present. Erosional lower contact. |
| 63 | 14.7 | Conglomeratic sandstone and conglomerate, medium to thick bedded, very light olive gray (5Y7/1), weathering dark-yellowish-orange (10YR6/6) speckled, coarse grained to pebbly, moderately to poorly sorted. Pebbles mostly vein                                                                                                                                                                                                                                                                                                                                                                      |

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| 62 | 17.4    | quartz, subangular to rounded, 0.5 to 5 cm in diameter (5 cm pebbles more common in lower part); also abundant light-olive-gray shale (0.5 to 5+ cm). Well jointed; joints are smooth, continuous, iron-stained. Erosional lower contact. Conglomerate, thick bedded, very light gray (N8), pebbly, moderately sorted, fining upward into 5 ft of medium bedded, very light gray (N8), coarse grained sandstone at top. Tabular bedded. Pebbles are overwhelmingly vein quartz, subangular to rounded; range from 0.5 to 4 cm in diameter, but mostly 1 cm or less; larger quartz pebbles are scattered throughout, not sorted into bands. Light-olive-gray shale clasts 4 to 8 cm in diameter are also common; largest is 16 cm. Conglomerate is friable; weathers with dark-yellowish-orange (10YR6/6) speckles. Abrupt lower contact. |
| 61 | 16.4    | Conglomeratic sandstone and conglomerate, medium to thick bedded, very light gray (N8), weathered grayish orange (10YR7/4), coarse grained and pebbly, fining upward into medium grained quartzose sandstone in upper 3 ft (middle 7 ft is conglomerate). Mostly tabular bedded, but containing a few large planar-crossbed sets to 2.3 ft. Pebbles mostly vein quartz, subrounded to rounded; 0.5 to 4 cm in diameter, but mostly 1 cm or less; scattered light-olive-gray shale clasts to 6 cm. Lower few feet not well exposed, and base covered.                                                                                                                                                                                                                                                                                     |
| 60 | 10.0±   | Covered interval beneath PA Rte. 93 (Valmont Parkway); probably siltstone and silty mudstone, greenish gray (5GY6/1) to yellowish gray (5Y8/1), micaceous, exposed in cut on right side of northbound lane of I-81 near Route 93 overpass. Section continues on north side of PA Route 93 along northbound entrance ramp to I-81. (Conglomeratic sandstone ledges exposed on north side of Route 93, east of unit 59 are included in unit 61).                                                                                                                                                                                                                                                                                                                                                                                           |
| 59 | 32.8    | Sandstone and conglomeratic sandstone, medium to thick bedded, very light gray (N8) (leached); fines upward from coarse grained and pebbly at base to predominantly medium grained at top; siliceous and micaceous. Basal 3 ft is pebbly conglomerate, consisting of rounded, vein-quartz pebbles to 3 cm in diameter and numerous olive-gray shale clasts to 11 cm. Claystone lenses at 5 and 11 ft above base, up to 1.3 ft thick, yellowish-gray (5Y7/2) to very light-gray (N8) weathered. Unit contains trough-crossbed sets to 3 ft thick. Sandstone is moderate-pink (5R7/4) weathered at top. Limonitic stains on fracture surfaces. Erosional lower contact.                                                                                                                                                                    |
| 58 | 2.0-6.6 | Laminated, very fine-grained sandstone grading upward to laminated siltstone and claystone, thinly partied, grayish-orange (10YR7/4), olive-gray (5Y7/2), and moderate-pink (5R7/4) weathered, micaceous. Shaly and rubbly weathering at top. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 57 | 1.6-2.3 | Sandstone, medium bedded, weathering yellowish-gray (5Y7/2) with rusty red speckles, coarse grained to sparsely conglomeratic, siliceous. Subrounded to rounded, vein-quartz pebbles, mostly 1 cm or less, iron-stained. Trough cross-laminated in sets to 1.3 ft thick. Unit contains a 0.5 ft                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

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|    |         | (±) pod of light-olive-gray (5Y5/2) shale-clast conglomerate 1.0 ft from top. Abrupt lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 56 | 1.0     | Shale-clast conglomerate, medium bedded, dominantly yellowish gray (5Y7/2), coarse sand to granule matrix, clast supported; shale clasts mostly flattened ovoids, commonly 5 to 8 cm in maximum diameter; few subrounded to rounded quartz pebbles to 1 cm. Sharp lower contact.                                                                                                                                                                                                                                                              |
| 55 | 23.0    | Conglomeratic sandstone, medium to thick bedded, medium light gray (N6), medium to coarse grained, moderately sorted; trough-crosslaminated in sets to 0.5 ft thick, with current ripples locally developed on bedding partings. Pebbles mostly white vein quartz, 0.5 to 1 cm in diameter; scattered through rock and locally concentrated into pods. Prominent channel cut-out passes through midst of unit, roughly dividing it into two similar, laterally equivalent subunits. Weathers rusty brown, limonitic. Erosional lower contact. |
| 54 | 0.8     | Silty mudstone and silty, very fine-grained sandstone, crudely thin bedded, light olive gray (5Y6/2), weathering shaly. Sharp lower contact.                                                                                                                                                                                                                                                                                                                                                                                                  |
| 53 | 15.7    | Sandstone, medium to thick bedded, medium light gray (N6), fine grained, siliceous; contains a poorly defined, 2.6 ft thick silty, very fine sandy zone, 2.3 ft from top. Weathers rusty brown, limonitic on fractures and exfoliation surfaces. Coarsely cleaved. Abrupt lower contact. Thickness of "lower Tumbling Run equivalent" = 240± ft                                                                                                                                                                                               |
|    |         | (Redbed and conglomerate sequence)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 52 | 0.3-3.3 | Mudstone, massive, rubbly to hackly, grayish red (10R4/2), medium parted. Light-olive-gray (5Y5/2) mottled and thinly parted at top. Thickens toward base of crop. Cleaved. Abrupt lower contact.                                                                                                                                                                                                                                                                                                                                             |
| 51 | 0.0-4.3 | Sandstone, thick bedded, light olive gray (5Y5/2), fine grained, siliceous, micaceous, cleaved; conspicuous rusty, limonitic crust on fracture surfaces. Unit wedges out at base of crop. Erosional lower contact.                                                                                                                                                                                                                                                                                                                            |
| 50 | 8.5     | Mudstone, massive, hackly, predominantly grayish red (10R4/2), locally mottled light olive gray (5Y4/2); very light-gray (N8), rippled siltstone (reduced zone) in upper 0.6 ft. About 2 ft above base is a lenticular (up to 0.6 ft thick) zone of calcareous red mudstone that weathers pitted and moderate brown (5YR3/4), overlain by 0.3 ft of pitted (leached) light-olive-gray, very fine-grained sandstone. Gradational lower contact.                                                                                                |
| 49 | 8.2     | Siltstone and silty mudstone, medium bedded, hackly, interbedded grayish red (5R4/2) and light olive gray (5Y5/2); colors interbedded on a 0.3 ft scale in the basal 3.0 ft, but grading laterally into each other in remainder of unit. Mudcracked and coarsely cleaved; cleavage may track mudcracks. Gradational lower contact.                                                                                                                                                                                                            |
| 48 | 1.6     | Mudstone, massive, hackly, grayish red (10R4/2); irregularly fractured, poorly cleaved. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 47 | 7.9     | Siltstone, medium bedded, light olive gray (5Y6/1), crudely banded, rusty weathered on joints and fracture surfaces. Contains several 1- to 6-in, very-fine-grained, parallel to                                                                                                                                                                                                                                                                                                                                                              |

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|    |         | trough-crosslaminated sandstone lenses. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 46 | 5.9     | Mudstone, massive, hackly, grayish-red ((10R4/2); probably burrowed and rootworked; intensely cleaved. Siltier and less cleaved in upper 0.5 ft. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                             |
| 45 | 3.3     | Sandstone, medium bedded, light olive gray (5Y5/2), fine grained; trough crosslaminations and low-angle channeling (frequent). Coarsely cleaved; numerous rounded exfoliation surfaces. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                      |
| 44 | 2.6     | Siltstone, massive, rubbly, grayish brown (5YR3/2) to olive gray (5Y3/2) (color changes laterally within unit). Conspicuous partings are less than 0.5 ft apart. Possibly some plant stems in olive-gray bed at top. Gradational lower contact.                                                                                                                                                                                                                                                                                                                         |
| 43 | 0.0-0.6 | Sandstone, medium bedded, lenticular, light olive gray (5Y5/2), fine grained, trough crosslaminated, locally micaceous. Coarsely cleaved. (Single discontinuous bed). Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                        |
| 42 | 3.3     | Siltstone and sandstone, interbedded, light olive gray (5Y5/2), thin to medium bedded, laminated in lower part; sandstone is fine grained, trough crosslaminated; siltstone is argillaceous. Blocky weathering; limonitic stain on joints and fracture surfaces. Gradational lower contact.                                                                                                                                                                                                                                                                             |
| 41 | 24.6    | Sandstone, thick bedded, dusky yellow green (5GY5/2), coarse to medium grained (fining upward), siliceous; tabular parted; trough crosslaminated (lower part) to planar laminated (upper part). At 5.2 ft above base is a pod of shale-clast conglomerate (up to 0.6 ft thick), approximately 13 ft wide. Limonitic stain on weathered surfaces. Abrupt lower contact.                                                                                                                                                                                                  |
| 40 | 3.6     | Sandstone and shale-clast conglomerate, interbedded, medium bedded, light olive gray (5Y5/2) to olive gray (5Y3/2). Unit consists of two lenticular coarse-grained sandstone beds and two lenticular "conglomerate" beds; "conglomerate" composed of olive-gray to light-olive-gray silty-clay-shale clasts to 6 in or more in diameter (average 4 in). Upper sandstone bed contains yellow weathered "oncolites" up to 2 inches in diameter. Erosional lower contact.                                                                                                  |
| 39 | 7.9     | Mudstone, massive, hackly, thin to medium parted, light olive gray, locally, silty. Sharp lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 38 | 8.8     | Sandstone, conglomerate and conglomeratic sandstone, interstratified, thick bedded, light olive gray (5Y5/2), coarse grained to pebbly (fining upward), moderately to poorly sorted, siliceous. Pebbles subrounded to rounded, predominantly quartz, to 4 cm in diameter, mostly 2 cm or less; occur in streaks 2 in or less thick (generally "one-pebble thick") except for 1-ft-thick pod about 5 ft from top of unit. Mostly planar bedded; trough-crosslamination sets to 3 in thick in upper 1 ft. Coarsely cleaved or crudely jointed. Gradational lower contact. |
| 37 | 13.1    | Conglomerate, very thick bedded, light olive gray (5Y5/2) (matrix), coarse grained to pebbly, poorly sorted, siliceous. Pebbles subangular to rounded; 1 to 10 cm in diameter, but largest common pebbles $\pm 4$ cm; polymict, approxi-                                                                                                                                                                                                                                                                                                                                |

|    |      |                                                                                                                                                                                                                                                                                                                                                                                                          |
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|    |      | mately 60% vein-quartz, 10% reddish quartzite, 15% greenish-gray quartzite, 10% dark-gray sandstone and chert, and 5% dark-gray siltstone; many quartz pebbles exhibit "rose" staining. Planar bedded; in upper part are several pods of medium light gray (N6), light-olive-gray (5Y6/1) weathered, coarse-grained, quartzose sandstone to 3 ft thick. Erosional lower contact.                         |
| 36 | 3.0  | Siltstone, thin to medium bedded; medium bluish gray (5B6/1), containing grayish-red (10R4/2) laminae, streaks and pods locally; very fine sandy; burrowed and mudcracked(?) (reddish spots and discontinuous, vertical streaks). Light-olive-gray weathered and argillaceous in upper 0.5 ft. Gradational lower contact.                                                                                |
| 35 | 1.3  | Mudstone, massive, hackly, grayish red (10R4/2); few disrupted medium-bluish-gray (5B6/1) laminae in lower and upper few inches. Medium-light-gray (N6), light-brown (5YR6/4) weathering calcareous nodules 0.5 to 3 cm in diameter concentrated in 2.5-in layer about 1 ft above base. Gradational lower contact.                                                                                       |
| 34 | 3.6  | Siltstone, coarsening upward into medium-grained sandstone, very thin to medium bedded; medium light gray (N6), with grayish red (10R4/2) laminae and bands in lower 2 ft. Upper sandstone is trough crosslaminated and micaceous, containing numerous red streaks and blotches (burrows?). Downward-directed "flame structures" (shallow mudcrack fillings?) in middle part. Gradational lower contact. |
| 33 | 7.2  | Mudstone, massive, hackly, grayish red (10R4/2). Several bluish gray (5B6/1), very silty bands to 0.5 ft thick in lower 3.9 ft. Intensely cleaved. Sharp lower contact.                                                                                                                                                                                                                                  |
| 32 | 0.6  | Sandstone, medium bedded, medium light gray (N6), weathering light olive gray (5Y5/2), very fine grained, planar bedded; contains a few grayish red splotches (burrows?). Single bed. Sharp lower contact.                                                                                                                                                                                               |
| 31 | 21.3 | Mudstone, massive, hackly, grayish red (10R4/2). Laminated, sandy and micaceous beds to 1 ft thick occur at 5 ft, 10 ft, and 16 ft above base. Intensely cleaved. Gradational lower contact.                                                                                                                                                                                                             |
| 30 | 1.3  | Sandstone, medium bedded, yellowish gray (5Y7/2), light olive gray (5Y5/2) weathered, mottled and laminated grayish red (10R4/2), very fine grained. Red laminae best developed in lower 0.5 ft; red flame structures at base. Burrowed?. Gradational lower contact.                                                                                                                                     |
| 29 | 5.9  | Mudstone, silty, massive, hackly, grayish red (10R4/2), medium parted. Few discontinuous beds of sandstone, light olive gray (5Y5/2) weathered, grayish red (10R4/2) mottled and laminated in lower 3 ft. Burrowed?. Gradational lower contact.                                                                                                                                                          |
| 28 | 3.9  | Sandstone, thick bedded, medium bluish gray (5B5/1), light olive gray (5Y5/2) weathered, very fine grained, siliceous. Trough crosslaminated in sets to 1.6 ft thick, some laminae having grayish-red (10R4/2) clay caps. Few red, argillaceous lenses to 0.5 cm thick. Red, vertical to inclined burrows? are common. Gradational lower contact.                                                        |

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| 27 | 2.6     | Siltstone, argillaceous, thin to medium bedded, predominantly grayish red (5R4/2); few, discontinuous, 2±-cm-thick, medium-light-gray (N6) sandstone beds in lower 0.6 ft. Sharp lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 26 | 2.0     | Sandstone, medium bedded, medium gray (N5) to medium bluish gray (5B5/1), very fine grained, current laminated and rippled. Three 0.6-ft beds separated by 2 to 5 mm thick, red mudstone drapes. Burrowed and mudcracked? (red blotches and streaks). Some wispy trails on top of red mudstone parting welded to upper sandstone bed. Sharp lower contact.                                                                                                                                                                                                                                                                                                                         |
| 25 | 2.0     | Siltstone, medium bedded, light olive gray (5Y5/2) and pale red (5R5/2); color changes laterally in upper part, but lower part is olive gray (also more hackly and argillaceous). Probably burrowed and/or rootworked, especially in lower part, where soft, red mudstone galls (burrows?) occur. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                       |
| 24 | 5.2     | Sandstone, medium bedded, greenish gray (5G6/1), fine to very fine grained (fining upward). Well developed planar laminations and trough crosslaminations; at least one planar crossbed set to 1 ft thick. Few very thin, discontinuous, red mudstone lenses. Red burrows and/or root traces occur infrequently on top of bedding partings. Coarsely cleaved. Gradational lower contact.                                                                                                                                                                                                                                                                                           |
| 23 | 3.3     | Siltstone, massive, rubbly, light olive gray (5Y5/2), fine sandy. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 22 | 6.2     | Sandstone, medium bedded, greenish gray (5GY5/1), weathered light olive gray (5Y5/2), very fine grained and silty; internally trough crosslaminated. Cleaved and badly broken; rounded exfoliation surfaces common. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 21 | 5.0     | Silty sandstone fining upward into siltstone, massive, rubbly to hackly, greenish gray (5GY5/1), light olive gray (5Y5/2) weathered, micaceous and argillaceous. Cleaved and badly broken. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 20 | 1.0     | Sandstone, laminated, very fine grained, grayish orange (10YR7/4) weathered, micaceous, with numerous quartz veins parallel to bedding. Gradational lower contact.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 19 | 11.1    | Sandstone, medium bedded, greenish gray (5GY6/1), weathered light olive gray (5Y5/2), fine to very fine grained (fining upward), micaceous (especially at base); mostly planar bedded, but with some internal trough crosslaminations. At 2.6 ft above base is laminated layer of weathered, very-fine-grained sandstone similar to unit 20. Sharp lower contact.                                                                                                                                                                                                                                                                                                                  |
| 18 | 0.0-9.8 | Calcareous breccia, thick bedded, dark greenish gray (5G4/1) (matrix) and medium light gray (N6) (clasts), fine grained to pebbly. Limy clasts are angular to rounded (many different shapes), mostly 1-6 cm in diameter; exhibit stratification parallel to bedding. Dark gray (N3), angular to subrounded, shaly, siltstone clasts, 1 to 10 cm in diameter (average 3 cm), are common; frequently oblique or perpendicular to stratification. Few sandstone beds to 0.3 ft thick at top of internal fining-upward sequences. Unit forms lens that tapers to extinction upslope (exposed length is about 75 ft). Lower contact mostly gradational, but locally abrupt and welded. |

- 17      9.2-11.5    Sandstone, medium bedded, light olive gray (5Y6/2), fine grained; tabular bedded, with abundant planar current-laminations; trough crosslaminated in lowermost part; channel (0.9 ft of relief) occurs 5 ft above base. Abundant pits 1 to 8 cm in diameter represent weathered-out limy clasts. Unit contains several pods of calcareous breccia, most notably about 1 ft above base (1 x 8 ft). Abrupt lower contact.
- 16      19.7        Mudstone, massive, hackly, grayish red (10R4/2), calcareous from 15 to 16.5 ft above base. Few medium light gray (N6) sandstone pods (lower middle part) and stringers (lower part). Intensely cleaved. Gradational lower contact.
- 15      1.6        Sandstone, medium bedded, medium gray (N5), mottled grayish red (10R4/2), silty to fine grained, rippled and trough crosslaminated, micaceous. Vertical red streaks and lenses may be burrows. Strongly cleaved. Gradational lower contact.
- 14      0.0-1.6    Sand-silt laminite, medium parted, grayish red (10R4/2) and medium light gray (interlaminated), containing a few sub-round limy nodules ("caliche"); rippled and trough crosslaminated. Grades laterally into thicker sandstone unit formed by merging of units 13 and 15. Gradational lower contact.
- 13      0.7        Sandstone, medium bedded, medium light gray (N6), fine grained; basal part is trough crosslaminated. Gradational lower contact.
- 12      1.6        Silty mudstone, containing vague intervals of silt-clay laminite, massive to laminated, grayish red (10R4/2), intensely cleaved. (May originally have been all laminated, but then disrupted by burrowing and rootworking). Gradational lower contact.
- 11      1.8-2.3    Sandstone, medium bedded, medium light gray (N6), very fine grained; containing trough crosslaminae distinctly inclined to basal surface. Local grayish red mottles and laminae, with vertical burrows beneath red laminae in middle of unit. Grades laterally into grayish red (10R4/2) sandy siltstone. Coarsely cleaved. Gradational lower contact.
- 10      13.4       Mudstone, massive, hackly to rubbly, predominantly grayish red (10R4/2); limy nodule ("caliche") zones at 1.3 and 3.3 ft above base. Numerous small greenish-gray reduction spots occur in discontinuous concentrations 0.5 to 2 in wide and up to 6 in wide that form distinct zones parallel to stratification. About 1 ft of sand-silt laminite at base. Intensely cleaved. Gradational lower contact.
- 9      0.0-0.7    Sandstone, massive (forming pods in grayish-red and medium-light-gray sand-silt laminite at top of unit 8), medium light gray, weathered light olive gray (5Y6/2), very fine grained and silty. Gradational into surrounding units.
- 8      20.0-20.7    Mostly mudstone and silt-clay laminate, massive to laminated, dominantly grayish red (10R4/2); limy nodules ("caliche") to 1.5 inches especially abundant in zones 7.9, 11.1, and 17.4 ft above base. Between 15.4 and 17.4 ft are many 1 to 3 mm greenish-gray reduction spots. Upper 2-ft± is sand-silt laminite, grayish red and medium light gray

|   |         |                                                                                                                                                                                                                                                                                                                                                                                                                 |
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|   |         | (N6). Coarser units exhibit current laminations; laminae in clayey units are disrupted. Gradational lower contact.                                                                                                                                                                                                                                                                                              |
| 7 | 6.6+    | Silty mudstone and silt-clay laminite, locally massive, grayish red (10R4/2) and light olive gray (5Y6/2). Laminated olive units are current rippled, lenticular (pinch and swell), and disrupted; contain many reddish blotches that may be burrows, as well as numerous reddish flame-structures; appear to occupy a shallow channel with a relief of 1.3 ft. Gradational lower contact.                      |
| 6 | 0.7-1.0 | Sand-silt laminite, medium parted; predominantly light olive gray (5Y6/1), but containing some grayish-red streaks. Lenticular ripple sets to 1 cm thick are common. Coarsely cleaved. Gradational lower contact.                                                                                                                                                                                               |
| 5 | 1.6     | Silt-clay laminite, dusky red (5R3/4), algal(?), locally disrupted by mudcracks, weathers hackly, limonite stained. Contains a questionable burrow, 13 cm long and 5 cm wide. Gradational lower contact.                                                                                                                                                                                                        |
| 4 | 9.5     | Interlaminated siltstone and sandstone (very fine grained), light olive gray (5Y6/2), hackly to rubbly weathering. Current laminated in both thicker sandstone layers and in sandy stringers in siltstone; some massive siltstone in lower part. Rusty and reddish-brown stained on exposed surfaces. Unit looks crudely disrupted.                                                                             |
| 3 | 2.6     | Sandstone (very fine grained) grading upward into coarse siltstone, medium bedded, dusky yellow (5Y6/4) weathered, planar current-laminated, micaceous. Gradational lower contact.                                                                                                                                                                                                                              |
| 2 | 7.5     | Sandstone, medium to thick bedded, medium gray (N5) to greenish gray (5G5/1), fining upward from coarse to fine grained, siliceous, micaceous; containing some rounded pebbles and granules to 1 cm. Exhibits small-scale tough crossbed sets 0.3 to 0.5 ft thick. Gradational lower contact.                                                                                                                   |
| 1 | 2.6     | Sandstone and conglomerate, medium to thick bedded, medium light gray (N6), coarse grained to pebbly, siliceous; sub-rounded to rounded quartz pebbles to 5 cm (abundant) sub-rounded dark-gray shale clasts to 2 cm (common). Conglomerate occurs in pods to 1-ft thick; numerous scattered pebbles in sandstone. Lower contact covered.<br>Exposed thickness of redbed and conglomerate sequence = 317.0 ± ft |

## APPENDIX C

### HISTORICAL CHRONOLOGY OF THE MINING INDUSTRY IN THE EASTERN MIDDLE ANTHRACITE FIELD AND NEARBY AREAS

compiled by  
Jon D. Inners  
Pennsylvania Geological Survey

In the Middle Coal fields, on the plateau on which Hazleton stands, there were once green fields which afforded ample pasture for cattle. Most of this is now torn by strippings, and the surface of this region today - presents an appearance which defies description.

Peter Roberts, Anthracite coal communities (1904)

- 1789 Construction of the Lehigh and Susquehanna Turnpike between Berwick and Mauch Chunk began.
- 1795 Tench Coxe bought a vast tract of land along the upper reaches of the Lehigh River that included much of what is now the Eastern Middle Anthracite field. In the same year he published A View of America, in which he noted the occurrence of coal in the "vicinity of Wyoming and Susquehanna" and "[o]n the headwaters of the Schuylkill and Lehigh."
- 1809 Jacob Drumheller became the first resident of what is now Hazleton when he opened a stage station and tavern near the "Hasselschwamm," i.e., the Hazel Swamp. (The upland plateau is poorly drained because of the temporary base level provided by the rim of resistant Pottsville conglomerate.)
- 1810 Lehigh and Susquehanna Turnpike completed, passing through future Beaver Meadows, Hazleton, Conyngham, and Nescopeck (approximately course of present PA Route 93).
- 1812 Nathan Beach discovered coal in what is now Banks Township, Carbon County, about one mile west of Beaver Meadows in the Jeansville basin. He opened a "quarry" there in 1813 and shipped coal to Berwick over the "Turnpike."
- 1820 Consolidation of the Lehigh Coal Mining Company and the Lehigh Navigation Company into the Lehigh Coal and Navigation Company marked the actual beginning of the anthracite industry.
- 1826 John Charles, a Conyngham blacksmith, discovered coal just west of present Hazleton. Traditional accounts say he was hunting in the area and made the initial find in the loose dirt at the entrance to a groundhog's burrow.
- 1829 (June) Lehigh Canal completed between Mauch Chunk and Easton.

- 1830 Beaver Meadows Railroad and Coal Company chartered. In 1836 a 26-mile railroad was built from the Beaver Meadows coal basin to the Lehigh Canal at Penn Haven, 6 miles above Mauch Chunk. Coal shipments began the following year.
- 1835 First Pennsylvania Geological Survey began work in the anthracite fields. Initial field studies were completed in 1841.
- 1836 (March 18) Hazleton Coal Company incorporated to mine coal in the area originally discovered by John Charles. Mining operations commenced the following year, Arioivistus Pardee (1810-1892), engineer and superintendent. The first shipments of coal went out in 1838.
- 1836 Experimental use of anthracite as the sole fuel on some locomotives of the Beaver Meadows Railroad. However, real progress in the use of anthracite as a locomotive fuel was not made until the 1850's.
- 1836 Coleraine Colliery opened at present Junedale, Carbon County, in the Jeansville basin.
- 1838 Lehigh Canal extended to White Haven.
- 1839 Pioneer Furnace near Pottsville produced pig iron using anthracite continuously for fourteen weeks.
- 1840 (July 3) David Thomas, an immigrant Welsh ironmaker, successfully blew in an anthracite blast furnace at Catasauqua, Lehigh County. Within fifteen years more iron was being smelted with anthracite than with any other fuel.
- 1840 First coal shipped out of the Buck Mountain area (now Foster Township, Luzerne County).
- 1844 Gideon Bast erected the first anthracite breaker at Wolff Creek Colliery near Minersville in the Southern field. Bast used a system of steam-driven roll crushers and screens developed by Joseph Battin.
- 1848 William Milnes founded Jeansville and opened first coal mine in that vicinity.
- 1850 Milnesville settled. William Milnes commenced mining operations there (Little Black Creek basin).
- 1850 Ario Pardee began producing coal at Cranberry in the Hazleton basin.
- 1851 (April 3) Hazleton incorporated as a borough.
- 1851 Packer, Carter and Company opened mines at Stockton in the Hazleton basin east of Hazleton.
- 1851 German Pennsylvania Coal Company began operations at Tresckow (Carbon County) in the Jeansville basin, sinking a shaft and building a breaker.

- 1854 Sharp, Leisenring, Foster and Weiss (Sharpe, Leisenring and Company) opened the Council Ridge Colliery at Eckley. The first shipment of coal was made on a newly completed branch of the Lehigh Valley Railroad in 1855.
- 1855 James Taggart opened a slope on the "Big Vein" (Mammoth) at the Spring Brook Colliery in Audenried (Carbon County), shipping his first coal on the Beaver Meadows Railroad in 1856. A second slope was initiated in 1858 and leased soon afterward to George K. Smith and Company.
- 1858 George B. Markle (1827-1888) established firm of G. B. Markle and Company in partnership with J. Gillingham Fell, Ario Pardee, and William Lilly. Markle was an accomplished mining engineer, inventing the "Markle Pump" and making numerous improvements in coal crushers and jigs.
- 1858 Mining of the Buck Mountain seam on McCauley Mountain (Columbia County) began.
- 1862 (July 4) F. W. Langdon, a mine foreman notorious for "short weighing," was openly stoned to death at a picnic at Audenried. This was one of the early crimes subsequently pinned on the "Molly Maguires."
- 1862 Freshet destroyed the White Haven extension of the Lehigh Canal. This part of the canal was subsequently abandoned.
- 1863 (November 5) George K. Smith, operator of the New York and Lehigh Coal Company mines at Yorktowne (near Beaver Brook), was assassinated in his home at Audenried, reputedly by "Mollies."
- 1865 (February) Coxie Brothers started their colliery at Drifton, shipping coal the next year.
- 1865 Upper Lehigh Coal Company laid out "patch town" of Upper Lehigh. Mining commenced the following year at two mines, and coal was first shipped out in 1867.
- 1868 John Siney (1831-1880), an Irish immigrant via Lancashire in England, succeeded in organizing the Workingmen's Benevolent Association (WBA) of Schuylkill County. At its peak, 30,000 miners, or four-fifths of all anthracite workers belonged to an expanded WBA.
- 1869 (September 6) Fire at the Avondale Colliery of the Steuben Coal Company near Pittston in the Northern field. 110 men and boys died when a new breaker, built directly over the only entrance to the mine, caught fire. This was the first major mine disaster in the anthracite fields, and no subsequent accident exacted a higher toll of lives. A few months later, the legislature passed the state's first mine safety act.
- 1869 (December 18) Mine cave-in at Stockton swallowed up the cottage of Isaac Rough, killing his entire family and two boarders besides, six in all. Breast-and-pillar mining of the Mammoth seam on a subvertical north-dip along the south side of the Hazleton basin resulted in catastrophic subsidence for nearly one-half mile along strike.

- 1869 A. Pardee and Company laid out the colliery and "patch" at Lattimer in the Little Black Creek basin.
- 1870 Slate picking tables and "breaker boys" introduced at the Hill and Harris Colliery in Mahanoy City in the Western Middle field.
- 1870 Franklin B. Gowen (1836-1889) became president of the Philadelphia and Reading Company.
- 1871 Branch line of the Lehigh Valley Railroad completed from Hazleton to Tomhickon and Derringer, stimulating development of the West Black Creek and Roberts Run basins.
- 1873 Lehigh Valley Railroad purchased 30,000 acres of coal lands, mainly in the Eastern Middle field.
- 1874 Lehigh Valley Coal Company obtained control of mines in Jeansville area from Spring Mountain Coal Company.
- 1875 Coxie Brothers Coal Company built a miners' hospital at Drifton that was used until the Hazleton State Hospital opened twenty years later.
- 1875 "The Long Strike." A violent, five month-long confrontation between workers and mine owners ended in a bitter defeat for the WBA. In a period of reprisals following the strike, the "Mollies" allegedly committed seven murders.
- 1876 "Molly Maguire" trials in Mauch Chunk (January) and Pottsville (May). At the second trial, James McParlan (alias "James McKenna"), a Pinkerton spy, testified against five men accused of murdering policeman James Yost. Franklin B. Gowen served with the prosecution and was successful in pinning much of the terrorism rampant in the coal fields on the Ancient Order of Hibernians.
- 1877 (June 21) "Black Thursday." Ten "Molly Maguires" executed in Mauch Chunk and Pottsville. Within a year and a half, ten more Irishmen died on the gallows at Mauch Chunk, Bloomsburg and Sunbury.
- 1877 (July-October) Great railroad strike. Labor unrest spread to the coalfields at the end of July, and on August 1, six strikers were killed and 54 wounded when Coal-and-Iron Police under W. W. Scranton fired into a crowd. In mid-August miners in the Hazleton area struck.
- 1877 A cave-in entombed miners Pierson and Mourish in the Jeddo No. 1 Mine. Their bodies were not recovered until June 20, 1922.
- 1878 (December 18) John "Black Jack" Kehoe, the reputed "King of the Mollies," was executed in Mauch Chunk for the murder of Frank Langdon in Audenried, more than 15 years previously.
- 1879 (January 14) James McDonnell and Charles Sharp were hanged at Mauch Chunk for the murder of Charles K. Smith in 1863, a last minute reprieve from Governor John Hartranft arriving minutes too late.

- 1879 (May 6) Gas explosion killed 5 miners at the Audenried Colliery of the Lehigh and Wilkes-Barre Coal Company.
- 1879 (October 9) Peter McManus executed in Sunbury for the murder of Frederick Hesser, night watchman at the Hickory Run Colliery (Northumberland County) on December 18, 1874. He was the twentieth and last of the "Mollies" to die on the gibbet.
- 1879 Coxe Brothers began developing mines in the Roberts Run and Black Creek basins, eventually opening the Gowen, Deringer, and Tomhickon Collieries.
- 1879 Eckley Coxe (1839-1895) opened the Drifton School of Industry, later to become the Mining and Mechanical Institute at Freeland. Coxe was a noted mining engineer, well known for his work on coal waste reclamation. He was president of the American Institute of Mining Engineers (AIME) from 1878 to 1880.
- 1880 At about this time, A. Pardee and Company began stripping of the enormously thick Mammoth seam at the "western spoon" of the Hollywood syncline in the Little Black Creek Basin.
- 1881 (July) Second Pennsylvania Geological Survey commenced organized studies in the anthracite fields.
- 1881 Coxe Brothers acquired the old Beaver Meadows Colliery north of Beaver Meadows (abandoned since 1850) and began to mine coal.
- 1884 (July-August) Mine workers struck against G. B. Markle and Company over deductions from pay for bills at the company store. They lost.
- 1885 Pennsylvania legislature passed a law making it illegal to employ boys under 14 years of age inside mines or under 12 in surface jobs.
- 1885 Miners' and Laborers' Amalgamated Association formed.
- 1885 Hazleton annexed the "Diamond Addition," doubling the size of the community. The added land encompassed the high ground on "Church Hill" (Council Ridge) northwest of the old borough line (now Diamond Street).
- 1886 Coxe Brothers took over mining operations at Eckley.
- 1887 (August 9) Construction of the Big Black Creek Canal began. It was finished on August 28, 1889. This relocation of Black Creek figured in the mine inundations which spurred construction of the Jeddo Tunnel.
- 1887 (August) Amalgamated Association called a strike in the Lehigh field and 20,000 men walked out. When the Knights of Labor joined in, the strike spread to the Schuylkill field. The mine owners, including Ario Pardee, the Coxes, and the Markles in the Hazleton area, stood firm, and the miners were forced to capitulate.
- 1887 Coxes opened Sheppton mines, shipping their first coal in 1891 upon completion of the Delaware, Schuylkill and Susquehanna Railroad.

- 1890 United Mine Workers of America (UMWA) formed by the merger of the Miners' National Trade Assembly 135 of the Knights of Labor and the American Miners' Federation, successor to the Amalgamated Association.
- 1890 Surface mining began around Eckley.
- 1891 (February 4) Mining accident at the Spring Mountain No. 1 Mine near Jeansville in the Honeybrook basin. A blast broke through a barrier pillar into old flooded mine workings, and the subsequent rush of water drown 13 men. Four men were rescued 20 days later.  
In that same month, the Hazleton Hospital opened under the financial tutelage of the Coxe family.
- 1891 Driving of the Jeddo Tunnel was begun under the supervision of John Markle, son of George B.
- 1891 Hazleton became a city.
- 1894 (July 17) Eight men killed in explosion of powder and dynamite at the East Sugar Loaf Colliery (Linderman and Skeer) near Stockton.
- 1894 John Rinne, assisted by John Fahy, began organizing UMWA locals in the Anthracite region.
- 1896 Mine cave-in on Lehigh Valley Railroad between Stockton and Hazleton caused derailment of passenger train and death of its engineer, Michael Lonzer.
- 1897 Fahy, now District President, lobbied to restrict Immigration, supporting the Campbell Act in the State Legislature.
- 1897 (August-September) The following train of events led inexorably to the "Lattimer Massacre":
- (August 14) Mule drivers walked off job at the Honey Brook Colliery near McAdoo. Superintendent Gomer Jones had set up a central stable for mules used in several Lehigh and Wilkes Barre Coal Co. mines, but drivers would not be paid for extra time required to driving mules from individual mines to stable. The next day a wild-cat strike idled the Honeybrook operation, and Jones was badly beaten up.
- (August 21) First pay envelopes with deductions for immigrant tax of the Campbell Act distributed. Employers passed a 3 cents-per-day tax for each adult immigrant employee onto the workers. Dissatisfaction spread throughout the coal fields, but was centered in the Slavic community of the Hazleton area.
- (August 27) 500 slavs struck the Van Wickle and Company colliery at Coleraine. Many marched from Beaver Meadows through Hazleton to Milnesville, trying to intimidate workers at other collieries to join strike.
- (September 3) Strikers marched from McAdoo to close Jeansville No. 1, Hazle, Cranberry, and Hazle Brook Breakers.

(September 10) The "Lattimer Massacre." About 300 miners marched from Harwood to Lattimer to close down Lattimer mines. Nineteen were killed and 32 wounded, when deputies under Luzerne County Sheriff James Martin fired on them with Winchester rifles at the west end of Lattimer.

(September 11) General John Gobin and the Third Brigade of state militia arrived in the Hazleton area to restore order.

(September 14) Strikes reached height, with 11,000 men and fifteen mines of Coxe Brothers, Lehigh Valley, Lehigh and Wilkes-Barre, Van Wickle, and Pardee companies not working.

(September 16) Workers began to return to work, having gained some concessions. Scattered clashes, especially between wives of Slavic miners under "Big Mary" Septak and company-men, continued for several more days.

1898 (January) At UMWA National Convention, 64 locals from the Anthracite region (half from the Lehigh area) were represented. This was second only to Illinois, which had 72 locals.

1898 (March 10) Sheriff Martin and his deputies were acquitted of the murder of Michael Cheslak (the only killing for which they were tried) at an acrimonious trial in Wilkes-Barre.

1899 John ("Johnny") Mitchell elected fifth president of the UMWA.

1900 (September 19) Mitchell called for general strike in the Anthracite fields.

(October 8-10) Clashes between strikers and Coal-and-Iron Police at the Coxe Brothers operations in Sheppton and Oneida left one policeman dead and another wounded. The state militia under General Gobin was called in to restore order.

(October 20) End of strike. Final settlement resulted in a 10 percent pay boost for the miners -- their first major victory in more than fifty years of disputes.

1902 (May 12 to October 21) "The Great Strike."

1902 (November 14) Anthracite Strike Commission opened its hearings in Scranton, Clarence Darrow being the miners' chief legal counsel. Hearings at Scranton and Philadelphia lasted 3 months.

1903 (March 10) Anthracite Coal Commission delivered its findings after the most exhaustive inquiry into the anthracite industry ever made. The miners won another 10 percent pay increase and creation of an Anthracite Board of Conciliation, but did not get recognition of the UMWA as bargaining representative.

This marked the beginning of an eighteen-year period of relative peace and rising prosperity in the anthracite fields. By this time more than 96 percent of all anthracite coal lands were owned by the railroads, with 91 percent of the deposits owned outright. J. P.

Morgan interests, through the Reading Co., controlled companies that transported one-third of all anthracite mined in Pennsylvania. But stability and higher wages were bought at the cost of the monopolistic practices exposed by socialist Scott Nearing in his Anthracite - an instance of natural resource monopoly (1915).

- 1905 (November 1) Coxe family sold its company and land to the Lehigh Valley Railroad for approximately \$18 million.
- 1911 (October 3) Cave-in at the Coxe Brothers' Drifton No. 2 mine at Freeland killed five men.
- 1914 Coal production in the Eastern Middle field peaked at 8.9 million tons.
- 1920 John Llewellyn Lewis became president of the UMWA.
- 1922 (April 1-September 10) Nationwide coal strike involving both anthracite and bituminous miners (163 days). Consumers of anthracite for home heating began to look to oil and natural gas.
- 1925 (September 1) Beginning of the longest strike in anthracite history (170 days).
- 1926 (February 12) John L. Lewis, head of the UMWA, signed pact with mine operators, effectively ending strike. The existing contract was extended for 5 years, but neither side really gained anything. The drift away from anthracite for home and commercial heating became a stampede. Wrote novelist John O'Hara of the devastating effects of the 1925-26 work stoppage:  
 Thus what were boom times for the rest of country were something less for Gibbsville [Pottsville]. The year of Our Lord 1929 saw many of the mines near Gibbsville working on a three-day a week basis. The blasts of the giant whistles at the collieries, more powerful than those of any steamship, were not heard rolling down the valleys as they had been before the 1925 strike, every morning at five and six o'clock. The anthracite industry was just about licked.

#### Appointment in Samara (1934)

- 1926 (November 16) Mine accident at Tomhickon mine. Water from an old channel of Black Creek broke into the No. 10 East Gangway and flooded the mine workings. Of six men originally missing, five were rescued on November 24.
- 1928 Due to hard times and high unemployment, "work equalization" emerged as a major issue in the anthracite fields.
- 1932 (November 14) Three men killed by cave-in and "rush of culm" at Highland No. 2 slope of the Jeddo-Highland Coal Company.
- 1933 J. L. Lewis gained recognition of the UMWA as the official collective bargaining agency for all coal miners in the country. The practice of using scrip to pay miners was also abolished.

- 1936 Contract gave miners an increase in wages and also contained a work-equalization clause that committed operators to employ as many as their mine workers as possible.
- 1937 As depression deepened, more than 12,000 men were involved in illegal bootleg operations throughout the Anthracite region.
- 1942 Bill passed by Congress authorizing the construction of a \$450,000 research laboratory in the Anthracite region. The project was designed to "determine how anthracite markets may be regained, maintained, and expanded, and to advance the health and safety of the workers in anthracite mining." It apparently fell victim to wartime neglect and was never accomplished.
- 1943 (April 27) Beginning of a series of short wartime strikes sanctioned by the UMWA that brought on federal take over of the nation's coal mines under Secretary of the Interior Harold Ickes.
- 1950 (June 12-October 25) Fifteen core holes drilled along the path of the "Conewingo Tunnel," a proposed 102-mile drainage tunnel that would have extended from Glen Lyon in the Northern field, through Shepton in the Eastern Middle field and Pottsville in the Southern field, to Chesapeake Bay. This is perhaps the last great scheme devised to revitalize the dying anthracite industry.
- 1953 Tomhickon Mine of Jeddo-Highland Coal Company shut down.
- 1954 Deep mining at Deringer Colliery (Jeddo-Highland Coal Company) ceased.
- 1955 (January) Jeddo No. 7 and Drifton deep mines discontinue operations. In 1962 the J. F. Lee Mining Company reopened the Drifton mine as the Drifton No. 1 Slope.
- 1955 (August 19) Hurricane Diane devastated northeast Pennsylvania. Nearly 9.5 inches of rain fell on the Hazleton area in 23 hours. Most of the remaining large underground mines in the Eastern Middle field were flooded. Within a few months, the majority had reopened; but the Lehigh Valley Coal Company closed the great deep mine at the Hazleton Shaft Colliery - in which nearly 600 men worked - sending convulsions through the Hazleton economy.
- 1956 CAN DO (Community Area New Development Organization) founded in Hazleton.
- 1959 (May) Stockton Slope of Jeddo-Highland Coal Co. ceased operations. The mine was reopened in 1961 as the No. 1 Slope of the Stockton Mining Company and operated until June, 1962.
- 1960 Audenried Mines, Inc., opened the No. 11 Mine at Audenried, the last deep mine that on occasion employed more than 50 workers. It ceased operations in 1966.
- 1962 Daniel J. Flood, area U.S. representative, ushered the Flood Amendment through Congress. This required the use of anthracite or coke in all

- military installations in West Germany, even if natural gas or fuel oil were cheaper.
- 1963 Only remaining deep mine at Eckley (operated by Gatti Engineering for past ten years) was closed.
- 1963 (August 13) Sheppton mine accident. Cave-in trapped three men robbing pillars 355 feet underground at the Oneida No. 2 Slope of the Fellin Mining Co. in the Green Mountain No. 3 Basin. The Pennsylvania Department of Mines and Mineral Industries initiated a massive cooperative rescue effort.
- (August 27) Two of the men trapped at Sheppton - David Fellin and Harry Throne - were rescued from a small pocket within the collapsed mine. Louis Bova, caught in another pocket nearby, had apparently died not long before; his body was never recovered. Bova was probably the last of many hundreds of men and boys to die underground in the Eastern Middle field.
- 1964 Pagnotti Enterprises acquired the Jeddo-Highland Coal Company.
- 1966 Jeddo-Highland (Pagnotti) procured present complement of heavy dragline equipment, including the mammoth 85-yd<sup>3</sup> machine now employed at the Ebervale stripping.
- 1970 Drifton No. 1 mine (J. F. Lee Mining Company) discontinued operations, marking the end of deep mining in the Eastern Middle Field.
- 1972 (January 1) Surface Mining Conservation and Reclamation Act of 1971 went into effect. Anthracite strip mines placed under backfilling and reclamation requirements similar to those of bituminous mines.
- 1973 Arab oil embargo.
- 1977 Anthracite Task Force formed in an effort to increase production and expand the markets for "hard coal."
- 1979 (January 12) Governor Milton Shapp signed a posthumous pardon for "Black Jack" Kehoe, a belated acknowledgment of the injustices that prevailed at the "Molly Maguire" trials 100 years ago.
- 1979 OPEC oil-price increase caused government action to encourage use of anthracite in place of fuel oil. Production rose for a few years, but then began to fall again.

## REFERENCES

- Ash, S. H., Kynor, H. D., Fatzinger, R. W., Davies, B. S., and Gilbert, J. C., 1950, Inundated anthracite reserves: Eastern Middle field of Pennsylvania: U. S. Bureau of Mines Bulletin 491, 51 p.
- Ash, S. H., Doherty, R. E., Miller, P. S., Romisher, W. M., and Smith, 1952, Core drilling at shaft sites of proposed mine-water drainage tunnel: U.S. Bureau of Mines Bulletin 513, 43 p.
- Ashburner, C. A., 1883, The geology of the Panther Creek Basin or eastern end of the Southern Field: Pennsylvania Geological Survey, 2nd ser., Report AA, 407 p.
- Aurand, H. W., 1971, From the Molly Maguires to the United Mine Workers: Philadelphia, Temple University Press, 221 p.
- \_\_\_\_\_, 1986, Population change and social continuity - Ten years in a coal town: Selinsgrove, PA, Susquehanna University Press, 139 p.
- Binder, F. M., 1974, Coal age empire: Harrisburg, PA, Pennsylvania Historical and Museum Commission, 184 p.
- Bolognani, B., 1981, A courageous people from the Dolomites: Edition and patronage of the Autonomous Province of Trent-Italy, 512 p.
- Bradsley, H. C., ed., 1893, History of Luzerne County, Pennsylvania: Chicago, S. B. Nelson and Co., 1509 p.
- Brenckman, F., 1913, History of Carbon County, Pennsylvania: Harrisburg, PA, James J. Nungesser, 626 p.
- Broehl, W. G. Jr., 1964, The Molly Maguires: Cambridge, MA, Harvard University Press, 409 p.
- CAN DO, 1974, The CAN DO story: Hazleton, PA, Community Area New Development Organization, Inc., 78 p.
- Coleman, J. W., 1936, The Molly Maguire riots: Richmond, Garrett and Massie, Inc., 189 p.
- Coleman, M., 1943, Men and coal: New York, Holt, Rinehart, and Winston, 350 p.
- Greene, V. R., 1968, The Slavic community on strike: Notre Dame, IN, University of Notre Dame Press, 260 p.
- Haine, Edgar A., 1987, Anthracite coal: Chicago, Adams Press, 214 p.
- Hudson Coal Co., 1932, The story of anthracite: New York, The Hudson Coal Co., 425 p.
- Lewis, A. H., 1964, Lament for the Molly Maguires: New York, Harcourt, Brace and World, Inc., 308 p.
- Miller, D. L., and Sharpless, R. E., 1985, The kingdom of coal: Philadelphia, University of Pennsylvania Press, 360 p.
- Munsell and Co., W. W., 1880, History of Luzerne, Lackawanna, and Wyoming Counties, Pennsylvania: New York, W. W. Munsell and Co., 540 p.
- Pennsylvania Department of Environmental Resources, 1986, Annual Report on mining activities: Harrisburg, PA, Pennsylvania Department of Environmental Resources, 536 p.
- Pennsylvania Department of Mines, 1953-1955, Annual reports for 1952-1954 - Anthracite Division: Harrisburg, PA, Pennsylvania Department of Mines.
- Pennsylvania Department of Mines and Mineral Industries, 1956-1966, Annual reports for 1955-1965 - Anthracite Division: Harrisburg, PA, Pennsylvania Department of Mines and Mineral Industries.
- Pennsylvania Geological Survey, 1912, The mineral production of Pennsylvania, 1911 - coal and coke: Pennsylvania Geological Survey, 3rd ser., Report 8A, 139 p.
- Roberts, E., 1984, The breaker whistle blows: Scranton, Pa., Anthracite Museum Press, 166 p.
- Roberts, P., 1904, Anthracite coal communities: New York, The MacMillan Company, 387 p.
- Rose, D., 1981, Energy transition and the local community: Philadelphia, University of Pennsylvania Press, 189 p.
- Trice, H. V., and Koehler, J. S., 1986, The Delaware, Schuylkill, and Susquehanna Railroad, In Metz, L. E., ed., Iron Issue: Canal History and Technology Proceedings, v. 5, p. 165-208.
- Wallace, A. F. C., 1987, St. Clair: New York, Adolph Knopf, 590 p.