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LAND USE AND ABUSE- THE ALLEGHENY COUNTY PROBLEM

Pittsburgh, Pa.
October 3 and 4, 1980



Host: The Pittsburgh Geological Society

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45th ANNUAL FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

LAND USE AND ABUSE
THE ALLEGHENY COUNTY PROBLEM

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Jane Freedman, who penned the above sentences, left herself out but deserves great credit for all her efforts and concern in putting together this guidebook.

AN INTRODUCTION TO THE GEOLOGY OF PITTSBURGH AND ITS IMPACT ON THE ACTIVITIES OF MAN

by

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"History is subject to geology. . ."

Will and Ariel Durant

This precept is not better demonstrated than in Pittsburgh and its environs. Pittsburgh was born of its geography and nurtured by its geology; the influence of these two factors pervades almost every facet of life in the region. The history of Pittsburgh, and its rise as a leading industrial center, was determined mainly by its geology. Blessed by an abundance of coal and other resources, Pittsburgh became the world's leading center of steel manufacturing and a focal point for many other industries. Like most expanding metropolitan areas, Pittsburgh experienced both positive and negative social, economic, and environmental effects from industrialization and urban growth. The geology of the region has its own positive and negative attributes, for Pittsburgh is not only a gift of its geology, it is also a victim of it.

The 45th Field Conference of Pennsylvania Geologists highlights the geology of Pittsburgh and its relationship to man's activities in the region. Unfortunately, a thorough treatment of this subject requires more than can be achieved in a single field trip or in a field guide. To help understand the complex relationship between geology and the activities of man in Pittsburgh, the geology will be introduced from the perspective of history.

The topography and geography of the Pittsburgh region are among its most striking features. Pittsburgh lies in a moderately dissected portion of the Appalachian Plateau (Figure 1) where a relatively flat, concordant plateau surface is deeply dissected by the drainage, producing steep-sided valleys having a vertical relief ranging from 425 to 560 feet (130 to 170 m). The upland areas generally lie at an elevation greater than 1200 feet (360 m) above mean sea level and constitute only about ten to twenty percent of the surface area of the region. The valley slopes account for about fifty to seventy percent of the area while the bottomlands constitute about twenty percent or less.

Pittsburgh is located at the confluence of the three largest rivers in the region, the Allegheny, Monongahela, and the Ohio. The Allegheny River, with an average discharge of about 18,750 cubic feet per second at Pittsburgh, flows from the north, originating in northern Pennsylvania and southern New York. The Monongahela River, with an average discharge of about 12,150 cubic feet per second, flows from the south, originating in east-central West Virginia. The Allegheny and Monongahela Rivers meet to form the Ohio, which has an average discharge of about 31,800 cubic feet per second just downstream from Pittsburgh. The Ohio River is a major artery of drainage that flows west from Pittsburgh into the interior of the conti-

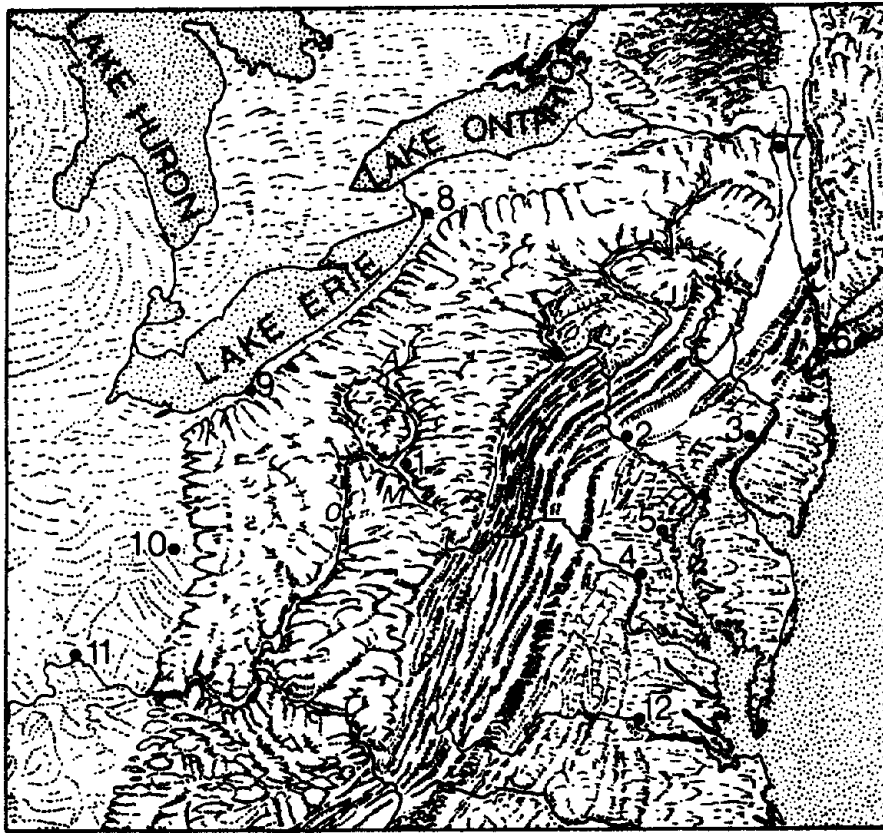


Figure 1. Physiographic setting for Pittsburgh (1) on the junction of the Allegheny (A), Monongahela (M), and Ohio (O) Rivers in the heart of the Appalachian Plateau. Other cities include Harrisburg (2), Philadelphia (3), Washington (4), Baltimore (5), New York (6), Albany (7), Buffalo (8), Cleveland (9), Columbus (10), Cincinnati (11) and Richmond (12). (Adapted from Thornbury, 1965).

nent, joining the Mississippi River at Cairo, Illinois, about 930 miles (1500 km) downstream from Pittsburgh.

The first inhabitants of the Pittsburgh region were probably the Paleo-Indians who may have occupied the area about 16,000 years ago, as indicated by archaeological findings at Meadowcroft Rock Shelter located on a small tributary to the Ohio River about 25 miles (40 km) southwest of Pittsburgh. The Paleo-Indians were hunter-gatherers who exploited the abundant animal and plant resources of the region. Lithic resources were readily available in the form of cobbles and pebbles of chert obtained from gravel deposits of glacial origin. Chert was also imported from the Flint Ridge area of Ohio, and from northern and eastern sources by people of later cultures who occupied the area. The Paleo-Indian culture was followed by the Archaic hunter-gatherer culture probably between 7000 and 8000 years ago, and the Archaic culture was supplanted by the Woodland culture about 3000 years ago when agriculture was first introduced in the area. The bottomlands of the

larger streams and rivers provided ample fertile land for cultivation by the prehistoric agriculturalists.

Two mound-building societies developed along the rivers and streams of this region during the Woodland cultural period. The first were the Adena mound-builders who occupied the region from about 3000 to 2000 years ago before they were displaced by the more advanced Hopewell culture that lasted from about 2000 years ago to 500 A.D. When Europeans first arrived in the Pittsburgh area, there were no permanent villages occupied by native Americans. Archaeological evidence indicates that most local prehistoric sites from this time seem to have been temporary camps used for hunting, travel stops, or resource exploitation. The foci of permanent Indian villages were located to the north, west, and south of Pittsburgh.

It was the strategic location at the confluence of the rivers that first attracted the attention of the European colonists to the "Forks of the Ohio" at what is now Pittsburgh. The conflicts between the British and French in Europe in the early and mid- 1700s were transported to North America as both nations struggled for domination of the continent. The French claimed the area west of the Allegheny Mountains as theirs, including the "Belle Riviere" (the combined Ohio and Allegheny Rivers); the English did not recognize these claims. A group of English colonials from Virginia formed an organization called the Ohio Land Company whose members included George Washington's brother and Governor Dinwiddie of Virginia. The Ohio Land Company claimed over half a million acres of the area around the Forks for trade and land speculation, land that the French had marked as theirs. Ensuing clashes between the French and English trading in the area prompted Governor Dinwiddie to send a 21 year old major of the Virginia Militia, George Washington, to deliver a protest to the French. Enroute, Major Washington travelled by the Forks and noted:

. . . I spent some time viewing the rivers, and the land in the Fork; which I think extremely well situated for a fort, as it has absolute command of both rivers. . . the Land at the point is 20 to 25 feet above the common surface of the water; and a considerable bottom of flat, well-timbered land all around it, very convenient for building. . .

(from Washington's Chronicle, in Lorant, 1975)

The confrontations with the French prompted the Virginians to build a fort at the Forks as suggested by Washington. Construction of Fort Prince George was initiated in March 1754, and was the first recorded Euro-American construction on the land that is now Pittsburgh. The unfinished colonial fort was abandoned one month later when a superior force of French and Indians threatened attack. The French then erected their own fort, Fort Duquesne, at the Forks. The French controlled the Forks for four years, repelling several English attempts to regain control. In November of 1758, the French burned and abandoned Fort Duquesne in the face of imminent attack by British forces headed by General John Forbes and Colonel George Washing-

ton. The English erected their own fort (now partially reconstructed in Point State Park) on the ruins of Fort Duquesne, and Forbes named it Fort Pitt in honor of the English Prime Minister. Fort Pitt received no attacks from the French, although it suffered a siege of Indian attacks in 1763 during "Pontiac's Conspiracy." The end of the Indian uprising reduced the need for Fort Pitt, and it was gradually dismantled in the mid-1760s.

The community that developed around the Fort continued to grow as a center of trade for the ever increasing travel from east to west. When the community was incorporated as a city in 1816, it was the major center for commerce in the west since most travel from the seaboard to the west went through to Pittsburgh. Henry Steele Commager summarizes the situation as follows:

. . .The historical significance of Pittsburgh was determined from the beginning, by geography... .The city that was to rise at this strategic point on the threshold of the Forks was at once the bridge from the East and the Gateway to the West, the most western of the great cities of the seaboard, the most eastern of the great cities of the valley: it is no accident that it has commanded that position now for a century and a half; its sovereignty unchallenged. . .

(Lorant, 1975)

Pittsburgh's economy was primarily based on commerce in the late 1700s and early 1800s, thereby living up to its "Gateway" status. As Pittsburgh grew, it required an ever increasing supply of goods, most of which were manufactured in the east. However, transporting large quantities of goods was incredibly difficult and expensive because rugged mountains formed a formidable barrier between Pittsburgh and the east. For this reason, Pittsburgh was forced to develop a manufacturing industry. By 1830 the commerce aspect of Pittsburgh's economy was eclipsed by manufacturing. Thus, Pittsburgh was founded and began to flourish as a center of commerce and manufacturing because of its geography. But Pittsburgh was only born of its geography, it owes most of its growth and eventual status as a leading industrial center to its geology.

The bedrock geology of the Pittsburgh region consists of Paleozoic sedimentary rocks composed mainly of shales, sandstones, siltstones, limestones and claystones (Figure 2). Less than 2 percent of the rock stratigraphy is coal, but it was coal that was to make Pittsburgh an industrial giant. The sedimentary sequence is approximately 3 miles (5 km) thick beneath Pittsburgh before Precambrian (crystalline) rocks of the "basement" are encountered. The sedimentary rocks and the surface of the basement dip gently to the southwest, along the axis of the Pittsburgh-Huntington structural basin (Figure 3). Although the rocks dip toward the southwest, there are many smaller folds whose axes are generally aligned northeast-southwest, that are superimposed on the basin structure (Figure 4).

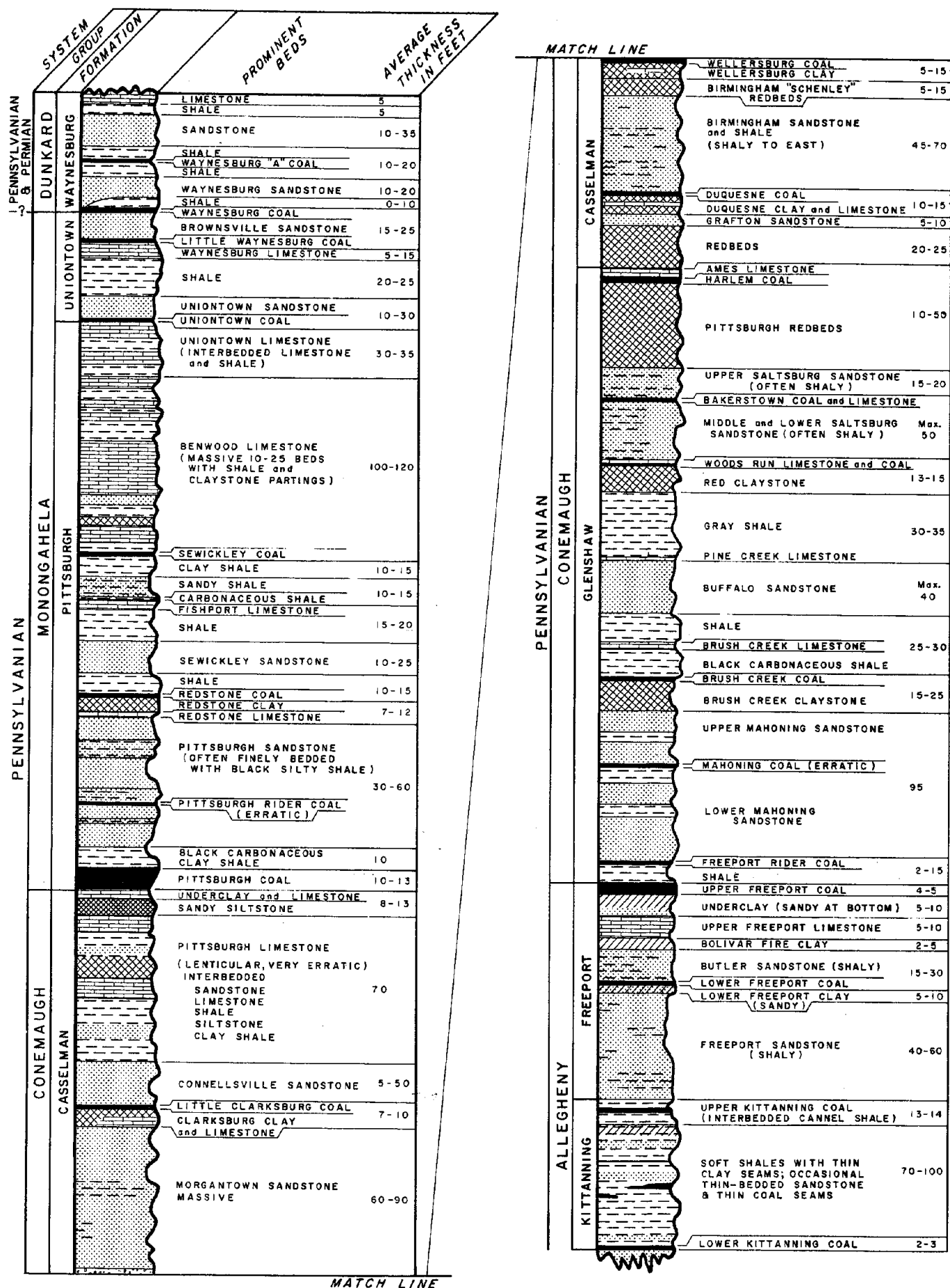


Figure 2. Generalized stratigraphic column for the Pittsburgh region (modified from section drawn by Ackenheil and Associates, Inc., Pittsburgh, Pa.)

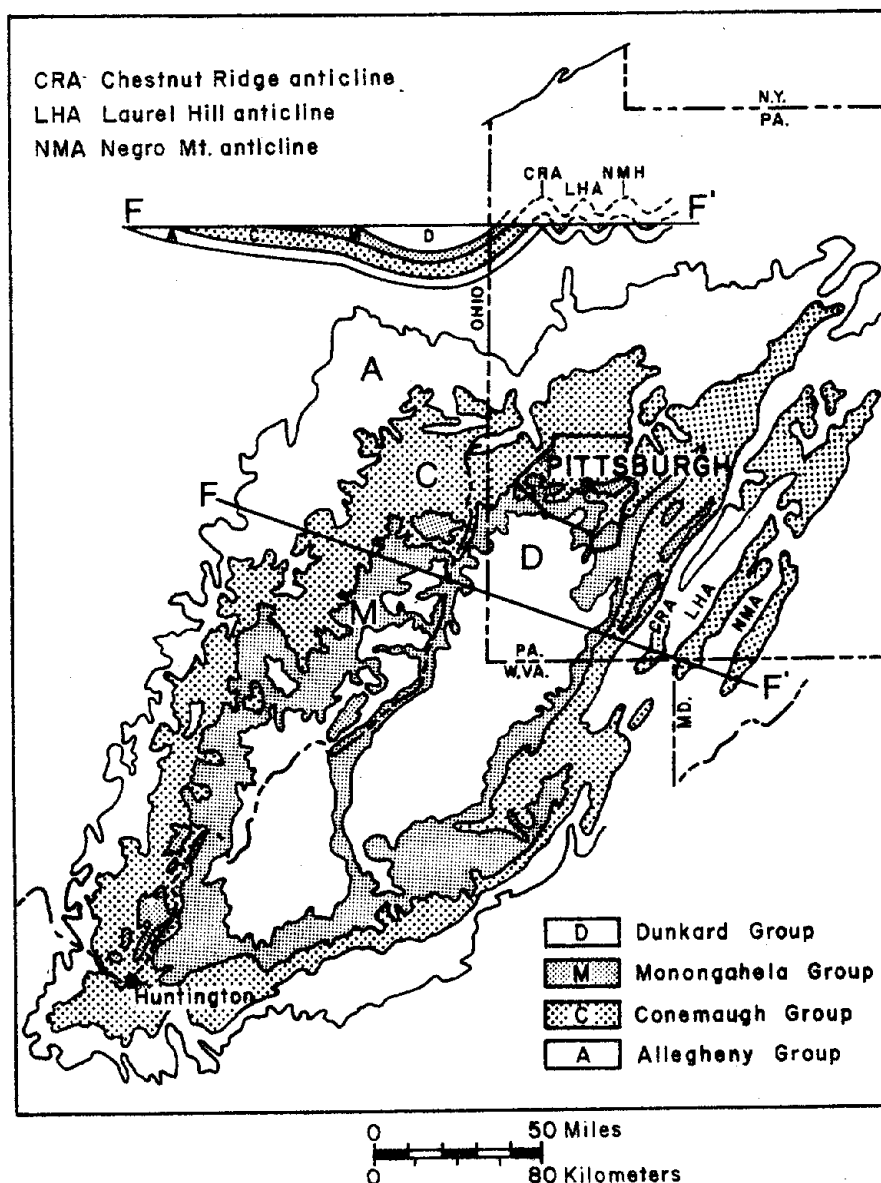


Figure 3. Geologic map of the Pittsburgh-Huntingdon Basin. (From Wagner et al., 1970).

The rocks outcropping in the greater Pittsburgh area belong to the Pennsylvanian Allegheny, Conemaugh, and Monongahela Groups, and the Permian Dunkard Group (Figure 3). Within the city of Pittsburgh, rocks outcropping below the approximate elevation of 1100 feet (335 meters) belong to the Conemaugh Group, while those above that elevation are Monongahela Group (Figure 4). These rocks were formed over 250 million years ago on a subsiding platform having shallow marine, deltaic, coastal swamp and lagoon depositional environments (Figure 5). The sedimentary environments often varied significantly over short distances, causing lateral facies changes to occur.

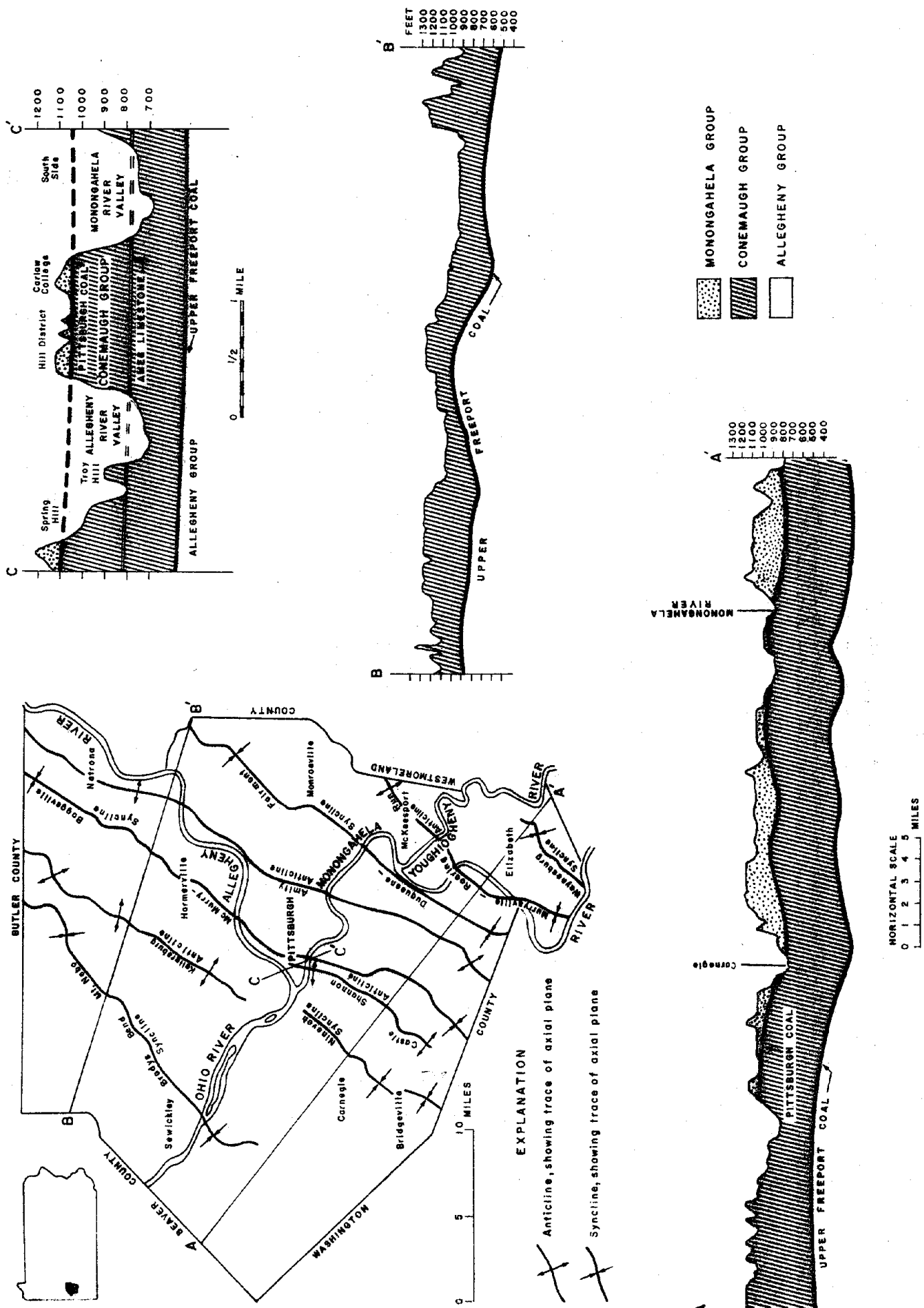


Figure 4. Structure map and cross sections in Allegheny County (adapted from Subitsky, 1975 and Wagner, and others, 1970.)

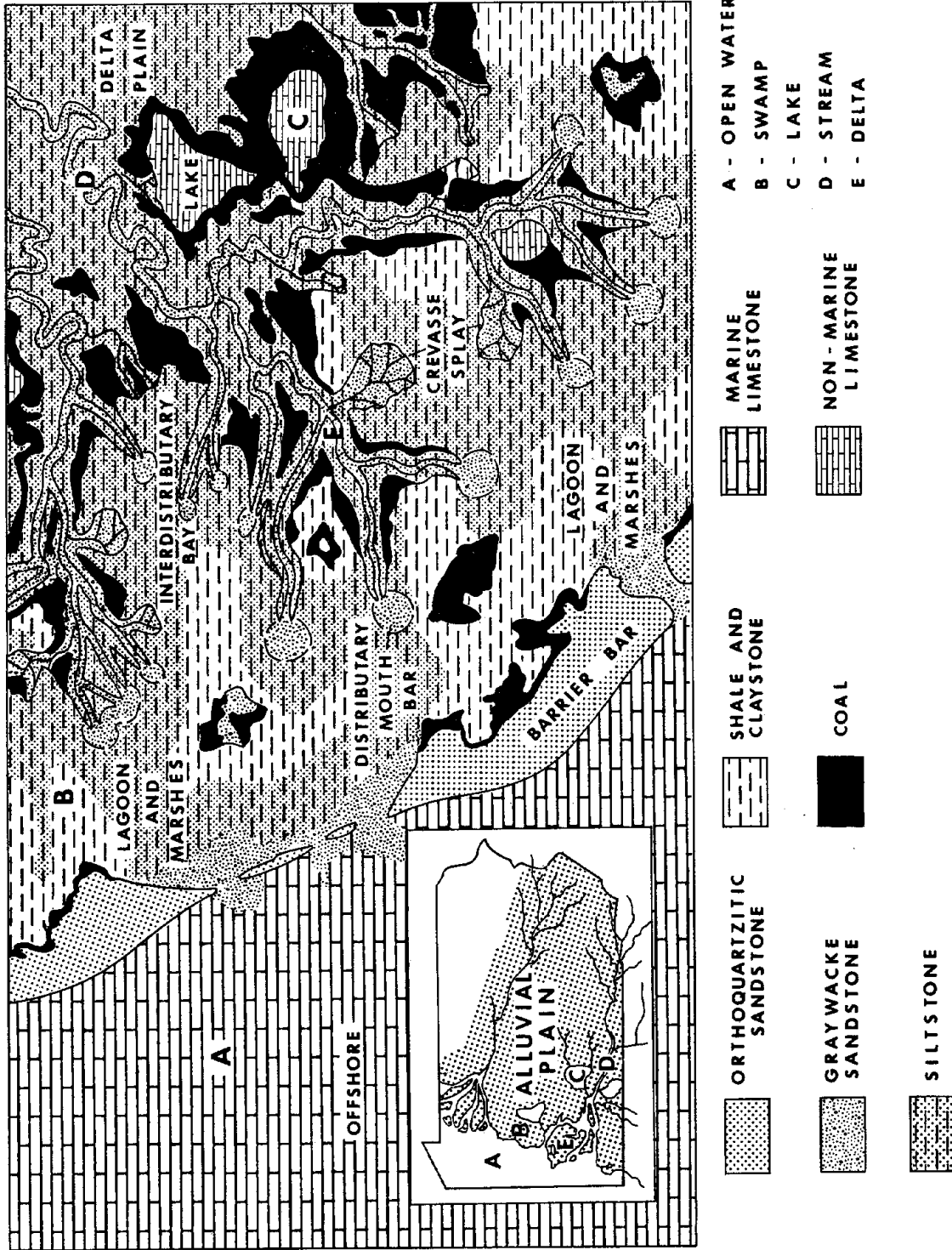


Figure 5. Schematic diagram of the depositional environments for the rocks in western Pennsylvania (adapted from Wagner, and others, 1970, (inset) and Donahue and Rollins, 1979.)

Thus, any one rock unit depicted in the stratigraphic column (Figure 2) may or may not exist at a particular locality. The most areally persistent, readily identifiable rock units in the Pittsburgh area are coal beds and limestones. The marker beds most widely used in the region are the Upper Freeport and Pittsburgh coals, and the Vanport, Ames and Benwood limestones.

The geologic structure of the area is characterized by beds gently dipping to the southwest within the Pittsburgh-Huntington Basin (Figure 3), which are mildly folded into anticlines and synclines having axial trends running roughly northeast-southwest, somewhat parallel to the axis of the basin (Figure 4). The dip of the beds is often slight enough to be described as nearly horizontal, but dips as much as 10 degrees are not uncommon. Generally, the anticlinal and synclinal structures become better defined and more axially persistent as one proceeds from Pittsburgh toward the intensely folded rocks to the east. Folding is less well defined to the west where structural axes are more sinuous and discontinuous, and folding is more open.

Faulting is not common in the area, but infrequent faults with minor vertical displacements are present. Minor tear faults (translatory) are also present, but are less widely recognized. The most important discontinuities in the rocks are joints. Tectonic joints and stress-relief joints (those formed parallel to valley axes and caused by the erosion of the valley which relieves lateral stress in the rocks) are recognized. There seems to be no strong joint set direction in the region, and there is wide variation from place to place. Both systematic joints (those that are well defined, planar, and somewhat regularly spaced in a bed) and nonsystematic joints (those that are irregularly spaced, often curved, and usually do not penetrate the full thickness of the rock unit) are present. Nonsystematic joints tend to be most prevalent in the claystones, shales, and some siltstones while the systematic joints occur in all units.

While Pittsburgh was not directly glaciated during the Pleistocene, the closest approach of Wisconsinan ice was about 30 miles (50 km) north of the city; the Allegheny and Ohio Rivers served as sluiceways for glacial meltwaters. The heavy sediment load in the glacial outwash caused river aggradation that is now represented by coarse sand and gravel deposits and low lying terraces along the Allegheny and Ohio Rivers. Much older alluvial sediments, possibly of nonglacial origin, occur in high terraces and old alluvial channels that occur about 325 feet (100 m) above the present channel. The age of the high level deposits is thought to be Illinoian.

In addition to deposition of outwash in the valleys, glaciation in northwestern Pennsylvania and eastern Ohio caused blockage of the preglacial north-flowing drainage. The blockage of drainage near Beaver, Pennsylvania, may have caused an extensive proglacial lake to form Lake Monongahela, possibly over 100 miles (160 km) long in this region. Although extensive lacustrine deposits have not been reported in Pittsburgh, pollen-bearing lacustrine deposits have been found near Morgantown, West Virginia, indicating the lake may have been at least as high as 1100 feet (335 m).

The most important factors affecting the growth of Pittsburgh were the mineral resources of the region including coal, oil, natural gas, iron ore, and the availability of attendant requirements such as water, building materials, power, transportation capabilities, and marketability. However, the single most important resource to affect Pittsburgh's growth and industrial stature was coal. Figure 2 shows twenty-four coals contained in the rocks of the area. Although no one locality contains all these seams, at least thirteen of the twenty-four have been strip or deep mined at one place or another in the region. The significant coal mined within Pittsburgh and the adjacent communities are the Pittsburgh and Upper Freeport seams (Figure 4).

The Pittsburgh coal is considered to be one of the richest economic deposits in the world. The U. S. Geological Survey estimated that the Pittsburgh coal alone yielded eight billion tons from the early 1900s to 1965, comprising thirty-five percent of all bituminous coal in the Appalachian Basin and twenty-one percent of the cumulative production for the entire United States. The Pittsburgh coal is essentially "worked-out" and no longer deep mined in Pittsburgh, although some old abandoned deep mines in the area are being stripped to recover coal from the pillars left in those mines.

The Upper Freeport coal lies about 660 feet (200 m) below the Pittsburgh coal (Figure 4) and is deep mined in a north-south belt east of the city and just north of the city. However, it is relatively thin and is not deep mined under the city.

The first record of coal mining in Pittsburgh was made by Captain Thomas Hutchins in 1859 when he noted a coal mine developed by the British soldiers on "Coal Hill," which is now called Mt. Washington. Coal was mined on a small scale until industrialization created a greater demand by the mid-1800s.

The main technique of coal extraction in the Pittsburgh region was, and still is, the room-and-pillar method. This method involves leaving as much as fifty percent of the coal in place for roof support in the early stages of mining. Commonly, the pillars themselves are extracted after initial mining is completed, thereby increasing the net recovery. In the 1970s, western Pennsylvania produced about 12 percent of the nation's coal using this technique.

The principal user of coal in the Pittsburgh region is the iron and steel industry. The iron industry began almost at the birth of the community. The first iron furnace reported in Pittsburgh was built on Two Mile Run (Shadyside) in 1793, and closed after only one year of operation for lack of local timber and iron ore. Although Pittsburgh's first iron furnace was unsuccessful, numerous furnaces operating in outlying areas closer to the ore did succeed. Because Pittsburgh was the center of commerce, trade, labor and marketing, the industry took advantage of these resources and iron forging became a lucrative business.

The iron ore came mainly from small mines operated north, east and southwest of Pittsburgh in Butler, Fayette, Lawrence, Somerset, and Westmoreland counties. The ore is mainly siderite (iron carbonate) with some hematite. Siderite occurs either as nodules in clay or shale or as a replacement mineral in limestone beds. There are six main ore-bearing horizons in the region: the Pittsburgh ore, located just below the Pittsburgh coal, Mahoning (Johnstown) ore, Freeport ore, Brookville ore, Mercer ore, and Mauch Chunk ore, each occurring within the units bearing those names (Figure 2). The development of the Superior ore province in the Great Lakes region eventually put the iron mining industry of western Pennsylvania out of business, but the iron and steel industry in Pittsburgh continued to grow because bituminous coal (coke) became an important ingredient in the process by the mid-1800s, and Pittsburgh was the hub of coal production. Eventually, Pittsburgh became the largest iron and steel producing area in the world.

Other industries proliferated in the region as a result of the exploitation of the local geologic resources. The Pittsburgh glass industry began about the same time as the iron industry, because the resources for making glass (sand and lime) were available, and it was difficult to import glass over the rugged mountains from the eastern manufacturing centers. Glass manufacturing first occurred in Pittsburgh in 1797 when Isaac Craig and James O'Hara began producing glass products on the southside of the Monongahela River. Today Pittsburgh produces eighty percent of the nation's flat glass products. The first cheap aluminum (\$2.00/pound) was produced in Pittsburgh on November 25, 1888, in a factory developed by Martin Hall, the inventor of the process. A large brick, pipe, and refractory manufacturing industry was fostered in the region by the occurrence of abundant clay (fireclay) and shale. Many other industries were nurtured on the geology and labor market of the Pittsburgh region.

One of the most significant resources, other than coal, to affect the development of the Pittsburgh area was oil and gas. The first oil encountered in Pittsburgh was in wells drilled to obtain salt from the "Salt Sands" of the Pottsville Group. Samuel M. Kier owned an oil "contaminated" salt well along the banks of the Allegheny River in Tarentum. In 1850, he tried to sell the oil as a natural health remedy while experimenting with refining it to produce a lamp fuel that would substitute for expensive whale oil. As a result of his experiments, he invented the oil lamp that bears his name, and, in 1854, began producing refined oil, thereby becoming the first oil refiner in America.

In 1859, the Drake Well was drilled near Titusville, about 90 miles (145 km) north of Pittsburgh, and major oil production was born. By 1871, sixty oil refineries were operating in Pittsburgh producing 36,000 barrels of oil per day. Natural gas was developed about the same time, with the first gas well near Pittsburgh being drilled in 1878 in Murrysburg, 12 miles (20 km) east of the city. In 1883, a gas pipeline was completed from Murrysburg to Pittsburgh to feed, among other things, the gas street lights of the city. A tremendous amount of gas and oil drilling occurred in the

Pittsburgh area in late 1800s and early 1900s. Although production peaked in western Pennsylvania in the 1890s, oil and gas is still produced in the area with about 220,000 barrels produced annually. In addition, a large capacity for storing natural gas in depleted reservoirs was developed in the last few decades.

The continued growth, building, and industrialization of the area necessitated exploitation of other resources in the region. Sources of construction aggregate were obtained from the local sand and gravel deposits in the river channels and terraces, from the limestone and sandstone beds, and from the slags produced as by-products of iron and steel industry. The largest source of high quality sand and gravel occurs in the glacially derived terrace and channel deposits of the Allegheny and Ohio Rivers. Large quantities of these deposits have been removed in the Pittsburgh area by dredging the river and excavating the terraces. The nonglacially derived sediments of the north flowing streams, such as the Monongahela River, and the high terraces of the region (Figure 6) contain sand resources but are not good sources for gravel because their gravel consists mainly of highly weathered, easily crushed sedimentary rocks.

The main sources of crushed stone in the region are the Vanport Limestone and the Loyalhanna Formation which outcrop north and east of Pittsburgh, respectively. Sandstone is available locally, but used to a lesser extent as are various forms of iron and steel making slags. As an example, in 1971 more than ten million tons of aggregate were used in the region, with sand and gravel comprising forty-seven percent, crushed stone twenty-five percent, and slags twenty-eight percent of the usage.

An ample supply of good quality water is a requisite for the successful development of any area. Pittsburgh generally has had abundant water resources to serve its needs. Most water was procured from wells prior to building the first public water works and reservoir on Grants Hill in 1828. Today, over ninety-eight percent of the domestic water used in Pittsburgh comes from Public Service suppliers who obtain water mainly from surface reservoirs, the rivers, or well fields developed in valley alluvium. Industry and business, however, use the largest quantities of water.

Groundwater in Pittsburgh was, and is, mainly obtained from valley alluvium while lesser amounts are obtained from bedrock wells. Wells developed in the coarse, glacially derived deposits in the Allegheny Valley have, on the average, higher yields (e.g. 350 gpm) than those in the valley fills not derived from glacial material. For example, the Monongahela River deposits are generally less coarse and dirtier than those of the Allegheny River, and only produce average yields of about 125 gpm (compare valley fills of the Allegheny and Monongahela Rivers in Figure 6). Yields of wells in valley deposits of the Ohio River, which receives sediment from the other two rivers, often lie somewhere between the average yields in the other two valleys.

Water yields from bedrock wells are, on the average, lower than those

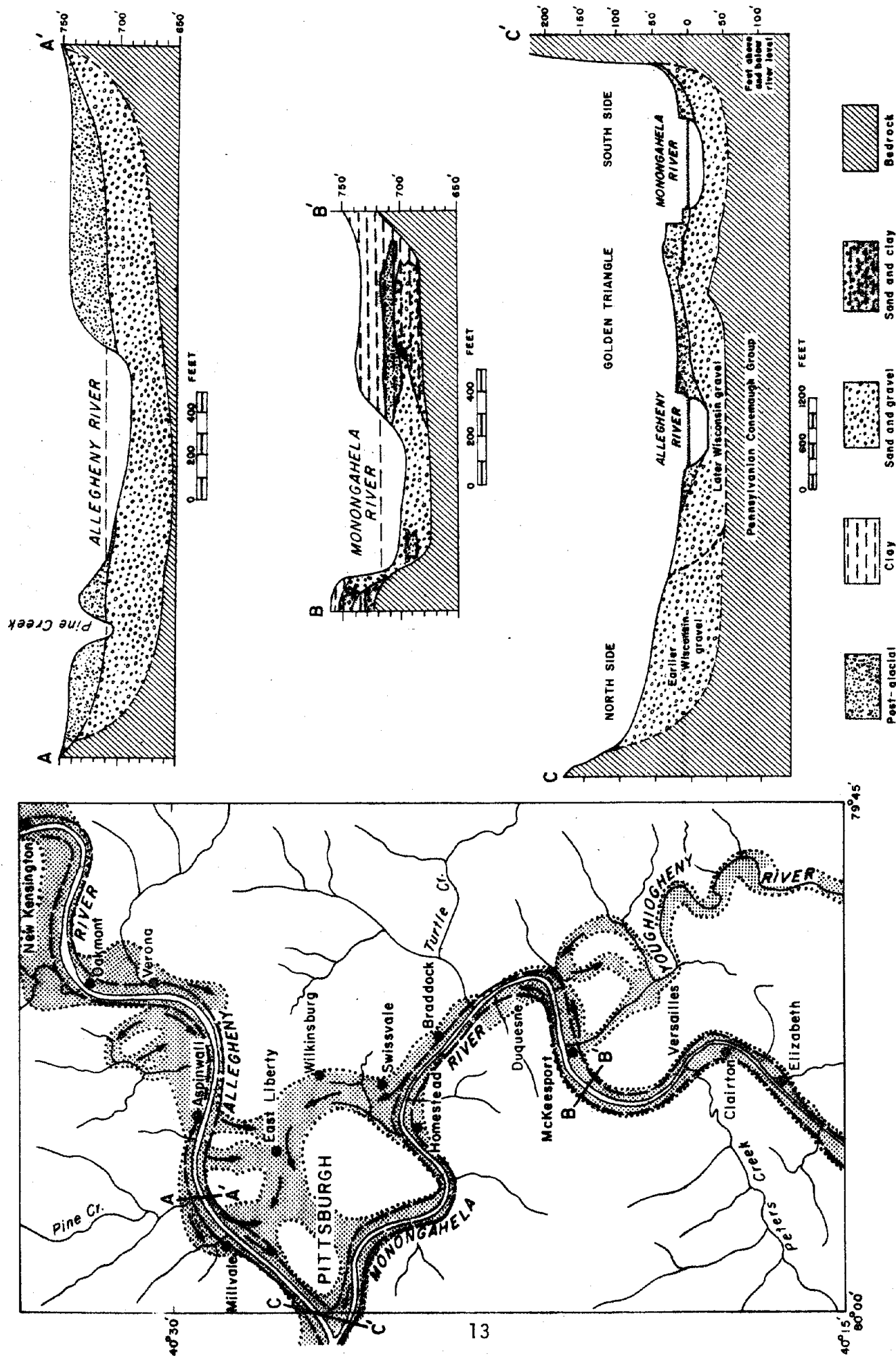


Figure 6. Map and cross sections of alluvial deposits in the Pittsburgh area. Stippled zone on map defines high-level terraces, and areas within dashed lines are low-level alluvial deposits. Arrows show flow direction of streams that formed high-level terraces (adapted from Wagner, and others, 1970 and Noecker, and others, 1954.)

in valley fills even though bedrock wells often tap several aquifers. The best bedrock aquifers are the sandstones. However, the intrinsic permeability of all the rocks in the Pittsburgh region is low, and the secondary permeability from fractures in the rocks is often the major factor controlling the quantity of water produced in the wells. With depth, the groundwater derived from bedrock tends to become softer and the total dissolved solids increases. The water quality often degrades rapidly at depths of 100 feet (30 m) and the water becomes too saline for most uses.

Pittsburgh's strategic location as a "Gateway to the West," and the increasing need to transport raw materials from the surrounding region to the local manufacturing centers necessitated use of the rivers as the chief avenue of haulage. Railroads did not enter the area until the 1850s, and the rivers provided the quickest, easiest avenue for transporting large loads, as they still do today. Boatbuilding was an important industry of Pittsburgh from its earliest days. The first steamboat on western waters was the "New Orleans," which was built in Pittsburgh in 1811. Although the Ohio River was a major pathway to the interior of the continent, travelling from Pittsburgh to the Mississippi in anything much larger than a canoe was usually restricted to the wetter seasons because the Ohio River was often too shallow for navigation during the summer and fall. In addition, transporting goods prior to the 1820s was usually unidirectional, downstream, because the current was too strong for upstream trips by larger boats. The advent of the steamboat on the Ohio River eliminated this problem, but the problem of seasonal navigation still remained.

A major obstacle to Ohio River navigation was removed in 1830 when a canal with three locks was constructed to by-pass the "Falls of the Ohio" at Louisville, Kentucky. However, seasonal travel was still required. The first lock and dam on the Ohio River, and the first movable dam in the United States was Lock and Dam Number 1 (Davis Island) built from 1847 to 1855, 4.5 miles (7.3 km) downstream from the "Point" at Pittsburgh. This greatly improved local navigation, but it wasn't until 1929, when a series of fifty locks, dams, and canalization had been completed, that the Ohio River was totally free of seasonal restrictions to navigation. Replacement and modernization of the locks and dams began in the 1950s to meet the demands of additional growth in the region. This reduced the total number of Ohio River locks and dams to 21. By 1938, navigation on the Allegheny and Monongahela Rivers was also improved with the completion of eight locks and nine dams. Today, Pittsburgh's waterways and its port handle more tonnage than any inland waterway in the world, including the Panama and Suez Canals, and it is the third busiest port in the U.S., following New York and New Orleans. However, the present lock and dam facilities around Pittsburgh are in dire need of repair and improvement because of deterioration caused by age and heavy usage.

Thus we have a brief profile of Pittsburgh, a city that owes its birth, growth, and maintenance to its geography and geology. The industrial tradition, and the industries that formed that tradition through history are still well represented in the region. At least 7800 manufacturing plants

are situated within 100 miles (160 km) of the city. The City of Pittsburgh has the third largest number of corporate headquarters in the nation, following New York and Chicago, and sixteen of "Fortune's Top 500" corporations are headquartered here, while forty-nine have plants in the region. Pittsburgh also has a large concentration of engineers and scientists, a spinoff from its industrial heritage. However, the point of this discussion is not to laud Pittsburgh's business and industrial facets, rather, it is to punctuate the somewhat enigmatic situation where a large industrial and technological center rose in an area that would seem to physically defy large-scale development because of its rugged topography, difficult access, and lack of easy building area. The fact that Pittsburgh did rise under these circumstances seems to attest to the important role of the geology of the region in the development of the area.

Unfortunately, Pittsburgh is not only a gift of its geology, it is also a victim of it. The rugged topography, relatively steep slopes and small area of natural flat land forced men to develop areas many would consider marginal. The only flat land suitable for large development was along the valley bottoms. Much of the valley bottom is flood prone, and a number of large, devastating floods have occurred in Pittsburgh. The most notable flood occurred on St. Patrick's Day in 1936 as a result of combined snow melt and precipitation in the drainage basin. The waters rose 21 feet (6.4 m) above flood stage, ravaging the city and causing many deaths, over 3,000 injuries, and leaving 100,000 people homeless, not to mention the damages to industries and businesses along the river in which most of the populace were employed. Since the 1936 flood disaster, nine flood control dams constructed in the basin have effectively reduced the flood hazard along the three major rivers. However, localized flooding still occurs, usually as a result of abnormally high-intensity precipitation within a larger storm cell. The high rainfall combined with saturated ground, high gradient slopes, high relief, and narrow chute-like tributary valleys causes rapid peaking of discharge and local floods.

The Pittsburgh region is also a victim of landsliding, and is within one of the most severely affected areas in the country (Highway Research Board Special Report 29). The severe landslide problem is fostered by a number of interrelated factors including the steep topography, humid climate and the nature of the rock and colluvial soils. Two main categories of slope stability problems occur in this region, earth flows (slumps) and rock falls.

The earth flows and slumps, relatively slow downhill movements of soil masses, constitute the largest problem in terms of damage and cost. If a single factor had to be selected as that most responsible for the severe slumping and earth flow problems in the area, it would be the occurrence of claystones, which are also called "redbeds," although they are also brown and gray. The characteristics of claystone most responsible for their association with landslides are low strength, rapid degradation when exposed to weathering, formation of low strength clayey colluvial soils on slopes, and the occurrence of predisposed planes of weakness in the form of slickensided, nonsystematic joints. Claystones weather rapidly and tend to form

thick colluvial soil deposits on hillslopes where erosion or mass wasting processes are not sufficient to remove it. The stability of the colluvial soil is usually marginal, and landsliding can be activated with only slight disturbance by man and/or heavy rainfalls. Since flat area is scarce in Pittsburgh, hillslopes are often developed and disturbance and activation of landsliding is inevitable unless proper precautions are taken. The claystone rock units are concentrated mainly in the Conemaugh, Monongahela, and Dunkard Groups which cover most of southwestern Pennsylvania, and unstable slopes are numerous in areas where colluvium derived from these units has accumulated.

Rock falls are also common in the Pittsburgh region, as one might expect in an area having numerous, high, man-made and natural cliff-like slopes. Many injuries, property damages, and deaths have occurred from rock falls. The single most disastrous rock fall occurred in December, 1942, when a rock fall crushed a bus that was travelling along Route 930 on the west side of the Ohio River, opposite Ambridge, killing 22 persons and injuring four others. The conditions for rock falls in Pittsburgh occur where massive, resistant beds (sandstone, shale, and limestone) are underlain by weakly resistant rock (claystone, coal, some siltstone) on high gradient slopes and in vertical cuts. Rock falls occur when the massive resistant rock beds are undermined by the weathering of the weaker rock beds. When the massive rock is sufficiently undermined, the rock breaks away and falls, usually separating from the main rock mass along natural fractures.

Geologic hazards associated with strip and deep coal mining pervade the area. Many abandoned coal mines still contain coal pillars or parts of pillars that support the mine roof. With time, the pillars deteriorate and collapse, causing roof collapse and subsidence often causing damage to structures on the surface. Mine subsidence also has caused fracturing and draining of shallow aquifers above the mined coal. For example, the Pittsburgh Sandstone overlying the mined-out Pittsburgh coal has been dewatered in southern Allegheny County, and the Mahoning Sandstone is locally dewatered over the mined-out Freeport coal north and east of the city. Another mine-related hazard is mine fires; uncontrolled fires in abandoned coal mines are common in the area. Finally, abandoned mines and unreclaimed mine areas are the greatest source of water pollution, specifically acid mine drainage, in the Pittsburgh region.

There are many other hazards in the Pittsburgh region that are related directly or indirectly to the geology. For example, expansion of carbonaceous shales due to pyrite oxidation has occurred beneath foundations of homes and schools, causing costly damage. Blast furnace and open hearth slags are often used as drain material beneath foundations and pavements and behind walls, and are normally excellent for this purpose. However, uncured open-hearth slag will expand when it is exposed to moisture and has caused damage. Surface and groundwater pollution hazards from coal mine, power plant, and industrial waste disposal are common in this region, and even though great advances have been made in the last decade to alleviate this hazard, unchecked sources of pollution still exist.

This discussion and the papers and field trip presented in this guidebook can only present a broad, somewhat superficial introduction to the complex relationship between geology and man in this area. References from which this narrative was derived are provided below for those desiring further information.

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Yes, but look at the bright side, Martha—
we don't live anywhere near Mt. St. Helens!

COAL AND COAL MINING

by

Steven L. Collins
Consolidation Coal Co.

COAL

Everyone knows what coal is...until they are asked for a definition. Generally, coal is distinguished from other dark-colored rock by its high content of organic material, and from its precursor, peat, by the higher specific heat of its organic fraction. One excellent definition was given by Schopf (1956) who addressed problems of defining the substance:

Coal is a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material, formed from compaction or induration of variously altered plant remains similar to those of peaty deposits. Differences in the kinds of plant materials (type), in degree of metamorphism (rank), and range of impurity (grade), are characteristic of the varieties of coal.

Although, strictly speaking, coal is not a rock because it is not comprised of mineral fragments, Schopf's definition is adequate for most geological applications.

Coal varies in rank from lignite, through subbituminous, bituminous, to anthracite. Standards for distinguishing between various ranks of coal are established by the American Society for Testing Materials (A.S.T.M.). By these standards, higher rank coals have higher specific heats and/or higher fixed carbon contents (A.S.T.M., 1979). Coals from western Pennsylvania are classified in the medium- and high-volatile bituminous ranks.

Many different schemes exist for classifying the constituents of coal. In one scheme, known as the maceral concept, coal is considered to be comprised primarily of macerals which are analogous to the minerals comprising other rocks. Vitrinite, exinite, inertinite, and fusinite are some of the more important macerals. They are identified by microscopic examination of polished sections of crushed coal. Applications of these petrographic characterizations include determining the proper proportions for blending coals to produce high quality coke, predicting the strength and friability of coke so produced, and interpreting conditions which led to the formation of the coal.

The approximate analysis, or "prox," is the most widely used scheme for describing coal constituents. It consists of tests rigidly defined by the A.S.T.M. (1979) for moisture (percent weight lost at 110° C.), volatile matter (percent weight loss at 950° C. minus moisture), ash (percent weight

remaining after combustion at 750° C.), and fixed carbon (100 percent minus moisture, volatile matter, and ash). Proximate analyses are usually augmented by analyses for sulfur content and heating value (expressed in Btu per pound of coal). In industry these analyses are the basis on which most coal is bought and sold and the worth of reserves are calculated. To the geologist, fixed carbon and volatile matter content indicate the geothermal history of the coal, higher proportions of fixed carbon indicating higher temperatures. Ash content measures the amount of mineral matter in the coal which may indicate patterns of detrital sedimentation in the peat-forming swamp. Sulfur content has been attributed in part to marine inundation following peat deposition.

Ultimate analysis (A.S.T.M., 1979) provides another widely used description of coal constituents. It consists of analyses for the chemical elements carbon (not fixed carbon), hydrogen, sulfur, nitrogen, and oxygen, and the analysis for ash. The primary use of the ultimate analysis is in predicting the combustion characteristics of coal.

COAL MINING

In western Pennsylvania, the first reference to coal mining was made in 1759 when a seam was opened south of the village of Pittsburgh near the location presently occupied by Mt. Washington Park. Coal from the thick Pittsburgh seam was so easily mined and of such high quality that it became widely used in homes and industry throughout the region. Indeed, the use of coal in Pittsburgh was so great that by 1800 visitors were noticing a smokey pall over the city (Evanson, 1942, p. 20-21, 165).

Several mining methods are now employed in western Pennsylvania. "Strip" or surface mining is the most noticeable. In this method, the soil and rock overburden is removed to expose the coal seam. The coal is then ripped with large power shovels and earth-moving equipment and loaded onto trucks. The economic feasibility of surface mining a particular deposit is determined to a great extent by the thickness and quality of the coal, the thickness and nature of the overburden, and the ratio of overburden thickness to coal thickness, a guideline which is now at least 20:1. The seams may be surface mined inward from the outcrop until the overburden to coal ratio is uneconomical. The resulting surface mine exposes large areas of bare rock, often flattening hilltops, and may follow topographic contours because of the flat-lying coal seams.

Often auger mining is practiced in conjunction with contour surface mining. A large-diameter auger is used to bore horizontally as much as 200 to 300 feet into the seam beyond the economic limit of the surface mine. Auger mining is inexpensive and has a high rate of productivity, but, unfortunately, only about 50 to 60 percent of in-place coal can be recovered by this method. Surface mining, in contrast, results in the recovery of about 90 percent.

Although less noticeable than surface mining, underground mining is

more extensive in western Pennsylvania. Underground mines are often classified by the type of access to the seam: "drift mine" is reached through an opening in the outcrop; a "shaft mine" is serviced by a vertical shaft; and a "slope mine" is accessed by an inclined tunnel. It is common, however, for a large underground mine to have more than one type of opening.

In the United States, underground coal mining is accomplished by room-and-pillar, longwall, and shortwall methods. In room-and-pillar mining (Figure 7), entries (tunnels) 15 to 20 feet wide and as high as the seam thickness are driven from 60 to 100 feet apart. Conventional (blasting) techniques or continuous miners are used to drive the entries. At right angles, cross-cuts of similar size and spacing are driven. Once a given section of the mine, a panel, has been developed "on the advance," the pillars are mined "on the retreat". All or most of a pillar is removed and the mine roof allowed to collapse. Retreat mining is the most hazardous method of extracting coal. In advance mining about 30 percent of the in-place coal is removed. When retreat mining is practiced under favorable conditions about 80 percent of the coal can be extracted.

Longwall mining utilizes sophisticated machinery to reclaim virtually all of the coal contained within the panels mined by that technique. Coal is torn from the face, which is usually about 100 feet wide, by shearing machines and carried out of the mine on conveyors. At the face, mechanized chocks support the roof while the shears do their work. At appropriate intervals the chocks, one by one, lower themselves several inches, advance, then raise again to support the roof. Several feet from the face, just behind the chocks, the roof continuously caves in.

Shortwall mining utilizes the same chocks as longwall mining, but coal is removed from the face by a continuous miner. Panels are usually several hundred feet wide and recovery is about the same as it is for the longwall method.

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As the Foreword says, "It is a beginner's book... ." All aspects of coal mining are treated in an easy style with clear illustrations, including many photographs taken in coal mines. Chapters on coal geology, uses of coal, mining methods, environment, safety, and other topics.

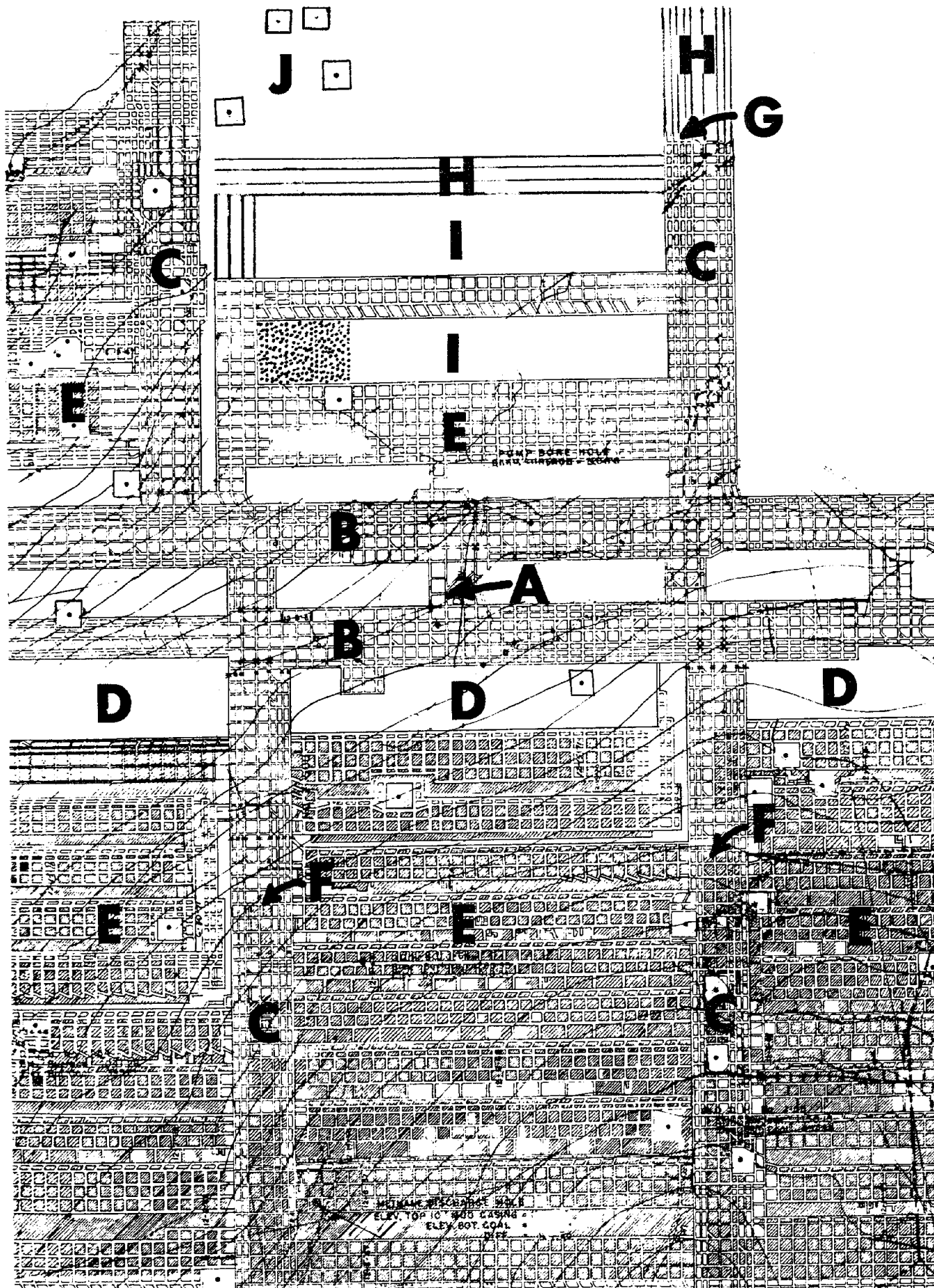


Figure 7. Map of part of a large underground coal mine. Contours indicate seam elevation in 5-foot intervals; the structure is an anticline. Scale: 1 inch = 2,000 feet.

A. Shaft. Ventilation of this mine is through a shaft.

B. Main Entries. The two sets of parallel entries are the primary means of reaching various parts of the mine.

C. Barrier Pillars. Weight of the overburden above main entries is borne by very large blocks of coal. Smaller square pillars (about 100 feet x 100 feet) support the roof immediately above the entries.

D. Submain Entries. At convenient intervals sets of entries are driven at right angles to the main entries to provide access to panels.

E. Room-and-Pillar Panels. Panels about 1000 feet x 6000 feet have been developed individually by driving entries and crosscuts, then retreat mined by removing pillars. Shaded pillars have been mined while unshaded pillars have been left because of adverse mining conditions.

F. Retreat Mining. Since the submain entries are no longer needed (the coal to which they provided access has been mined), their pillars are being removed at these points.

G. Advance Mining. Entries are being driven into blocks of unmined coal to allow access for longwall mining. Entries for room-and-pillar mining were driven in the same manner.

H. Projections. Mining of entries and cross-cuts will proceed along the indicated lines.

I. Longwall Panels. Panels 1000 feet x 6000 feet will be mined by longwall machinery. Stippled area indicates extent of longwall mining.

J. Gas Wells. Coal within 150 feet of unplugged gas wells may not be mined because of the danger of gas leaking into the mine. In a 5-foot-thick coal seam about 5000 tons of coal must be left for each well. There are 28 wells in this part of the mine, an unusually large number.

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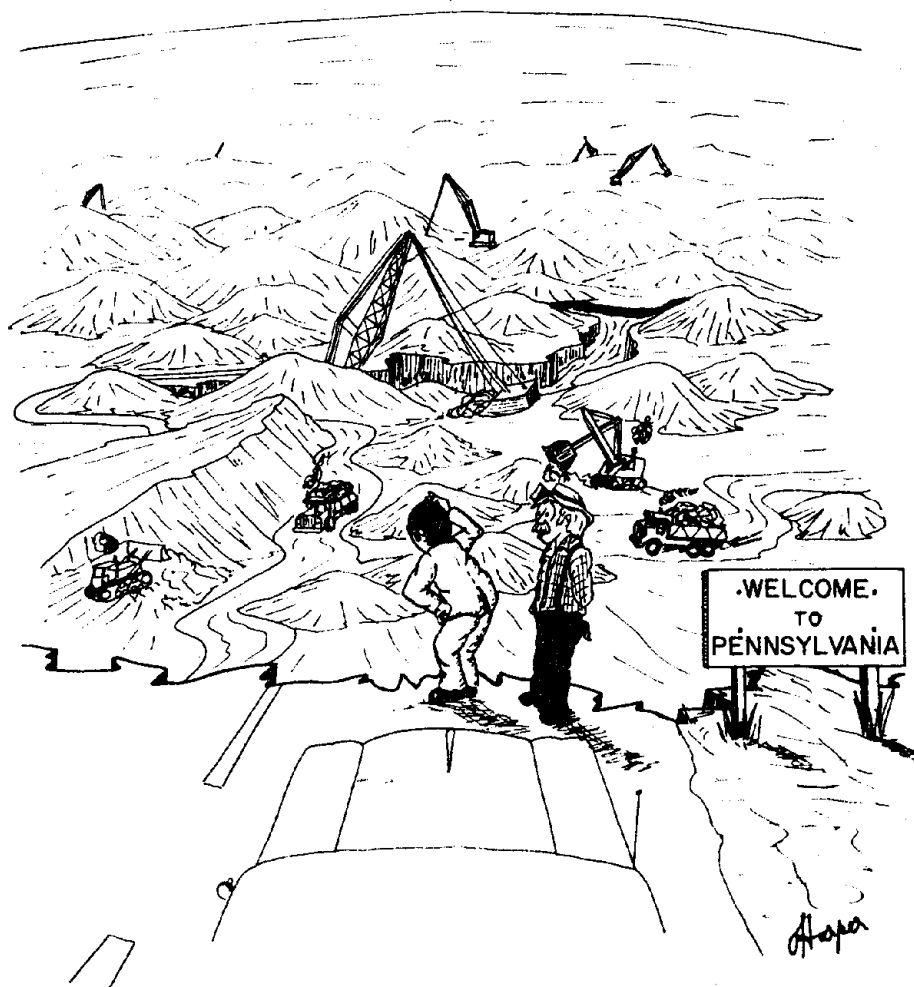
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Pennsylvany? Yep! It used to be right over thar!
'Course, that were 'fore the price o' coal went up!

MINE SUBSIDENCE IN THE PITTSBURGH AREA

by

Robert W. Bruhn

INTRODUCTION

Movements of the ground surface due to underground coal mining are by no means a new occurrence in the Pittsburgh area, as attested by the following, taken from Young and Stoek (1916):

...The outcrop of the Pittsburgh Coalbed extends for many miles in western Pennsylvania, and above these shallow workings many sinkholes have formed. These have attracted very little public attention, as they are considered to be of only a temporary character and most of the buildings above the mined areas are frame and the damage to them has also been only temporary, for if tilted out of line, these buildings have frequently resumed their normal condition after a few months.

While subsidence continues to take place in much the same way it has for over a century (although somewhat differently than alluded to above), it appears to be drawing far more attention nowadays from a far less tolerant public. This added attention can doubtlessly be attributed to the irregular, unpredictable, and continuing series of incidents of damage to homes at scattered locations over the tens of square miles of abandoned coal mines as well as to occasional incidents over active mines (Figure 8). In recent years, an annual average of about 60 abandoned mine-related incidents in western Pennsylvania create hazards or sufficiently damage property to be reported by newspapers or be investigated by state agencies concerned with mine subsidence abatement. Documented subsidence incidents in Allegheny County, 1971-75, numbered 1 annually per 35,000 individuals residing over abandoned mines in the Pittsburgh coal, or 1 annually per 10,500 housing units (Bruhn, Magnuson, and Gray, 1980b). Although corresponding figures have not been compiled for subsidence incidents above active mines, the frequency is apparently quite low as well--the probable result both of the limited area now being mined beneath highly populated areas and the measures being exercised by mine operators to protect surface structures. These figures notwithstanding, potentially damaging subsidence presents a continuing source of unrest to many property owners.

A brief review is given below of the general characteristics of subsidence as it occurs in the Pittsburgh area, based on several hundred cases of subsidence documented in the past 50 years, many of them by the Commonwealth of Pennsylvania and the U. S. Bureau of Mines.

MINING

Some of the first reported mining dates to the late 1750s when British troops stationed at Fort Pitt, near what is now central Pittsburgh, mined coal from Mount Washington overlooking the fort (Eavenson, 1938). As the demand

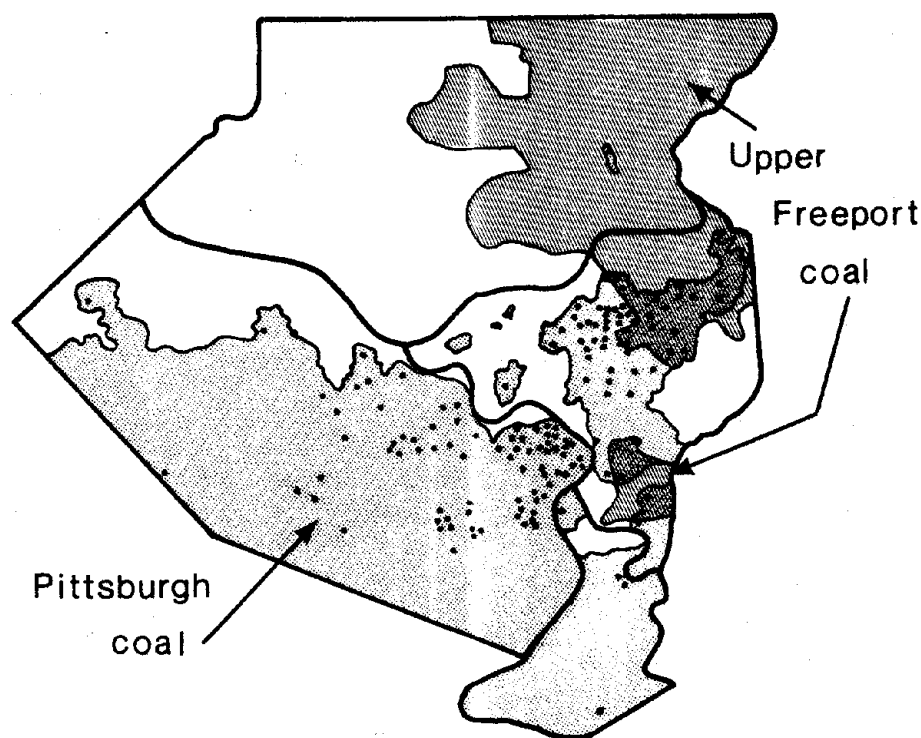


Figure 8. Areas of Allegheny County underlain by coal mines. Each dot represents an incident of subsidence documented during the past 20 years.

for coal increased, mining gradually spread away from the city to where the coal is several hundred feet below ground surface. The "Pittsburgh" coal, as it was named in the 1840s by H. D. Rogers of the First Geological Survey of Pennsylvania, extends over 6000 square miles into West Virginia, Ohio, and Maryland, and has become recognized as one of the United States' most valuable resources.

The Pittsburgh coal is now nearly worked-out beneath the Pittsburgh area (Allegheny County), but still contributes more than 80 percent of the coal produced by underground mining in southwestern Pennsylvania (Table 1). Deep mining in the Pittsburgh area is conducted primarily in the Upper Freeport coal (known locally as the Thick Freeport or Double Freeport), found in economically mineable thicknesses under the northeast sector of Allegheny County (Figure 8). The Bakerstown, Redstone, Sewickley, and Waynesburg coals have also been mined in the Pittsburgh area at various times in the past, but to a far more limited degree. Table 2 lists the coals mined in the Pittsburgh area and their stratigraphic position.

Nearly all of the coal in western Pennsylvania has been mined by room-and-pillar methods. Mines have ranged from little more than burrows dug into the hillside to extensive operations occupying thousands of acres.

Table 1. Underground coal mine production by county and coal, southwestern Pennsylvania.

| (thousands of tons - KT) | | | | | |
|--------------------------|--------------|------------|---------------|--|-------------------|
| <u>COUNTY:</u> | <u>COAL:</u> | SEWICKLEY | PITTSBURGH | UPPER FREEPORT (incl. Thick & Double Freeport) | County Totals: |
| ALLEGHENY | --- | --- | 364 (2) | 2,504 (7) | 2,868 |
| FAYETTE | --- | --- | 661 (2) | --- | 661 |
| GREENE | --- | 763 (4) | 4,377 (5) | --- | 5,140 |
| WASHINGTON | --- | --- | 9,535 (15) | --- | 9,535 |
| WESTMORELAND | --- | --- | 610 (1) | 122 (2) | 732 |
| Total Production | | 763 | 15,547 | 2,626 | 18,936 |
| Percent of Total | | 4 | 82 | 14 | 100 |

(number of operating mines in parenthesis)

Since the turn of the century, mining has generally been conducted in two phases--the advance, where entries and rooms are driven into the coal, and the retreat, where coal pillars separating the rooms and entries are systematically extracted. Figure 9 depicts this sequence in a mine operated in Allegheny County between 1900 and 1920. Modern methods employ square pillars rather than long narrow pillars, but the underlying principal remains the same. Because caving of the overburden accompanies the extraction of pillars, subsidence of the ground surface today is essentially coincident with mining, permitting safe construction of buildings on the surface a year or two after mining with little danger of future subsidence. Much of the mined-out area beneath the greater Pittsburgh area unfortunately has not completely subsided, owing either to the occasional inefficiency of the old mining methods or to mining methods where collapse of the mine openings was not part of the operation. As a result, the potential for subsidence remains many years after mine abandonment.

TYPES OF SUBSIDENCE

Subsidence features above mines in the Pittsburgh coal region are cate-

Table 2. Coal in Allegheny County mined by underground methods*

| Coal | Stratigraphic Position Relative to Pittsburgh Coal (feet) | Group | Formation | Nominal Mined Thickness (inches) | Status |
|----------------|---|-------------|------------|--|--|
| Waynesburg | +300 | Dunkard | Waynesburg | 30 | In past, mined locally for domestic use in Allegheny County. |
| Sewickley | +125 | Monongahela | Pittsburgh | 54 | In past, mined locally for domestic use in Allegheny County. At present, mined commercially in Green County. |
| Redstone | + 50 | Monongahela | Pittsburgh | 30 | In past, mined locally in Allegheny County. |
| Pittsburgh | 0 | Monongahela | Pittsburgh | 72 | Chief underground source of coal in southwestern Pennsylvania, but second to Upper Freeport in Allegheny County. |
| Bakerstown | -300 | Conemaugh | Glenshaw | 30 | In past, mined locally for domestic use in Allegheny County. |
| Upper Freeport | -600 | Allegheny | Freeport | 50 (Upper Freeport) 78 (Thick Freeport) | Chief underground source of coal in Allegheny County. |

*These and other coals in the county may also be mined by surface methods.

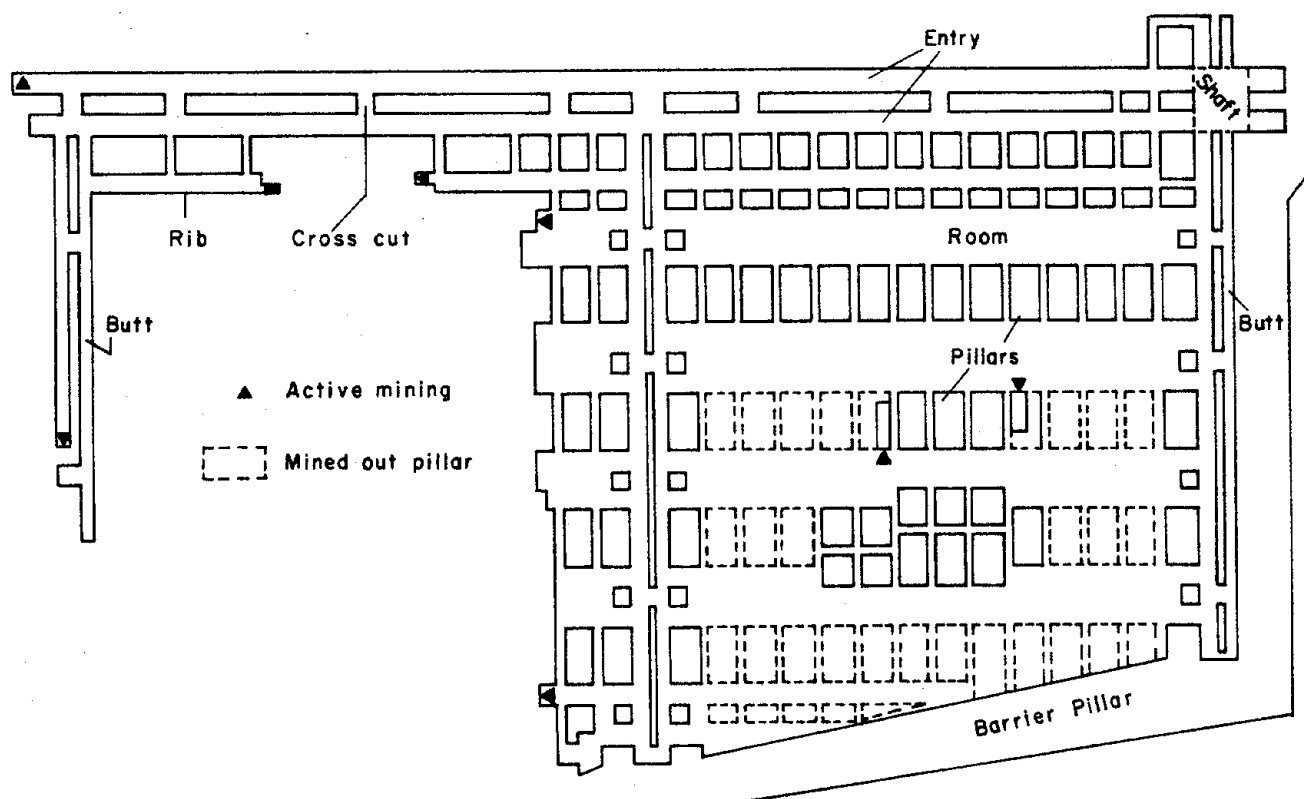


Figure 9. General plan of mine development common in Allegheny County during early Twentieth Century (after Wagner, Heyman, Gray, and others, 1970).

gorized as either sinkholes or troughs (Figure 10).

A sinkhole is a crater-like depression in the ground surface that occurs from collapse of the overburden into a mine opening (generally an abandoned room or entry). Because the feature generally bells out with depth, and because erosion may increase the diameter near ground surface, the sinkhole may resemble an hourglass in profile.

A trough is a shallow, often broad, dish-shaped depression that develops when the overburden sags downward into a mine opening in response to pillar extraction, in the case of an active mine, or in response to roof collapse, crushing of mine pillars, or punching of pillars into the mine floor in the case of an abandoned mine.

Under certain circumstances, ground cracks and slope instability are also manifestations of mine subsidence. The collapse of a concrete or wood cover over an abandoned mine shaft is more properly regarded as a structural failure.

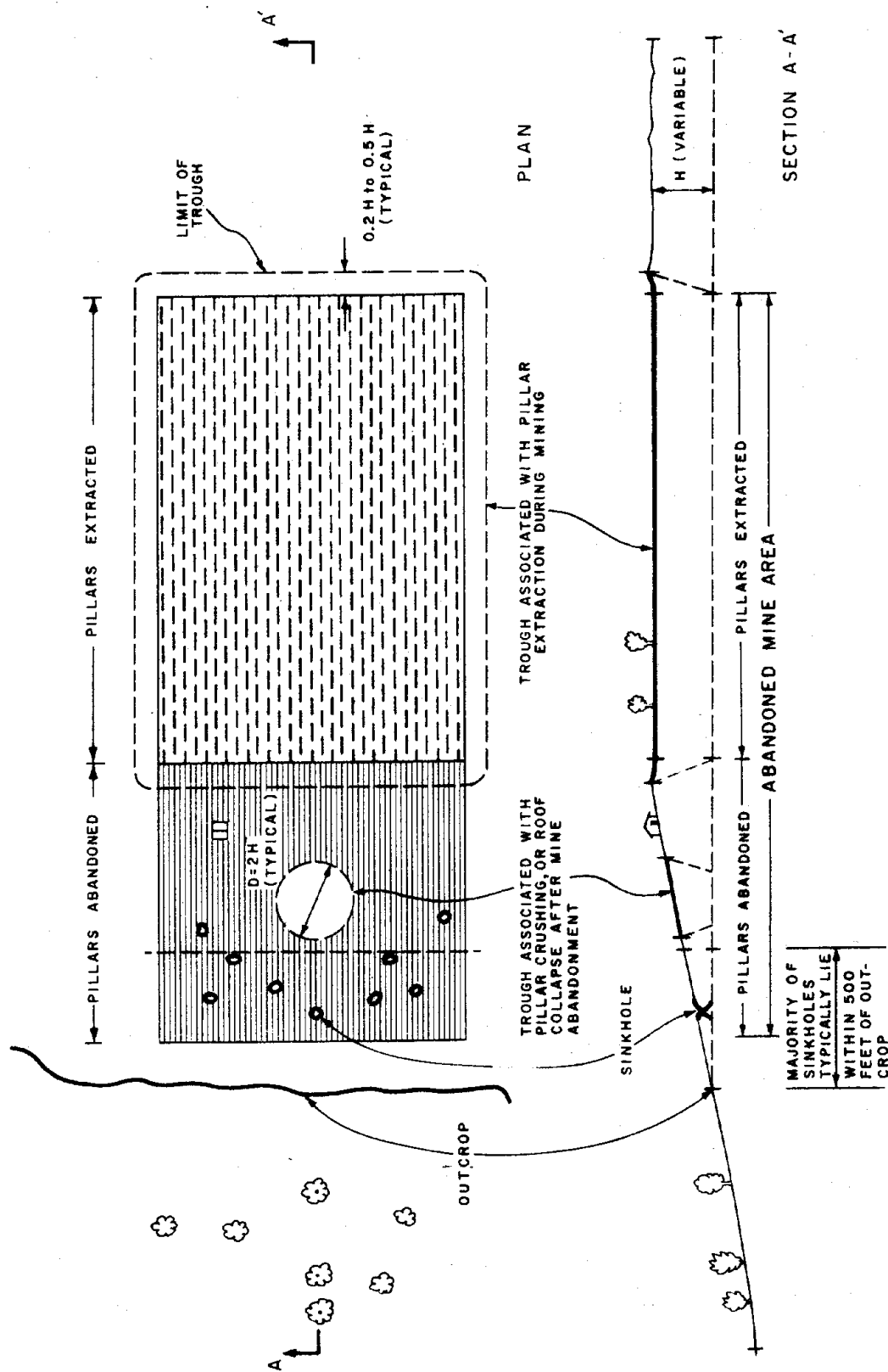


Figure 10. Typical modes of mine subsidence in western Pennsylvania

GEOMETRY OF SUBSIDENCE FEATURES

Active Mines: Most subsidence troughs above active mines are somewhat larger than the mined-out area beneath (Figure 10). They commonly extend a distance 20 to 50 percent of the overburden thickness beyond the boundary of the area where pillars have been extracted - the distance being dictated by the mechanical properties of the overburden, topography, state of stress, etc. The maximum subsidence at the center of a trough is generally 40 to 60 percent the height of the mine opening -- a maximum of 2.5 to 3.5 feet of subsidence for the 6-foot Pittsburgh and Thick Freeport coals.

Abandoned Mines: Subsidence troughs associated with abandoned mines resemble those of active mines, but are commonly much smaller. The diameter of trough above an abandoned mine is typically 1.5 to 2.5 times the overburden thickness, reflecting the limit to which the overburden can bridge over local crushed pillars or roof failures before sagging into the distressed area (Bruhn, Magnuson, and Gray, 1980b). Trough diameter appears to bear no relation to overburden thickness when punching of pillars into the mine floor is the causative factor.

Whereas troughs are generally found where the overburden thickness exceeds 70 feet, sinkholes tend to predominate at lesser overburden thicknesses (Bruhn, Magnuson, and Gray, 1980a). Sinkholes are generally less than 15 feet in diameter and 10 feet in depth -- a consequence of their collapse origin and the 20-foot width of most abandoned mine openings in the region. Competent strata above the coal are known to limit sinkhole development in some areas, but not enough information is available to determine the effect region-wide.

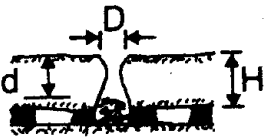
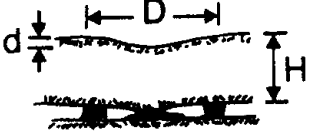
Table 3 summarizes data from more than one hundred incidents of sinkhole and trough subsidence above abandoned mines in the Pittsburgh coal region. Similar subsidence features can be found above the other mined-out coal. Local differences in overburden strata and soils may influence dimensions to some extent. Thick terrace soils, for example, promote broader sinkholes and troughs than thin colluvial and residual soils.

TIME OF OCCURRENCE

Active Mines: Eighty-five to 90 percent of the ground movements associated with total extraction mining take place when the pillars are removed. Residual movements are generally complete within two years after mining. Almost no movement is associated with the advance phase of mining.

Abandoned Mines: In western Pennsylvania subsidence incidents over abandoned mines have been reported less than a decade after mining and more than a century. More than half of all reported subsidence incidents have taken place 50 or more years after mining (Bruhn, Magnuson, and Gray, 1980b). The time of occurrence of subsidence is undoubtedly governed by the rate of deterioration of the rock strata and coal pillars, and is probably hastened by the robbing of pillars by small operators years after initial mining, modification of the ground surface by excavation or fill placement, modification of surface drainage, and other factors. It is interesting to note that the frequency of reports of sinkhole development appears to reflect the quantity

Table 3. Characteristics of subsidence features associated with abandoned mines in the Pittsburgh coal region (Bruhn, Magnuson, and Gray, 1980a)

| | Sinkholes | Troughs |
|-----------------------------|---|---|
| 1. Mode of development | Roof collapse | Roof collapse, Pillar crushing, Pillar punching |
| 2. Geometry* | | |
| a. Characteristic Profile: |  |  |
| b. Diameter, D: | | |
| Range | 1.5 - 45 ft ^o | 30 - 1600 ft ^Δ |
| Mean | 9 ft [170] ⁺ | 300 ft [15] |
| 80% | 12 ft | 300 ft |
| c. Depth, d: | | |
| Range | 1.5 - 45 ft | 0.2 - 3 ft |
| Mean | 14 ft [170] | 3 ft [15] |
| 80% | 18 ft | 3 ft |
| 3. Occurrence | | |
| a. Overburden thickness, H: | | |
| Range | 2.5 - 150 ft | 35 - 450 ft |
| Mean | 45 ft [212] | 120 ft [15] |
| 80% | 70 ft | 150 ft |
| b. Distance from outcrop | 75% of occurrences within 500 ft ^x | No apparent relationship |

*Height of typical mine opening is 5.5 to 6 feet

⁺Number in brackets denotes size of sample

^oSinkholes are roughly circular in plan, i.e., $D_{\max} = D_{\min}$

^ΔNominal trough diameter $D = (D_{\max} + D_{\min})/2$

D_{\max}/D_{\min} : Range = 1 - 3.2; Mean = 1.45 [15]

Relationship of trough diameter D to overburden thickness H

D/H: Range = 0.4 - 4.7; Mean = 2.0 [15]; 80% lie between 0.5 and 2.5; and 50% between 1 and 2

^xHillslope inclinations commonly range between 10 and 20 degrees

of precipitation experienced in the preceding three to eight months, a probable consequence of the same weatherability and strength losses of rock strata that have been responsible for the numerous landslides in the region. It is also interesting to note that recurrent episodes of subsidence have been reported at more than 30 sites in the past twenty years -- ground movements sometimes taking place two or three times at intervals of a year or more (Bruhn, Magnuson, and Gray, 1980a).

Eventually, collapse of the old mines will be complete and the threat of future subsidence will be over, but this may take hundreds if not thousands of years. The time at which subsidence will take place at a particular location is wholly unpredictable, and the prospects for making reasonable predictions in the future are dim.

LOCATIONS OF SUBSIDENCE INCIDENTS

Active Mines: Subsidence is assured wherever coal pillars are extracted. Permanent pillar support is commonly provided locally to support homes, schools and other buildings. Depending on individual circumstances, local pillar support may be provided at the mine operator's expense as a requirement of state law or at the surface owner's expense through a purchase arrangement with the mine operator. Buildings supported by permanent pillars have sometimes been damaged by subsidence, generally as a result of pillars punching into the underclay mine floor or crushing, but the frequency of occurrence has been low -- less than one-half percent of the more than twenty thousand buildings that have been supported by pillars over the past ten years (T. Alexander, personal communication). Subsidence problems associated with active mines in western Pennsylvania are at the present time minor compared with those of abandoned mines. It is, nevertheless, never minor to those whose structures are affected.

Abandoned Mines: Most sites of subsidence above abandoned mines represent locations where mine openings were not completely closed upon completion of mining. Sinkholes, being of roof collapse origin, are commonly located within 500 feet laterally of the outcrop, where the overburden thickness is less than about 80 feet (Figure 10). Trough subsidence, not being limited by overburden thickness, has been reported several hundred feet above mine level. Experience shows future subsidence cannot be ruled out in any mined-out area unless it can be established that properly designed permanent pillar support has been provided or the mine openings are completely closed. It is worth noting that surface development, mine dewatering, fires set at outcrop, and other activities by man have sometimes been the immediate cause of subsidence. For this reason, all prospective site activities by property owners should be evaluated for their possible consequences on underlying abandoned mines.

INFERENCES DRAWN FROM SUBSIDENCE CASES

Several concepts potentially important to engineers, developers, and others concerned with the planning, design and construction of buildings above mines in the Pittsburgh area are apparent from a review of the several hundred subsidence cases documented thus far, and are summarized from Bruhn, Magnuson, and Gray (1980a):

1. There is no identifiable height above an abandoned mine that ensures a site total freedom from subsidence, nor necessarily a reduction in severity of damage to structures unless total extraction of coal has been achieved during mining and the potential for further ground movements is nil. An increased interval between abandoned mine and ground surface, however, seems generally associated with a reduced frequency of subsidence. Total extraction produces movements at ground surface during mining regardless of overburden thickness. Relationships between overburden thickness and severity of damage to structures have not been studied for active mines in western Pennsylvania.
2. Unless total extraction has been achieved, there is no identifiable time after mining when the threat of subsidence is clearly past, and there appears little assurance that subsidence will be limited to a single episode. Areas undermined by efficient total extraction methods, however, are generally free of subsidence which would be detrimental to new construction one to two years after completion of pillar extraction.
3. Although the specific cause of subsidence above an abandoned mine is not often determined, it is apparent that in some cases activities by man have hastened the onset of subsidence if not initiated it.
4. Methods to effectively minimize subsidence damage to structures in abandoned mine areas include mine stabilization by grouting and backfilling with granular materials, and/or provision of structures with appropriate foundations, construction joints, etc. In areas overlying active mines, it is common practice to furnish local coal pillar support if a structure is to be protected from mine subsidence. With current methods it is not possible to predict ground movements with sufficient accuracy to design for them.

At present, geological influences on subsidence are not well understood. It is anticipated that current studies being sponsored by the Department of the Interior (U. S. Bureau of Mines), the Department of Energy and other groups will shed some light on this topic and thereby assist the profession in making more refined assessments of site conditions. This in turn will, it is hoped, lead to more economical design of structures above mine areas and an improved understanding of peripheral topics, such as the manner in which underground mining affects the groundwater regime.

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Gosh, Mister, the Boss'll be awful mad if he finds out you been trespassin' in his mine!

APPLIED GEOLOGY
IN THE EVALUATION OF TRANSMISSION STRUCTURE LOCATIONS
ALLEGHENY COUNTY, PENNSYLVANIA

by

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INTRODUCTION

The location and design of virtually all construction projects in the Pittsburgh region are affected by a variety of engineering problems associated with the area's diverse geologic features. Therefore, it is standard procedure to review the general geology of a potential construction site and to determine the presence of any geologic formation or conditions associated with construction hazards common to the Pittsburgh region. This includes locating mined coal seams, landslide-prone soils, and soft soils such as those found in alluvial deposits or waste dumps. Flood levels are determined for sites in low areas because of the flood-prone nature of Pittsburgh's steep-side valleys.

In 1978, the Duquesne Light Company requested GAI Consultants, Inc., of Monroeville, Pennsylvania, to evaluate geologic conditions at select sites along a proposed transmission line route. Transmission structures were located at approximately 1000-foot intervals. Each potential structure location required investigation. It is the purpose of this paper to review the office investigative procedure utilizing published geologic, topographic, and hydrologic data to evaluate each site and to report the preliminary findings and recommendations of the investigation. From this review it is hoped that a general appreciation and understanding will be obtained of the types and diversity of geologic problems encountered in the Pittsburgh region.

SITE LOCATION

The proposed 138 KV transmission line route, located in Allegheny County, parallels Peters Creek, a tributary of the Monongahela River. After several changes of the route location in the early planning and review stage, a final preliminary route and thirteen structure sites were selected by the Duquesne Light Company as shown by Figure 11. From west to east, the structure sites are numbered 100-0, 101-0, 101-1, 101-2, 101-3, 101-4, 101-5, 102-0, 103-0, 104-0, 104-1, 104-2, and 105-0. Elevations along the route range from approximately 740 to 1020 feet. (Following completion of the work reported herein, the three structures at the west end of the line were relocated in a southwesterly direction to intersect the Elrama-Dravosburg Line approximately two spans south of the original point. This alternate route extended 2050 feet and required a double-pole structure at the angle point. A similar geologic evaluation was conducted for these sites.)

GENERAL GEOLOGY

The preliminary investigation required a detailed search of the geologic literature. The results of this study indicated the following route conditions: the rock strata dip gently to the west along the northwest flank of the Murrysville Anticline, and include the lower part of the Pittsburgh Formation (Monongahela Group) and the Casselman and Glenshaw Formations (Conemaugh Group).

The Pittsburgh Formation, which caps the hilltops, consists of gray shales, limestones, and some sandstones with the Pittsburgh coal at its base. Below the Pittsburgh coal are the Casselman and Glenshaw Formations composed of gray or greenish shales and sandstones with a few thin coal seams and some limestones. The uppermost member of the Glenshaw Formation is the Ames Limestone which may be up to eight feet thick. Beneath the Ames are 15 to 50 feet of variegated red and green shales and claystones termed the Pittsburgh Reds. Immediately below the Glenshaw Formation is the Upper Freeport coal which occurs about 650 feet below the Pittsburgh coal. A cross section in Figure 11 along the proposed route shows the location of the structure sites with respect to the Pittsburgh coal and the Ames Limestone.

ANALYSIS OF GEOLOGIC CONDITIONS

The information obtained from the general geologic investigation indicated two possible problems along the route: (1) mine-related hazards associated with the underlying Pittsburgh and Upper Freeport coals, and (2) unstable slope conditions resulting from the predominantly shale and claystone units comprising the hillsides. Examination of the topographic map (Figure 11) indicates that the transmission route crosses Peters Creek at several points. Sites located in the vicinity of the river crossing may be subject to flooding and/or located in areas of soft soils. The topographic map shows both alluvium and industrial waste in the valley.

The initial investigation, therefore, indicated that four geotechnical problems might be encountered along the route:

- | | |
|--------------------|---------------|
| 1. Coal mining | 3. Soft soils |
| 2. Unstable slopes | 4. Flooding |

Each of these potential problems was investigated on a site-specific basis.

Coal Mining

There are two mineable coals in the vicinity of the transmission route - the Upper Freeport coal and the Pittsburgh coal. The elevations of the coals at all sites were determined from USGS Field Study Maps MF-693A (Bushnell, 1975) and MF-693B (Bushnell and Peak, 1975). These elevations were used to complete the cross section shown in Figure 11.

The Upper Freeport coal does not outcrop anywhere along the proposed route. Although this coal is approximately 36 inches thick under the transmission line route (Bushnell and Peak, 1975), it had not been mined prior to 1974. It may be mined in the future between Sites 100-0 and 101-1; however,

because of the quality, the Upper Freeport coal underlying Site 101-1 and the route east of Site 101-0 is not considered mineable (Bushnell and Peak, 1975.)

The Pittsburgh coal underlies Sites 100-0, 101-0, 101-1, 101-2, and 101-3. The possibility of mining activity at these sites was investigated and the following information obtained. The Pittsburgh coal was mined out prior to 1940 by the Solar Fuel Company in its Alice and Rachel Mines (Division of Mine Subsidence Regulation, 1970). The WPA (Works Project Administration) map, Pittsburgh No. 8, showed the mining activity extending essentially to outcrop. A minimum of 25 feet of overburden was usually required for deep mine operations during the period the Alice and Rachel Mines were active (William Black, Consolidation Coal Co., personal communication). The cover above the Pittsburgh coal at Site 100-0 (see Figure 11) is about 25 feet and WPA Mine Map 8 shows mining extending essentially to outcrop indicating the coal has probably been mined. Site 101-0 was approximately at the level of the Pittsburgh coal and it was suspected that the coal had been surface mined. This is not indicated on the USGS 7.5' topographic map; however, a topographic map of the study area prepared from a 1973 aerial photograph by Eastern Mapping Company suggested the possibility of surface mining. Site inspection would resolve this question. Site 101-1 lies about 80 feet above the Pittsburgh coal and is probably undermined. The Pittsburgh coal underlying Site 101-2 was probably not mined due to the thin overburden (less than 25 feet). Surface mining is indicated at Site 101-3 on the USGS 7.5' topographic map. The Pittsburgh coal is absent east of Site 101-3.

To summarize, five sites at the western end of the route appeared to be affected by either surface or deep mining of the Pittsburgh coal. The Upper Freeport coal poses, at present, no problem as it is either unmined or of unmineable quality. At this stage in the investigation, a cursory field inspection indicated one additional, mine-related problem. Approximately 100 feet south of Site 101-3, what appeared to be smoke from a mine fire was observed. The Bureau of Mines subsequently verified the existence of a mine fire in the immediate vicinity. A plug barrier had been installed by the Bureau of Mines in 1968 for extinguishing the fire. Burning of the coal had developed outside the area of the 1968 work and the Pennsylvania Department of Environmental Resources was planning additional work in the area.

Detailed subsurface and field investigations were undertaken to determine which of these sites might require special design considerations. These investigations revealed that Sites 100-0, 101-0, and 101-2 had been surface mined and no special design considerations were necessary. Sites 101-1 and 101-3, however, were undermined and it was recommended that both these sites be stabilized by grouting. Subsurface temperatures in the vicinity of Site 101-3 were monitored to determine the extent of the mine fire hazard. Sufficiently high temperatures were measured to justify extra grouting to provide additional protection for the pole structure.

Unstable Slopes

The relief along the route is about 280 feet and slopes of up to 80% are present. The Conemaugh Group, which produces slide-prone soils due to the predominance of shales and claystones, occurs along the middle and west-

ern half of the line (Briggs, Pomeroy, and Davies, 1975).

Areas with potential slope stability problems (Briggs, Pomeroy, and Davies, 1975) shown on Figure 11 include historic landslides, slopes with conspicuous slope creep, and outcrop areas of thick "redbeds" and associated rocks which often weather to form slide-prone colluvial soils. This does not exclude the remaining slopes from possible slide activity, but is meant to outline the more highly suspect zones. Of the thirteen structure locations, approximately six are located in the vicinity of a landslide-prone slope (100-0, 101-0, 101-1, 101-2, 101-3, and 101-5). One additional site, 102-0, is located adjacent to the scarp of a recent slide (November, 1964). The slide occurred adjacent to, and as a result of, fill placement during construction of the Ravensburg Bridge which spans Peters Creek.

It was recommended that the conditions at Site 102-0 receive special attention during the subsurface investigation. Following field reconnaissance, all but Sites 101-5 and 102-0 were considered reasonably safe from landsliding. Subsurface exploration at Site 102-0 showed a sandstone bed at shallow depth. Because of the location and type of rock near the ground surface, landsliding was judged not to be a hazard. However, for foundation design it was recommended that lateral support of the soil overburden and an interval at the top of rock equivalent to one diameter of the drilled pier foundation be neglected at Sites 101-5 and 102-0.

Soft Soils

The valley of Peters Creek contains soft soils in the form of alluvial silt possibly interfingering with wedges of clayey colluvial soils. Soft soils may also occur at locations which are covered by strip mine spoil and industrial waste.

Directly northeast of Site 105-0, previous subsurface investigation (D'Appolonia Consulting Engineers, 1978) had revealed 25 to 45 feet of miscellaneous fill which consisted mainly of granulated slag with some pockets of cinders, coke, coal, and fly ash. The fill in turn was underlain by 11 to 28 feet of floodplain deposits consisting mainly of silty clay with seams of fine sand and gravel. Underlying the alluvial deposits is bedrock which varies from elevation 704.4 to elevation 713.3. The rock varies from a gray-green soft to medium-hard siltstone to claystone. The U. S. Army Corps of Engineers (1973) topographic map indicated that the Peters Creek floodplain along the eastern portion of the route (Sites 103-0 through 105-0) was located at elevation 740. Since that time, the stream bed has been altered, apparently by the deposition of slag. The map further indicates that the floodplain of Peters Creek in the vicinity of Site 101-4 was originally much wider; the creek at elevation 760 was located approximately 500 feet further west than shown on the 1969 photo-revised topographic map.

In summary, six of the sites could be underlain by soft soils. These include 101-4, 103-0, 104-0, 104-1, 104-2, and 105-0. It was recommended that the subsurface exploration programs at these sites consider the potential soft soils.

Flooding

Due to the close proximity of several sites to Peters Creek, the 100-year flood elevation was obtained from the Pittsburgh District Corps of Engineers (U. S. Army Corps of Engineers, 1973) and from the January 24, 1979, issue of the Federal Register. These sources, respectively, showed the 100-year flood level at the mouth of Peters Creek to be elevation 751. The 100-year flood would affect only Site 103-0, located near the Ravensburg Bridge at elevation 737, 14 feet below the 100-year flood level. The designers were alerted to the flood potential.

SUMMARY

As a result of a preliminary geologic investigation, potential problem sites were identified and additional investigations conducted prior to design. It is apparent from this study that even the smallest construction site (such as that required for a transmission line structure) can be affected by the geologic conditions commonly found in the Pittsburgh region. All projects can, therefore, benefit from a detailed geologic/engineering investigation. Knowledge of geologic conditions and associated hazards common to the Pittsburgh region allows the experienced investigator to gain insight into potential problems with only a general geologic investigation. The results of this initial geologic investigation, combined with field inspection and the necessary subsurface exploration, ensure that the design and construction of the transmission line can be completed in an economical manner consistent with safety from geotechnical hazards.

ACKNOWLEDGMENT

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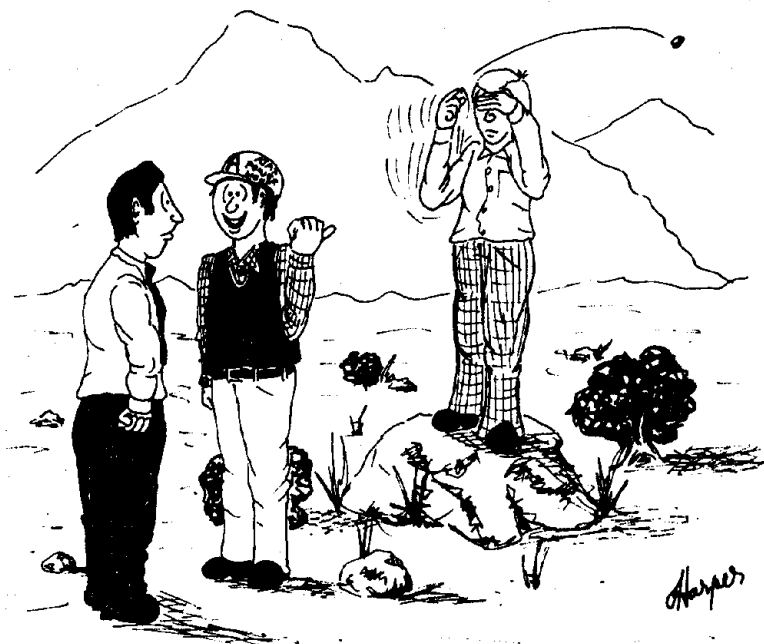
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We spent months and thousands of dollars on environmental impact statements, geologic surveys, and engineering feasibility studies, but in the long run this turned out to be the most effective method of locating high-tension-line tower sites!

GEOLOGIC FACTORS THAT AFFECT SLOPE STABILITY IN THE GREATER PITTSBURGH REGION, PENNSYLVANIA

by

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INTRODUCTION

The Greater Pittsburgh Region (Figure 12) is within the Appalachian Plateau physiographic province and is underlain primarily by cyclothemic Pennsylvanian and Permian sedimentary rocks. In this region, the potential for landsliding is high. More than 3,000 recent and at least 12,000 older slides are recognized in Allegheny and Washington Counties alone (Pomeroy and Davies, 1975; Pomeroy, 1978a).

Recent landslides in the region are generally less than 200 feet (60 m) in maximum horizontal dimension and less than 10 feet (3 m) thick. Most slides take place in silty-clayey to clayey soil; slides in bedrock are uncommon and are restricted to steep valley walls along major streams and tributary drainages. Slumps, earthflows, debris slides, and rockfalls are the most prevalent types of landslides. Transitional forms of the landslide types are abundant, and the distinction among the various types is often arbitrary. However, most landslides in the region are slumps-earthflows as defined by Varnes (1978). Slumps in fill are numerous within the more densely populated areas of the region. Soil creep, though not considered a landslide process, nevertheless contributes heavily to damage.

Natural factors which affect slope stability include slope steepness and configuration, precipitation, presence of old landslides, and the oversteepening of slopes by stream erosion. Other natural factors are related to the physical character, composition, and distribution of the bedrock and soils that underlie the slopes.

INCOMPETENT ROCKS

The rocks of the greater Pittsburgh area are cyclic, and hence, of diverse and heterogeneous character; slope-stability problems are largely related to underlying incompetent rock types wherever they are present in the section. Particularly susceptible to slumping and earth flowage are deeply weathered slopes underlain by fine-grained redbeds of the Conemaugh Group (Pomeroy, 1979; Pomeroy and Davies, 1975) and by certain fine-grained, non-red rock units, particularly in the Dunkard Group (Pomeroy, 1978a).

Red mudstone, claystone, and shale units in the Conemaugh Group are thickest and most widespread near the top of the Glenshaw Formation (Pittsburgh redbeds), but they also are present at other horizons lower in the Glenshaw Formation and in the basal and upper middle parts (Clarksburg redbeds) of the Casselman Formation. These redbeds and derivative soils are of primary concern not only because they are widespread and susceptible to slid-

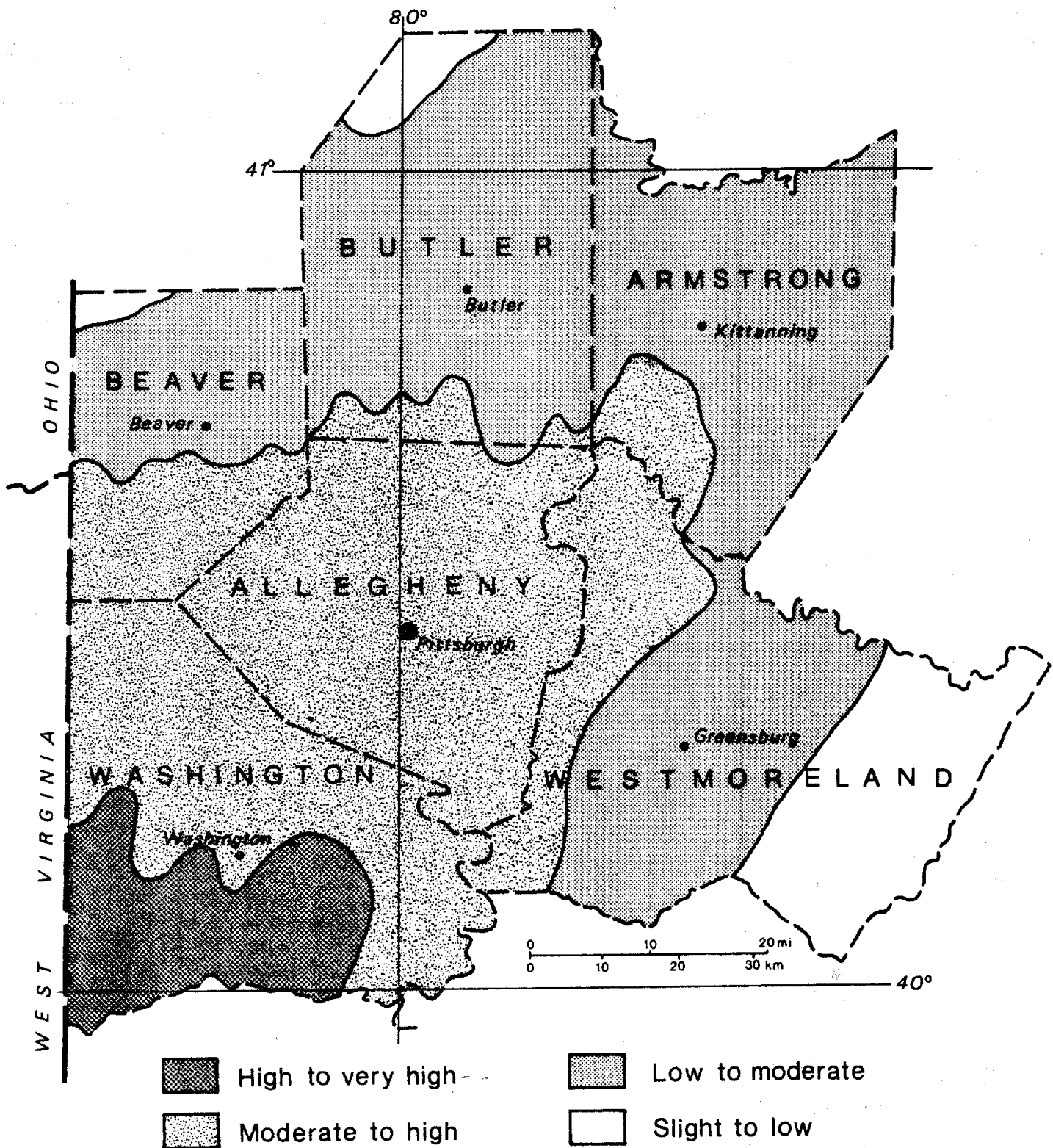


Figure 12. Generalized map showing susceptibility to landsliding in the Greater Pittsburgh Region.

ing, but also because they underlie densely populated areas -- Allegheny County, northwestern Westmoreland County, southern Butler County, and southeastern Beaver County.

A second group of rocks whose weathered products are susceptible to sliding includes non-red mudstone and claystone, particularly those in the Dunkard Group in southern Washington County and southwestern Westmoreland County. Although these rocks are of more limited areal extent than the redbeds of the Conemaugh Group, the density of slides in areas underlain by the 790-foot (240-m)-thick Dunkard Group is higher than that on slopes underlain by the Conemaugh Group. Landslides are abundant anywhere in the Dunkard terrane and are not limited to specific sequences, although they are more common in the upper part of the section, which is dominated by the non-red mudstone units.

Lithologic maps for eastern and central Washington County show a close relationship between earthflows and accumulations of weathered claystone and limestone (Kent and others, 1969; Berryhill and others, 1971). Slides have also taken place on thick units of mudstone having a high clay content, on slopes resting on underclay (particularly in the Upper Freeport coal zone of the Allegheny Group), and above other non-red claystone, mudstone, and shale units in the Pottsville, Allegheny, Conemaugh, and Monongahela Groups.

Glacial till (Illinoian) in a small area (not shown in Figure 12) of the northwestern part of Butler County is also susceptible to landsliding. Slumped material derived from the till typically includes a relatively homogeneous bluish- to brownish-gray clay (Pomeroy, 1978b).

Although rock falls are not restricted to any particular stratigraphic unit, they are most common where massive sandstone or limestone overlies weaker rock. Thick sandstone and limestone units are exposed in cliffs in the Allegheny, Conemaugh, and Monongahela Groups.

STRATIGRAPHIC THICKNESS AS IT RELATES TO SLOPE STABILITY

Winters (1972) concluded from his slope-stability study of the Pittsburgh redbeds in Allegheny County that arcuate scars and slump benches are most abundant and biggest in the areas that contain the thickest sections of the redbeds. Pomeroy and Davies (1975) confirmed the high concentration of landslides in these same areas, which are north of the Ohio River and east of McKeesport, and noted a correlation between the thickness of the Clarksburg redbeds and landsliding in the area north of the Allegheny River between O'Hara Township and Riverview Park (not shown in Figure 12).

A landslide reconnaissance study (Pomeroy, 1978a) showed that the thickest mudstone units in Washington County are in the upper part of the Dunkard Group (Greene Formation), which is also the stratigraphic interval having the highest landslide density.

LANDSLIDE-PRONE SOILS

Throughout the Greater Pittsburgh Region, rocks are normally not well exposed, but rather are masked by a fine-grained soil mantle or regolith. The

regolith is relatively thin on upper slopes but increases in thickness to a maximum of about 100 feet (30 m) near the toes of slopes. Soils weathered from red and non-red mudstone and claystone are sensitive to mass movement. Clayey to silty soils are friable and relatively low in weight per unit volume when dry; however, they retain water, becoming heavier and more plastic, hence more susceptible to downslope movement. An extrapolation of U. S. Soil Conservation Service (1974) figures for soil types and acreage in Washington County reveals that landslide-prone soils (that is, soils having a slope of at least 8 percent and a moderate to high shrink-swell ratio) occupy approximately 75 percent of the total area; they occupy only 18 and 20 percent of Allegheny and Beaver Counties, respectively.

PHYSICAL PROPERTIES OF ROCKS AND SOILS

Cyclic sedimentary rocks possess widely differing physical properties that affect their stability. Sandstone is at least five times as strong in compression and at least three times as strong in shearing strength as claystone (Philbrick, 1953). Sandstone from the Conemaugh Group has a bearing capacity more than four times as great as that of the Pittsburgh redbeds (McGlade and others, 1972).

Slaking: Many red and non-red claystones and mudstones in the region slaked within an hour to a few hours after immersion in water. The samples tested included weathered red claystone derived from the Pittsburgh and Clarksburg redbeds of the Conemaugh Group and weathered gray claystone derived from the Dunkard Group. Weathered red shales (fissile) from the Conemaugh Group, however, did not slake.

Atterberg limits: Atterberg limits indicate that soils derived from the Dunkard Group possess a slightly higher plasticity index than those derived from Conemaugh Group rocks. The expansion potential of the sample is regarded as moderate if the plasticity index is 5 to 25 and high if the plasticity index is greater than 25. The expansion potential of samples from both stratigraphic groups ranged from moderate to high.

Weathering and abrasion: Kapur (1960), in his study of the weathering of the Pittsburgh redbeds, concluded that each cycle of freezing, thawing, drying and saturation produces a loss in strength and an increase in moisture content in the weathered rocks. The rates at which rock strength is lost and moisture content is increased diminish as cycling continues. Bonk (1964) stated that the size of the weathered particles from redbeds definitely decreases as the number of weathering cycles increases.

Younger Pennsylvanian and Permian non-red mudstones and claystones from Washington County have been subjected to weathering and abrasion tests that demonstrate the effects of compactive forces and repeated wetting and drying cycles upon disaggregated samples (Berryhill and others, 1971). The results showed that the effect of a single compactive force (hammer test) is almost equivalent to four cycles of wetting and drying.

Permeability and porosity: Both permeability and porosity are relevant to the landslide process because susceptibility to sliding is increased when excessive pore-water pressure in clay decreases its shear strength. Rocks

and soils are most likely to be saturated by water in zones where permeable materials overlie relatively impermeable materials.

The red clayey soils derived from the Conemaugh Group have a relatively high porosity (as much as 40 percent), but their permeability is relatively low and as little as 1 to 5 percent of the pore water is drained by force of gravity (Subitzky, 1975).

The clay content of soil samples from landslides overlying Dunkard Group rocks is slightly higher than that of samples derived from Conemaugh Group rocks. The clayey soils have relatively high porosity and low permeability similar to those of the red clayey soils of the Conemaugh Group. The clayey material in both groups has the capacity to absorb copious quantities of water that cannot easily pass through it, resulting in soil movement.

Mineralogy: X-ray diffraction studies of Dunkard Group samples indicate that the clay fractions of these samples consists of illite, vermiculite, kaolinite, and mixed-layer minerals in decreasing order of abundance. The clay mineralogy is similar to that of soils derived from the Conemaugh Group except that the soils derived from the Dunkard Group tend to have a slightly greater proportion of expandable minerals. Similar clay-mineral data were obtained from the same units in the Greater Pittsburgh Region by Ciolkosz and others (1979). The moderate to high shrink-swell potential of most soils derived from the rocks of the Dunkard Group and of soils derived from certain rocks of the Conemaugh Group is attributable to both the relatively high clay content and the moderately high expandable-mineral content.

In a study of equivalent rock units in southeastern Ohio, Fisher and others (1968) found that clay-mineral suites in unstable redbeds consist dominantly of illite degraded by the leaching of potassium ions. These authors concluded (p. 79) that "simultaneous deposition of ferric iron with degraded illitic clay prevented reabsorption of the bonding potassium ion in the depositional environment. The continued presence of iron has greatly inhibited the reconstitution of the clay throughout diagenesis and late geologic time." Fisher and others (1968) indicated that degraded illite and montmorillonite react similarly in the presence of water except that expandability is not as great in the illite.

SUMMARY

Landslides in the Greater Pittsburgh Region are commonly thin and take place in silty-clayey to clayey soil. Most landslide forms are slumps-earthflows. Slope stability is affected by geologic factors related to the physical character, composition, and distribution of the bedrock and soils that underlie the slopes.

The highest density of mass movement is in southern Washington County along slopes underlain by mudstone of the Dunkard Group. In Allegheny County and adjacent areas, soils derived from red mudstones of the Conemaugh Group are responsible for most slope-stability problems.

Slide-prone soils derived from both the Conemaugh and Dunkard Groups have a relatively high porosity and low permeability. These soils slake within an hour to a few hours after immersion in water. Samples from both stratigraphic groups possess a moderate to high expandability.

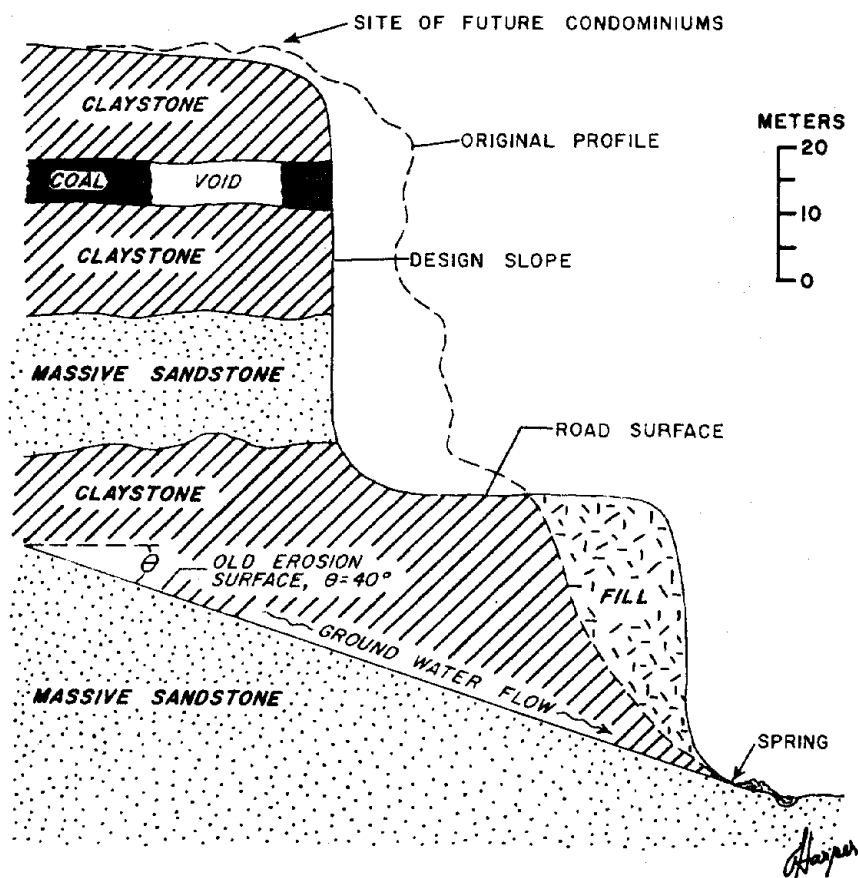
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HARPER'S GEOLOGICAL DICTIONARY



CLAY (klā) *n.* The common name of a suite of
 1.) silicate minerals or 2.) soft, easily weathered
 and eroded rocks preferred by local engineers,
 contractors, and construction firms as foundation
 material for buildings, roads and other features.

A BRIEF SUMMARY OF OIL ACTIVITIES IN WESTERN PENNSYLVANIA

by

Brandon Hussing
The Peoples Natural Gas Co.

The discovery of crude oil in Titusville at the Drake well in 1859 marked the beginning of the oil industry in Pennsylvania, the United States, and the world (for more historical information on the Drake well, see Lytle, 1959). Drilling increased rapidly from the middle to late 1800s, and Pennsylvania led the nation in total production into the early 1900s until the great Texas fields went on production. Primary production peaked between 1880 and 1895 with the development of the Bradford and McDonald fields, and secondary production peaked between 1935 and 1945 when the Bradford field was put under intensive water flooding. Pennsylvania's reserve figures are as follows:

Estimated original oil in place is put at 6,668,990,000 barrels. Total production to date is 1,294,934,000 barrels. Estimated ultimate recovery is placed at 1,343,095,000, leaving proven reserves at 48,156,000 barrels. The Pennsylvania oil patch is broken into seven producing districts: Warren County, Middle District (Clarion, Forest, and Venango Counties), McKean District (McKean and Potter Counties), Elk County, Crawford and Erie Counties, Clinton County and the Southwest District (Allegheny, Armstrong, Beaver, Butler, Fayette, Greene, Jefferson, Mercer and Washington Counties) (see Figure 13). Reserves for the individual districts are as follows:

| | |
|--------------------|------------------|
| Clinton | N.A. |
| Crawford and Erie | 489,000 bbls. |
| Elk County | 1,771,000 bbls. |
| McKean County | 18,552,000 bbls. |
| Middle District | 15,490,000 bbls. |
| Southwest District | 3,233,000 bbls. |
| Warren County | 8,651,000 bbls. |

Oil in Pennsylvania occurs in sandstone reservoirs in rocks of Pennsylvanian, Mississippian, Upper Devonian, and Silurian age. The majority of the production in the past has come from the Upper Devonian reservoirs. These producing formations are part of the Catskill Formation (also referred to as Venango or Cattaraugus) and "Chemung" sandy facies and are probably representative of delta plain, beach, or nearshore depositional environments. These oil-bearing sands as a general rule are medium grained with medium to high porosity. Within these beds, a lens or lenses occur which are made up of coarser or even conglomeritic sandstone. These lenses are generally softer and more porous than the surrounding sandstone. This is what is referred to by the drillers as the "pay zone." These porous lenses range from a few square feet to several square miles in area with the thickness ranging from one to fifteen feet or more. It must be noted that these pay streaks are not present in all formations. Some formations may be oil saturated throughout. The anticlinal theory is generally followed concerning the structural position of the oil fields but not all field positions are influenced by

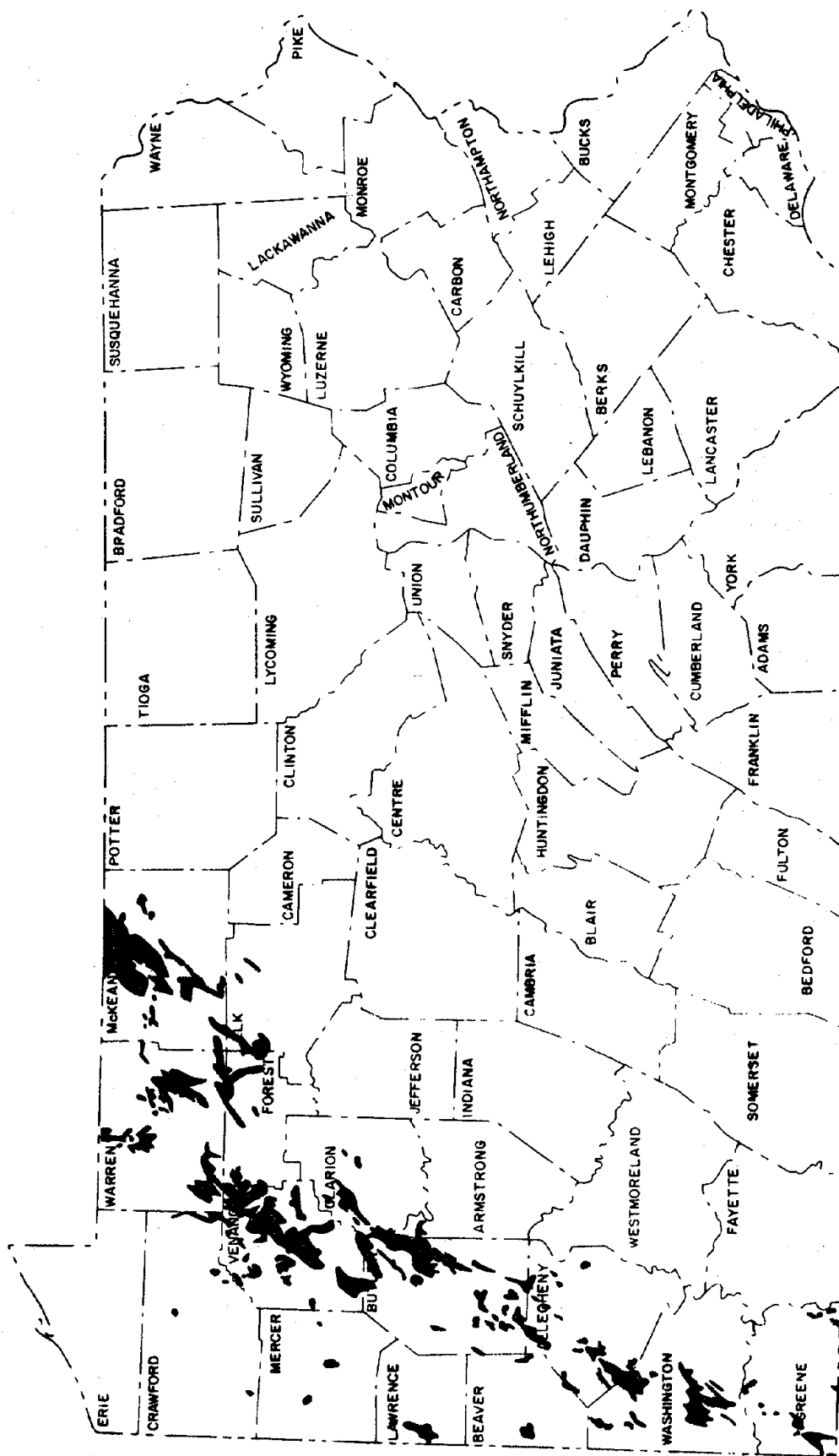
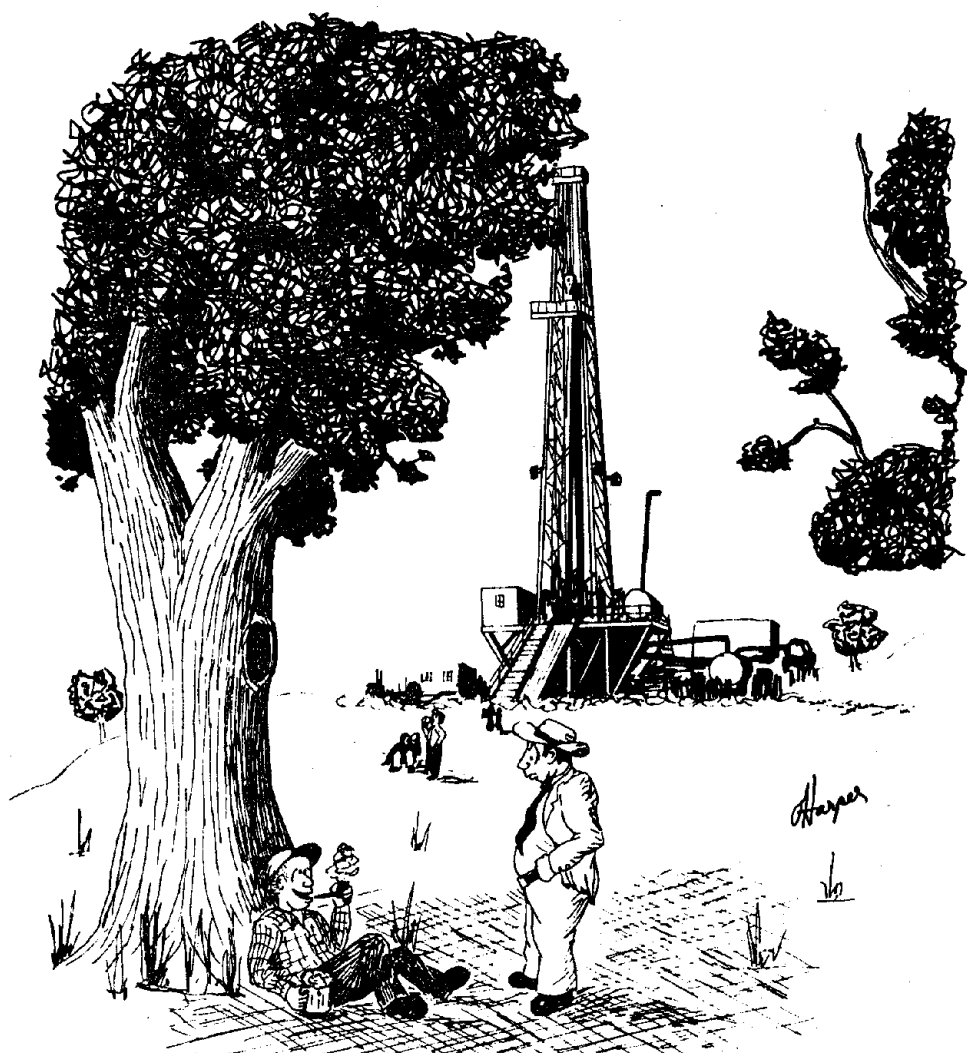


Figure 13. Map of the principal oil fields of Pennsylvania

structure. Many of the field positions are stratigraphically controlled.

REFERENCE

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We wuz drillin' through a purty thick lime rock at 300 feet when the bit hit a cavern apparently used by the local brewery fer housin' their storage vats! Now nobody gives a damn what the price of oil is!

ROAD LOG OF FIELD TRIP

DAY 1

Friday, October 3, 1980

| Inc. Mil. | Cum. mil. | |
|--------------|--------------|--|
| 0.0 | 0.0 | Mansfield Avenue at Holiday Drive entrance to Holiday Inn, Central (Green Tree), headquarters for the Field Conference. TURN LEFT onto Mansfield Avenue. Hidden from sight in the valley paralleling Mansfield Avenue to the southeast is the Pittsburgh and West Virginia Division of the Norfolk & Western Railway, originally constructed in 1904 as part of Jay Gould's Wabash Road. Here the line enters a tunnel at elevation 1005 feet, approximately 85 feet above the level of Pittsburgh coal, the basal unit of the Pittsburgh Formation, Monongahela Group. The tunnel descends at an approximate 2 percent grade to emerge 4750 feet to the northeast at elevation 915 feet, whereas the coal structure rises in the same direction. At the other end, the track is about 55 feet stratigraphically below the Pittsburgh coal, in the Casselman Formation, Conemaugh Group. |
| 0.1 | 0.1 | Mansfield Ave. curves right, crossing the center line of the N&W tunnel. |
| 0.1 | 0.2 | Intersection Mansfield Ave. and Poplar St. TURN RIGHT. |
| 0.2 | 0.4 | KEEP RIGHT and enter Route 279 North (toward Pittsburgh). This is also U. S. Route 22 and 30 and the Parkway West. |
| 0.6 | 1.0 | Large area of fill on left is site of future shopping mall. The fill is composed mostly of construction materials. |
| 0.6 | 1.6 | Gob pile (coal-mine waste) mostly hidden by trees on wooded slope to right is at site of abandoned underground mine in the Pittsburgh coal. |
| 0.5 | 2.1 | Gabion wall on left has been installed for protection of slope. |
| 0.1 | 2.2 | Exit 5 A. KEEP RIGHT to Route 51 South (Saw Mill Run Blvd.). |
| 0.2 | 2.4 | MERGE RIGHT on Route 51 South. |
| 0.3 | 2.7 | TURN LEFT onto Woodruff St. Note differential weathering and overhang of Connellsville Sandstone above claystone in road cut beyond railroad overpass. |
| 0.2 | 2.9 | Cut slope on right exposes part of the Casselman Formation; Connellsville Sandstone in lower part and interbedded claystone and shaly sandstone above. |

- 0.2 3.1 Slope on left shows hummocky topography from soil creep and minor slumping in colluvium below Pittsburgh coal.
- 0.1 3.2 TURN LEFT onto Merrimac St. This is the approximate level of the Pittsburgh coal (boundary between Conemaugh and Monongahela Groups).
- 0.3 3.5 TURN RIGHT onto Grandview Avenue.
- 0.2 3.7 STOP 1. Mt. Washington Overlook at intersection of Grandview Avenue and Bertha Street. This site is about 100 feet above the Pittsburgh coal.

AN INTRODUCTION TO THE PITTSBURGH AREA by Walter Skinner

OVERVIEW

The ideal overview of the Pittsburgh area, center of population for Allegheny County, is taken from Mt. Washington, which will be our first stop. Pittsburgh is historically linked with its geology as well as with its rivers. While water made the area accessible, the local geology played a significant role in its development. Easily accessible Pittsburgh coal became the first commercial fuel and gas the second.

Gas was first piped into Pittsburgh in 1883, and the first pool to be developed in the Pittsburgh area was the Homewood pool (1884). In addition, numerous sands contributed varying amounts of gas and oil and led, I believe, to the appearance of a unique structure to the area, namely, the standard pipe derrick. I do not believe the pipe derrick found use very far from local mills. Some of these rigs are still standing in the area, and some are still used for minor oil flow.

Fireclay obtained from the Pittsburgh coal horizon supported a thriving industry at one time as did the clays and shales in the area. At one point, in the early part of this century, over fourteen brick and tile companies had active plants in the Pittsburgh vicinity, a couple of which are still in production.

The Morgantown Sandstone, which we will see in outcrop at several localities, was a prominent building stone in the period from 1900-1920 and the only prominent dimension stone used in the area. One other thin sandstone in the Casselman Formation and a couple of beds lower in the Glenshaw Formation have been used for crushed stone and road metal.

Naturally, in speaking or thinking of mineral resources, the Pittsburgh coal is most frequently mentioned. Considered the largest, single mineral resource in the world for its consistency and areal extent, the Pittsburgh seam has been stripped or deep-mined over more than 6500 square miles.

For the first day we will be seeing features in the Conemaugh Group and a little of the Monongahela Group. (The Pittsburgh coal is placed at the base of the Monongahela Group.) Day two will deal with both the Monongahela

and Conemaugh Groups; none of the Allegheny Group is encountered on the field trip routes. Please refer to Figure 2 in the guidebook for the generalized stratigraphic column for the area.

Stop #1

We are standing on Mt. Washington near the horizon of the Pittsburgh coal. The Morgantown Sandstone crops out somewhere near the middle of the bluff below us and the Ames Limestone horizon is near the base of the hill. That places us near the top of the Casselman Fm., with the Ames at the top of the Glenshaw Fm. Dip can be roughly estimated by looking up the Monongahela River, in front of us, to the J & L works on the far side of the river in the distance. The top of the roof sections mark the approximate outcrop of the Ames on the Parkway East. There is a gentle south to southwest regional dip which explains the fact that the Pittsburgh coal crops out south of the Ohio River and east of the Allegheny River, and is found progressively deeper to the south.

Below us is the Monongahela River. To the northwest is Three Rivers Stadium and the end of the Allegheny River and beginning of the Ohio River which may also be seen in the distance. The point at the confluence of the rivers is called just that - the point. Point Park embraces the outline of Fort Duquesne; the stone edifice with the flag over it is the blockhouse. (We would certainly be remiss if we did not mention the local idea that we must live with, namely that there is a "fourth river" flowing beneath the Allegheny. The fantasy of the "underground river" has its origin in the water-bearing glacial gravels which underlie the region.)

As one looks upriver on the Allegheny past Point Park, the Hilton Hotel and behind that, the Gateway Complex can be seen. The building with the blue border is the State Office building. Along the far side of the Monongahela is the Mon parking wharf, which is a parking area until the river rises. When this occurs, parking is banned there, and the inbound lanes of the Parkway East, which with masterful planning and foresight pass below normal river level in this area, are also closed to traffic.

The tallest building in our view is the U. S. Steel building. During its construction, some of the problems associated with building in an old area were encountered. In 1795, the site of the Steel building was the location of Hoggs Pond. In 1830, the pond was filled in and the Pennsylvania Canal crossed the property. Before or during 1884, the Pennsylvania Railroad tunnel was dug (It is still in use today). Construction of the U. S. Steel building necessitated the modification of the tunnel at the building site. The tower is set on a 15-foot-thick slab, and plans called for a 390-foot tunnel to be built 35 feet above the lowest parking level. The resulting steel-framed, reinforced concrete tunnel is 21 feet high and 19 feet wide, and passes through the concourse area. The roadbed is insulated against vibration in the building by 1-1/4-inch, asphalt-impregnated planks topped with three 1/2-inch-thick rubber mats turned up at the edge all below the stone ballast. Rubber mats (3/8 inch thick) are placed between the rail plates and timber ties. The curve of the tunnel through the property was modified to fit the structure, to be isolated from the substructure, and to be connected to the main structure only at trestle-column base plates. The tunnel is fire-

proof and soundproof as well as vibration proof. The building is also designed to flex about 6 inches and then oscillate with an amplitude of about 1 foot with a frequency of about 7 cycles per minute during an 84 mph wind for 20 minutes. This velocity is considered a once in 50 year possibility.

Upriver along the Monongahela River is the red brick administration building of Duquesne University, visible over the end of the Smithfield Street bridge in the foreground. The six story building, made of bricks cast on the location by the Holy Ghost Fathers, was once the tallest structure in Pittsburgh and sits on the bluff above former river channels.

It is apparent that the structures within and around the Golden Triangle are within one or more flood plains. The area is cut by former channels of rivers and streams created and modified during glacial runoff. The waters of the Monongahela flowed through what is now Wilkinsburg, East Liberty, and Oakland and mixed with the waters of the Allegheny, leaving islands as high points on what is now called the 900-foot level or terrace. The Cathedral of Learning of the University of Pittsburgh, is one of many buildings whose foundation studies indicated stream deposited material from the former Monongahela River channel in excess of 40 feet thick. The communities we will see on the trip up the Allegheny are for the most part built on alluvium and obtain a good part of their water supply from our "fourth river" flowing within these gravels. The urban expansion that has occurred in the greater Pittsburgh area has taken building development into areas of steep hills and gently dipping bedrock. These factors, along with lithologic variations, are the primary causes of landslide problems. Fill, overloaded slopes, unknown mined-out areas, and ignorance of hazards all contribute to these problems.

- 0.3 4.0 TURNAROUND at intersection of Grandview Avenue and Shiloh Street.
- 0.3 4.3 Pass overlook site.
- 0.1 4.4 TURN LEFT onto Merrimac Street.
- 0.4 4.8 BEAR RIGHT onto Woodruff Street.
- 0.4 5.2 TURN RIGHT onto Saw Mill Run Blvd. Route 51.
- 0.4 5.6 STAY LEFT toward Carnegie and Airport. Follow I-279 South.
- 0.2 5.8 Gabion wall on slope to right. The strata in this slope belong to the Casselman Formation.
- 0.2 6.0 STAY RIGHT to Route 19 South.
- 0.1 6.1 TURN LEFT onto Route 51 South, toward Uniontown.
- 0.3 6.4 MERGE onto I-279 North (Parkway West). Follow Route 376 sign into Fort Pitt tunnel under Mt. Washington, staying in left lane. The tunnel cuts through the lower part of Casselman Formation.
- 1.2 7.6 North end of Fort Pitt tunnel. Keep left on bridge for Fort Duquesne Blvd. This bridge crosses the Monongahela River. The Ohio River, formed where the Monongahela and Allegheny rivers

meet at the Point, can be seen to the left.

- 0.3 7.9 TURN RIGHT onto Fort Duquesne Blvd. (10th St. Bypass). Follow 10th St. along Allegheny River. Three Rivers Stadium, home of the Pirates and Steelers is in view to left.
- 0.8 8.7 STRAIGHT AHEAD, proceed under Penn Central Railroad (Conrail) overpass. The new David L. Lawrence Convention Center is on right.
- 0.3 9.0 Road swings to right. Proceed straight ahead to Greyhound bus station.
- 0.2 9.2 TURN LEFT at Greyhound station on Liberty Ave. Downtown Pittsburgh buildings in sight are Federal, U. S. Steel, and U. S. Post Office buildings, and Penn Central Station (now vacant). The dome-shaped building is the Civic Arena (this dome is retractable).
- 0.4 9.6 Cut slope on right above railroad tracks exposes the lower part of the Casselman Formation, specifically the Birmingham Shale (which contains a large percentage of sandstone), and the Schenley redbeds composed of red claystone.
- 0.5 10.1 Small gully on right (beyond bus parking lot) was the site of a major landslide (debris-flow type) in 1920. The slide disrupted Bigelow Blvd., a main road leading from the downtown area, and the Penn Central Railroad tracks. This account of the slide is adapted from Scharff (1920) and Ackenheil (1954):

When Bigelow Blvd. was first constructed in 1896, it curved around the head of the small valley on a fill. Movement in that fill began 2 years after the fill was emplaced, and intermittent small-scale landsliding continued until 1920. The site was used for dumping material that fell onto Bigelow Blvd. from above. Contractors also used the site for dumping. In 1920 when the Blvd. was "improved" by straightening out the curve somewhat, additional fill (30,000 cu. yds.) was emplaced to make room for the straightened road. Within days this fill became water-saturated and began flowing. It continued to do so for about a month and a half, at a maximum rate of 10 in. per hour on November 22, 1920. General G. W. Goethals, who had directed work on Panama Canal landslides, was brought in to assess the problem and make recommendations for corrective measures. His immortal words were "Let 'er slide!" What the City did was to remove the landslide material until equilibrium was reached (Dec. 6), install a system of stone underdrains, and then a wood crib filled with crushed stone. A granulated slag embankment was then placed above the crib to provide the drainage needed

to maintain the stability of the slope. Damages to the railroad alone (which had 8 tracks blocked) amounted to eight hundred thousand (1920) dollars.

Although this experience was a good lesson regarding the dangers of blocking a natural drainage way with fill of low permeability without adequate underdrainage, to this day incorrect procedures are still practiced in the Pittsburgh area resulting in many landslides.

- 0.5 10.6 TURN LEFT onto 31st Street bridge and proceed across the Allegheny River and Herrs Island, which is 2.5 miles upstream from the Point (Pittsburgh does not have a 3-Mile Island!). This and other islands in the river are composed of glacial outwash, sand and gravel of Wisconsin age.
- 0.6 11.2 North end of 31st Street bridge. TURN RIGHT onto Route 28 North (E. Ohio St.). The Ames Limestone, a marine fossiliferous limestone about 2.5 feet thick, crops out in the bank on the north side of the river about 10 feet above road level. This thin limestone is a valuable key bed in the Conemaugh stratigraphic section. It is underlain here by 20 feet of claystone known as the Pittsburgh redbeds. In Allegheny County, this claystone ranges from 12 to 60 feet in thickness. It is generally red in color but not exclusively so. The claystone and its weathering products have low shear strength. This is one of the horizons at which landsliding commonly occurs in the Pittsburgh area. Stratigraphically the top of the Ames is the boundary between the Glenshaw and the Casselman Formations.
- 0.7 11.9 STAY RIGHT on Route 28. Washington Crossing Bridge on right. George Washington crossed the Allegheny at this site on his first official mission at age 21 in late December, 1753 (The Journal of Major George Washington, 1959). He was sent by Governor Dinwiddie of Virginia to deliver a message to the French commander in the Ohio Valley, the message in effect requesting the French to get out. Washington and his guide, Christopher Gist, constructed a raft to get from the north shore of the river to what was at that time an island in the river. The island has since been eliminated by a fill extending from the north shore. Washington and Gist were thrown from the raft by the turbulent stream and large blocks of ice floating in it, but made their way to the island and spent the night. Next morning they found the river frozen over enough to complete the crossing on the ice.
- 0.3 12.2 Millvale Boro on left. The roadcut just beyond (northeast) exposes 75 to 100 feet of the Casselman Formation from Pittsburgh redbeds up to the Birmingham shale and sandstone.
- 0.2 12.4 The steep slope on left for the next half mile is the site of periodic earthflow-type landsliding. Colluvial soil, derived mainly from the Schenley and Pittsburgh redbeds, when saturated

with water, slowly moves down the slope to road level, requiring the closing of the inside traffic lane until cleanup crews remove the debris. A recent earthflow is seen at Mile 12.7 and another at 12.9.

- 0.9 13.3 Shaler Twp. waterworks on left. FOLLOW ROUTE 28 NORTH.
- 0.3 13.6 Etna Boro on left. Road crosses Pine Creek, an Allegheny River tributary.
- 0.3 13.9 West end of roadcut that extends for the next half mile or more. This cut exposes part of the Glenshaw and Casselman Formations from the Upper Saltsburg Sandstone up to the Connellsville Sandstone. The conspicuous sandstone/shale unit about half way up is the Birmingham. The white coloration toward the top of it is a calcite encrustation of joint faces. Calcium carbonate leaches downward from nodular limestone in the claystone above, and is precipitated along joints in the sandstone. The Boro of Sharpsburg is on the right. At this locality the route crosses the axis of the McMurray Syncline.
- 0.8 14.7 Bridge over Kittanning Pike.
- 0.8 15.5 Highland Park Bridge on right. FOLLOW ROUTE 28 NORTH.
- 0.2 15.7 Aspinwall Boro on right. There was a major landslide here that removed the outbound lane of Route 28 (the one we are driving on) and several adjacent houses in 1976, about 10 years after the road was built. The repair costs totaled more than 1.5 million dollars. The failure was in fill material derived from a cut on the upper side of the highway where the Pittsburgh redbeds occur. It is probable that the unstable underlying foundation soil on which the fill was placed was one of the principle causes of the landslide. A reinforced earth wall was used as a corrective measure to provide slope stability (Figure 14.)
- 0.6 16.3 Filter beds and water filtration plant of the City of Pittsburgh on right.
- 0.4 16.7 Fox Chapel exit from Route 28. PROCEED ON ROUTE 28 NORTH.
- 0.2 16.9 Bridge over Squaw Run.
- 0.3 17.2 KEEP LEFT ON ROUTE 28 NORTH toward Kittanning. Do not go through Blawnox.
- 0.3 17.5 Entering RIDC Industrial Park (Regional Industrial Development Corporation). For the next half mile the highway traverses a fairly flat area underlain by about 50 feet of sand and gravel of a "high-level" terrace. This terrace is about 200 feet above the present Allegheny River, and is composed of Illinoian outwash deposits. Before the Industrial Park was developed, this area was part of the Allegheny County Workhouse farm.

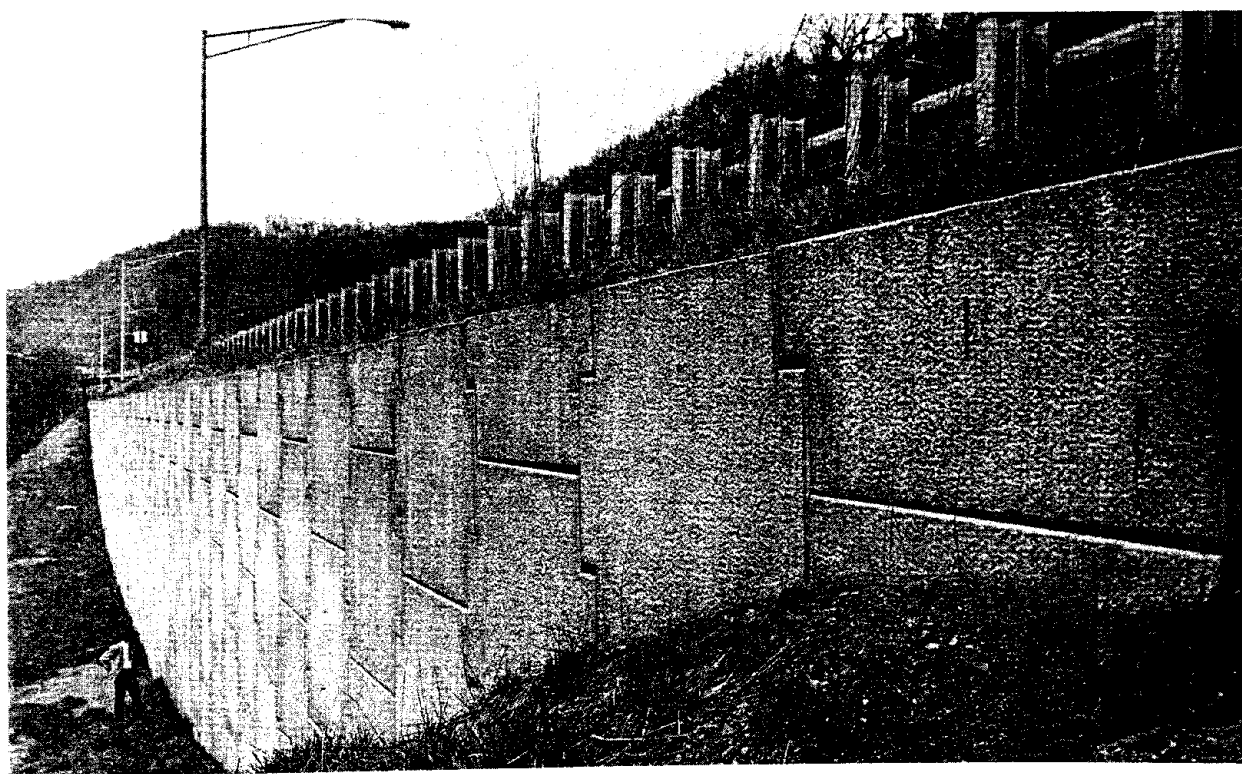
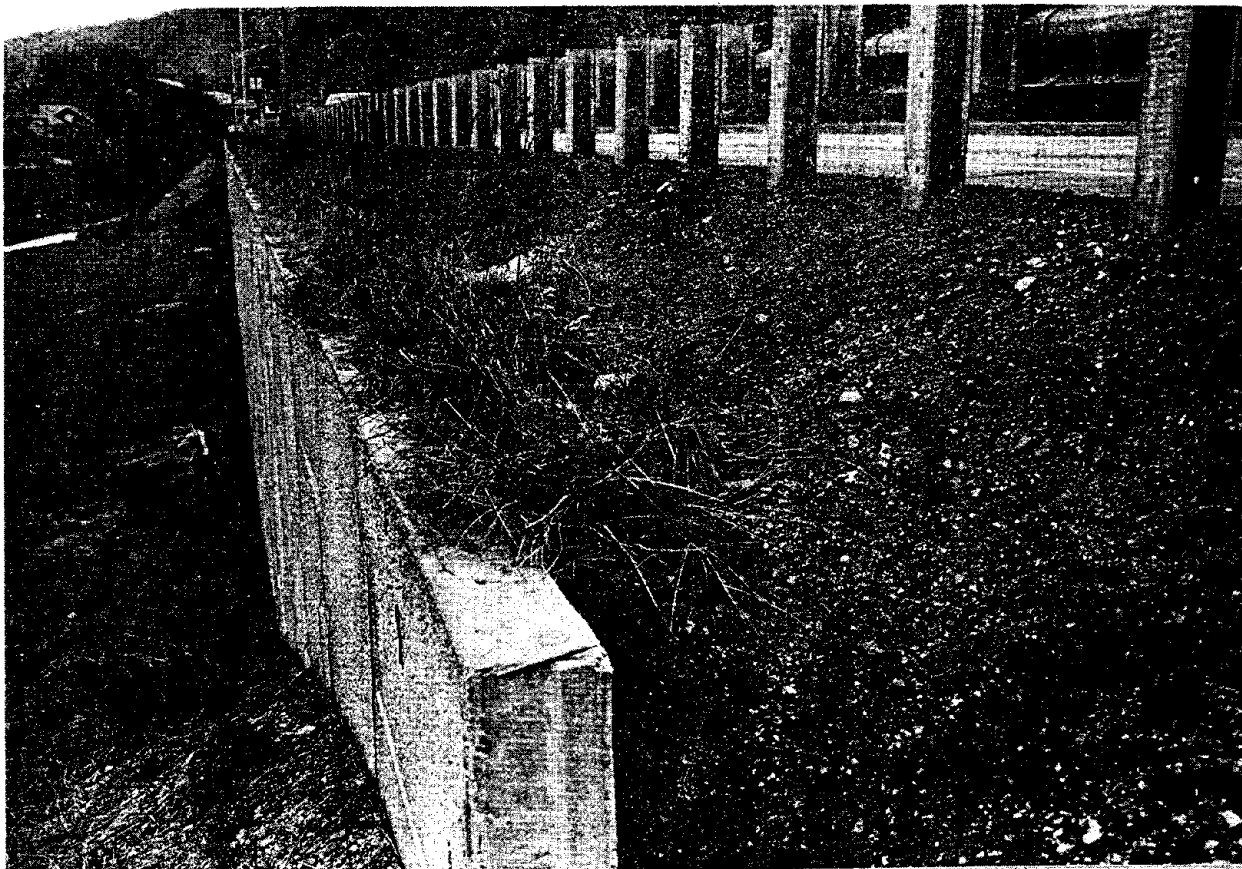


Figure 14. Two views of the reinforced earth wall at landslide site on Allegheny Valley Expressway (Route 28) at Aspinwall, looking west.

- 0.8 18.3 Holiday Inn on right.
- 0.7 19.0 Cross over Powers Run Road.
- 0.2 19.2 Road cut on left shows two earthflow-type landslides at the level of Pittsburgh redbeds. The original cut slope was steeper, but because of landsliding, the slope was flattened. This extended the cut laterally, thus necessitating the removal of houses, contrary to original plans.
- 0.2 19.4 South end of extensive highway cut. This exposure continues for about one mile and exposes roughly 275 feet of the Conemaugh Group, from below the Woods Run Limestone horizon to the Clarksburg redbeds. Figure 15 is a photograph of this cut with the stratigraphic units and other features identified. The prominent black layer about a third of the way up the cut is black shale at the horizon of the Bakerstown coal. A few inches of coal can be seen just below this black shale. About 30 feet below the black layer is an unnamed channel sandstone body that lenses out laterally in what are probably lenticular crevasse-splay deposits adjacent to a channel fill.
- 1.1 20.5 North end of road cut at Hulton Bridge over Allegheny River. Note minor slump at extreme north end. Figures 16 and 17 show details of the exposed section here.
- 0.2 20.7 Harmar Mine (left) of Consolidation Coal Company where the Upper Freeport coal has been mined for metallurgical coal since 1918. Mining is at a depth of about 300 feet. The complex of green buildings is a cleaning plant. Coal is loaded directly from the plant onto barges at the dredged-out mouth of Deer Creek.
- 0.2 20.9 Tailings from coal-cleaning operation on left.
- 0.2 21.1 TURN RIGHT at exit from Route 28 toward Oakmont.
- 0.2 21.3 TURN RIGHT to Route 28 North (Yellow Belt).
- 0.1 21.4 TURN RIGHT toward Oakmont on Freeport Road.
- 0.4 21.8 Guys Run Rd. intersection. STAY IN LEFT LANE.
- 0.5 22.3 TURN LEFT and cross Hulton bridge on Yellow Belt. The island to the left is Twelve Mile Island. Continue straight on Hulton Road.
- 0.3 22.6 East end of Hulton bridge.
- 0.2 22.8 TURN RIGHT on Allegheny Avenue. Here the route is on the "low-level" terrace composed of Wisconsinan outwash.
- 0.7 23.5 TURN RIGHT on Washington Avenue and continue to Oakmont Yacht Club at end of road.



Figure 15. Roadcut on Route 28 in the Conemaugh Group, 0.4 mile north of Powers Run Road.

| | |
|---|---|
| C1 - Clarksburg redbeds | Ba - Bakerstown coal |
| M - Morgantown Sandstone (shaly facies) | S1 - Lower Saltsburg Sandstone (shaly facies) |
| S - Schenley redbeds | WR - Woods Run Limestone |
| Bi - Birmingham sandstone and shale | Us - Unnamed Sandstone |
| D - Duquesne coal | R - Route 28 (Allegheny Expressway) |
| A - Ames Limestone | F - Freeport Road |
| P - Pittsburgh redbeds | RR - Conrail tracks |
| Su - Upper Saltsburg Sandstone (shaly facies) | |

0.3 23.8 STOP 2. Oakmont Yacht Club (Mile 12 on Allegheny River). Here the group will board the U. S. Army Corps of Engineers' barge for a trip down the Allegheny. The geology along the river will be discussed en route.

Allegheny River

River
Miles

12 Oakmont Yacht Club. Extensive roadcut across the river (west side) exposes Conemaugh strata from below Woods Run Limestone

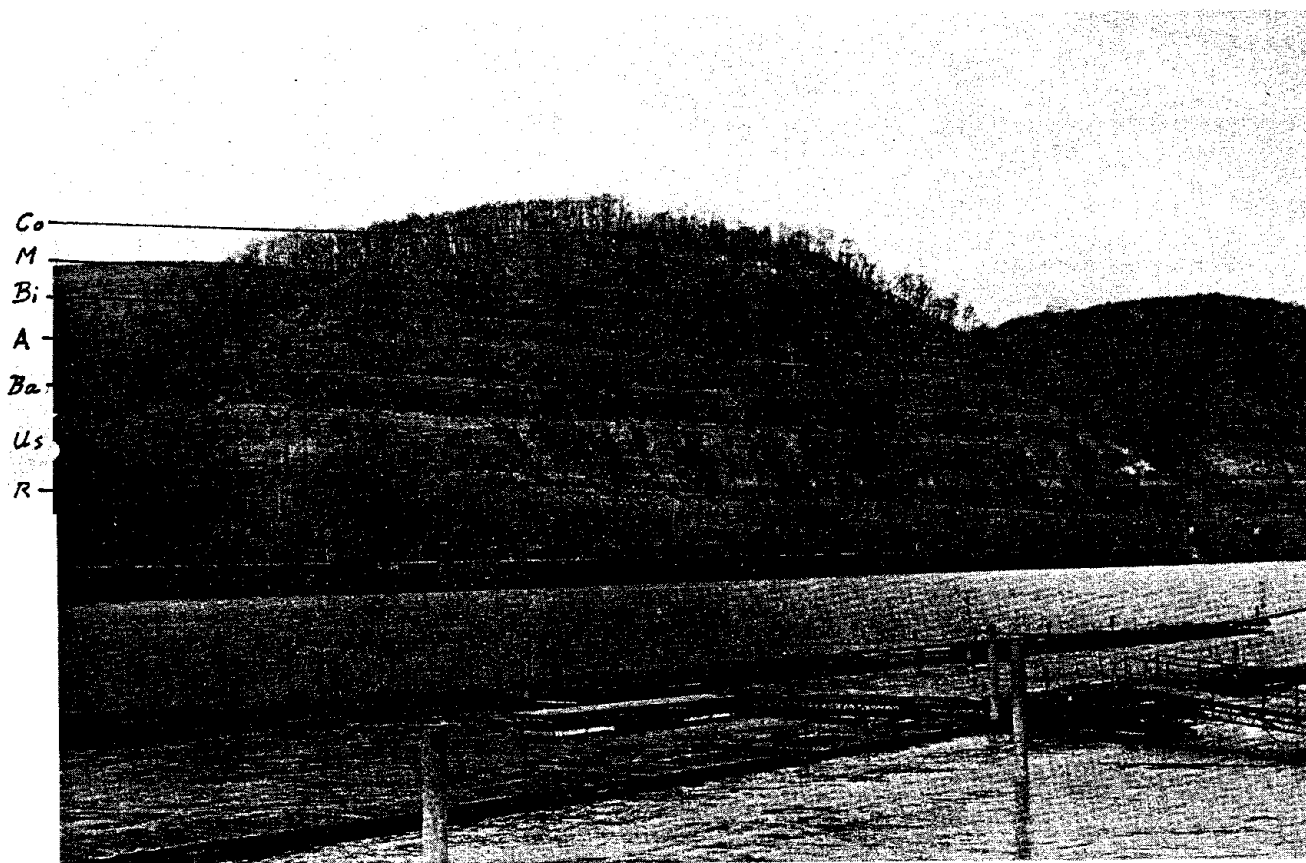


Figure 16. View at north end of the Route 28 roadcut at Hulton Bridge.

- | | |
|---|--|
| Co - Connellsville Sandstone | Ba - Bakerstown coal |
| Cl - Clarksburg redbeds | Sl - Lower Saltsburg Sandstone (shaly facies) |
| M - Morgantown Sandstone (shaly facies) | |
| S - Schenley redbeds | WR - Woods Run Limestone |
| Bi - Birmingham sandstone and shale | Us - Unnamed sandstone, with crevasse splay (cs) |
| A - Ames Limestone | PC - Pine Creek Limestone |
| P - Pittsburgh redbeds | R - Route 28 (Allegheny Valley Expressway) |
| Su - Upper Saltsburg Sandstone (shaly facies) | RR - Conrail tracks |
| F - Freeport Road | |

Oakmont Yacht Club docks in foreground.

to Schenley redbeds (see Figures 15, 16, and 17). Small tributary directly across river from Yacht Club has been filled with "waste" material from Route 28 excavation. A housing development on top of this fill is contemplated.

11.3 Powers Run valley on right.

11.1 Roadcut (right) exposes the Brush Creek limestone to Saltsburg sandstone interval of the Conemaugh Formation. Village of Verona on left.

10.0 Sycamore Island on right and Nine Mile Island on left. Near down-

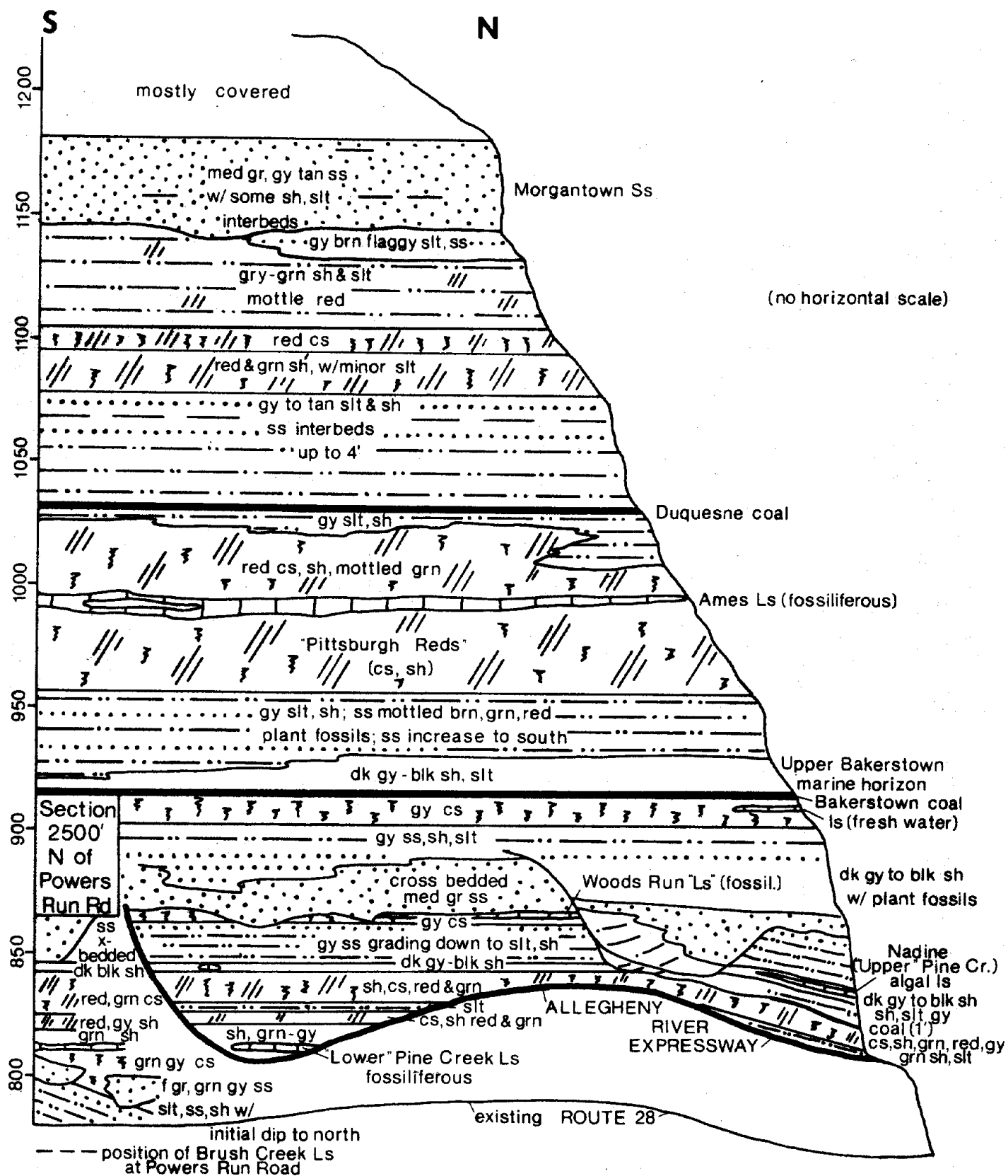


Figure 17. Sketch of the stratigraphy of the outcrop at Hulton Bridge along the Allegheny River Expressway (after D. R. Kelley, W. R. Wagner, R. Lund, 4/71).

stream end of Sycamore Island note abandoned wooden barge. That has been there a while.

9.5 Blawnox Borough on right.

9.1 Papercraft plant on right. Note flattish upland area beyond. This is an Illinoian terrace with about 50 feet of pea- to marble-size gravel on it.

8.6 Mouth of Squaw Run adjacent to marina in dredged-out cove on right. Cliff exposure on left is Brilliant Cut. It was the site of a major bedrock landslide in 1941. Two earlier landslides occurred here in 1930 and 1931 after excavating for the relocation of the Pennsylvania Railroad tracks. In March, 1941, a train rounding the curve was derailed and a slump involving an estimated 109,400 cu. yds. of material (Ackenheil, 1954) followed. The rock mass moved with a backward rotation; the head dropped about 15 feet, and, at the toe, 3 railroad tracks were thrust upward, one for a maximum of about 5 feet. The movement was rapid. The failure was attributed to water pressure that built up in the slope in an open joint in the Birmingham Shale (sandstone facies) which is the cliff-forming unit. Although it was known in the 1930s that this joint was opening, little attention was paid to it. Water could not freely drain to the surface at the contact between the Birmingham and the impermeable clay unit below (Duquesne clay) because of ice blockage. The failure surface was concave upward; its lowest position was located stratigraphically in the Woods Run claystone, which is one of several weak claystone units in the Conemaugh Group.

The site was re-studied by Hamel (1972) and by Gray, Ferguson, and Hamel (1979). A generalized cross section from those papers is shown in Figure 18.

8.0 City of Pittsburgh Water Treatment plant and pumping station. The steep valley wall on left has an abundance of colluvial soil on it. Periodic landslides on this slope close Allegheny River Blvd.

6.6 Highland Park bridge and Lock No. 2 (Figure 19).

6.3 Six Mile Island on right.

6.0 Sharpsburg Borough on right. Roadcut exposes part of the Conemaugh Group, from the Pittsburgh redbeds to the Connellsville Sandstone. The axis of the McMurray Syncline crosses the river at this locality. The trend of the axis is northeast.

5.4 62nd Street (Fleming) bridge.

4.6 Mouth of Pine Creek (concrete culvert) on right. Etna Borough beyond.

4.4 Shaler Township Waterworks plant on right (red brick building). The steep valley wall behind this plant and downstream for a half mile is landslide prone. Colluvial soil from Pittsburgh redbeds and Schenley

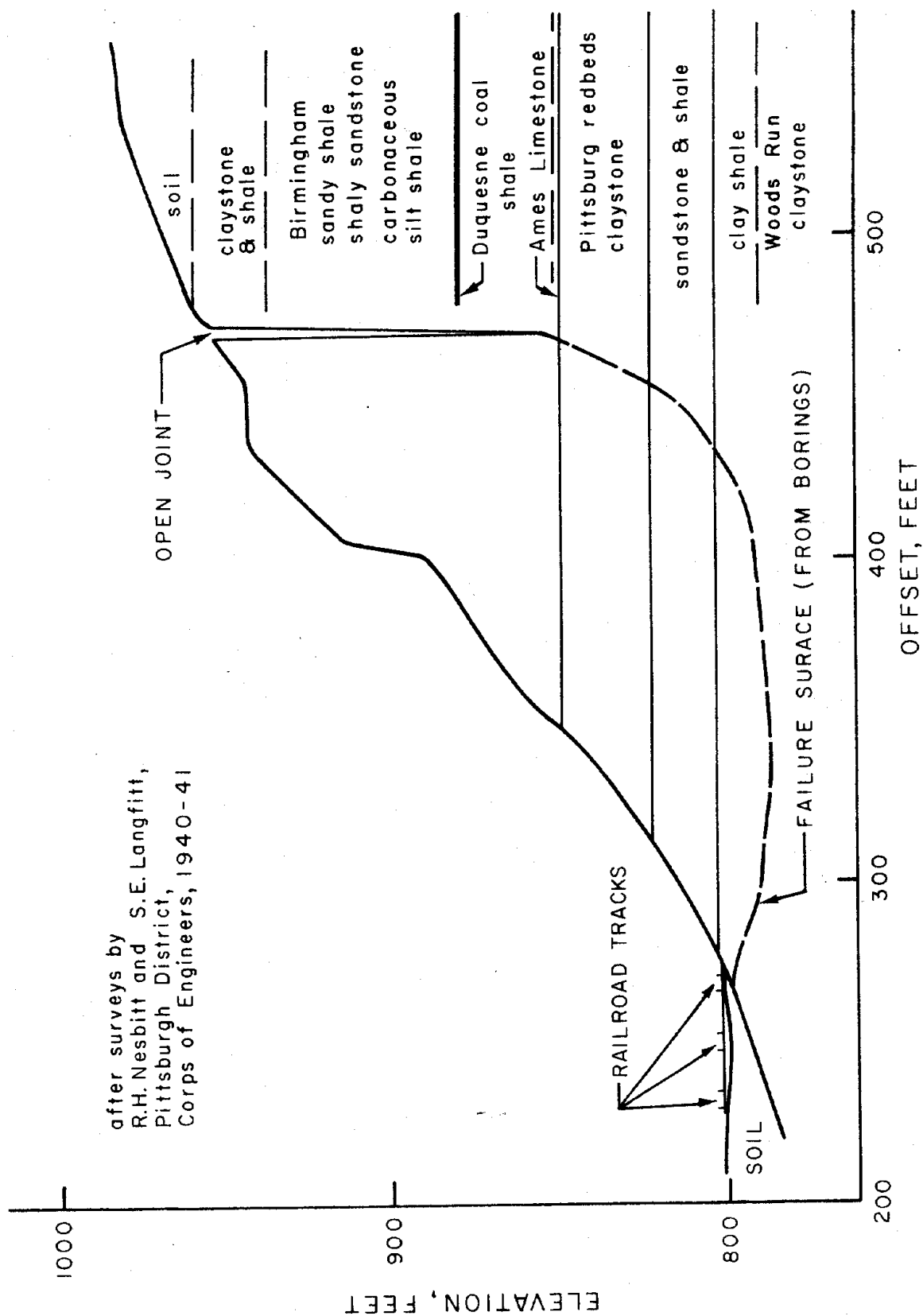


Figure 18. Generalized cross-section, Brilliant Cut (modified from Hamel, 1972, and Gray, Ferguson, and Hamel, 1979).

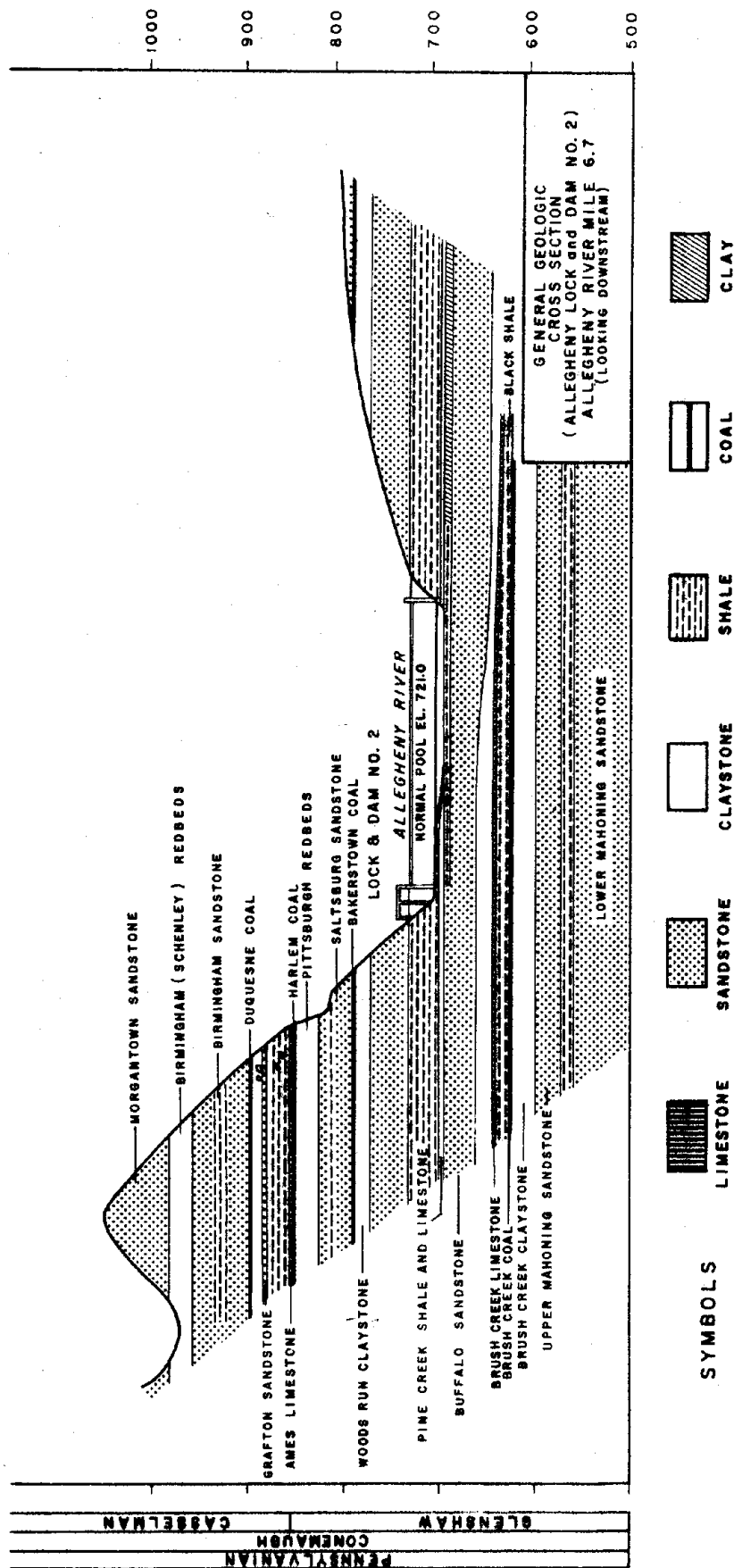


Figure 19

redbeds contribute to the landslide problem.

- 3.7 Roadcut at Millvale exposes Conemaugh Group from Pittsburgh redbeds up to Birmingham member (shale and sandstone).
- 3.2 Washington Crossing bridge.
- 2.9 Herrs Island (upstream end).
- 2.5 31st Street bridge. The Troy Hill section of Pittsburgh can be seen to right. This is built on the Illinoian High-level terrace.
- 1.9 - 1.3 H. J. Heinz plant (the original one) on right. The 16th Street bridge leads to the plant.
- 1.0 - 0.0 Downtown Pittsburgh. The tallest building (60 stories) is the U. S. Steel building. Roberto Clemente Park on right. We pass under the 9th Street, 7th Street, 6th Street, and Fort Duquesne bridges in order.
- 0.0 Point State Park. The water fountain at the Point is supplied by ground water from the Wisconsin outwash gravel. Three Rivers Stadium on right. At the Point, the Allegheny joins the Monongahela to form the Ohio River.

Ohio River

Miles

- 0.1 Note the Fort Duquesne Incline on left. This takes passengers to and from Duquesne Heights, and is one of two operating inclines in Pittsburgh, all that remain from 17.
- 0.5 Exposures in the bluff on left are in the middle part of the Conemaugh Group.
- 0.8 West End bridge.
- 1.6 Upstream end of Brunot Island on left. The island is named for the Brunot family who once inhabited it. Duquesne Light Company's power generation plant is located on the island. Prior to 1972 coal was used as fuel at this plant, but because of environmental concerns it switched to oil in 1972.
- 2.7 Western Penitentiary on right (in Woods Run section of Pittsburgh).
- 3.1 Alcosan sewage treatment plant on right (Allegheny County Sanitary Authority).
- 3.2 McKees Rocks bridge. The sandstone cropping out in bluffs along the stream for the next two miles is Buffalo Sandstone lying about 130 feet above the Upper Freeport coal.

- 4.5 Small island on left is Davis Island.
- 4.9 - 5.0 Upstream end of Neville Island. Westview Authority Water Treatment plant is located at this end of the island. Water is obtained from wells in the Wisconsin gravel beneath the river.
- 6.0 Emsworth Lock. Disembark and reboard buses.

Inc. Cum.
Mil. Mil.

- 23.8 Emsworth Locks. The exposure in the adjacent cliff is the Buffalo Sandstone (Glenshaw Formation). For geologic cross section at this site see Figure 20.
- 0.1 23.9 TURN RIGHT on Brighton Rd. Here we are in Ben Avon Boro.
- 0.1 24.0 TURN RIGHT on Ohio River Blvd. (Route 65).
- 0.3 24.3 Enter Emsworth Boro.
- 0.4 24.7 Intersection of Route 65 and Lowries Run Road. Stay straight on Route 65.
- 0.8 25.5 Roadcut on right exposes the Buffalo Sandstone. Several rock falls have occurred at this site. Neville Island in Ohio River is in view at 11 o'clock.
- 0.7 26.2 Enter Glenfield Boro. More Buffalo Sandstone exposed on right.
- 0.2 26.4 KEEP LEFT. Follow Route 79 signs toward Erie.
- 0.4 26.8 TURN RIGHT and go under bridge. Enter village of Glenfield. Much of this village was removed because of the construction of Interstate Route 79. Morgantown Sandstone is exposed at top of cut on left.
- 0.3 27.1 Cut on right exposes part of the Glenshaw Formation below Pine Creek Limestone.
- 0.3 27.4 TURN RIGHT and enter I-79.
- 0.5 27.9 STOP 3. Slide "A" site at Station 910 marker on I-79.

At this site we see where extensive landsliding occurred because of undercutting of older landslide masses at the stratigraphic level of the weak Pittsburgh redbeds. Later, at STOP 4, we see a proposed highway construction site (I-279) with potential for landsliding in essentially the same geologic setting. See index map (Figure 21) for location of STOPS 3 and 4, and see Figure 22 for stratigraphic section of Glenfield area.

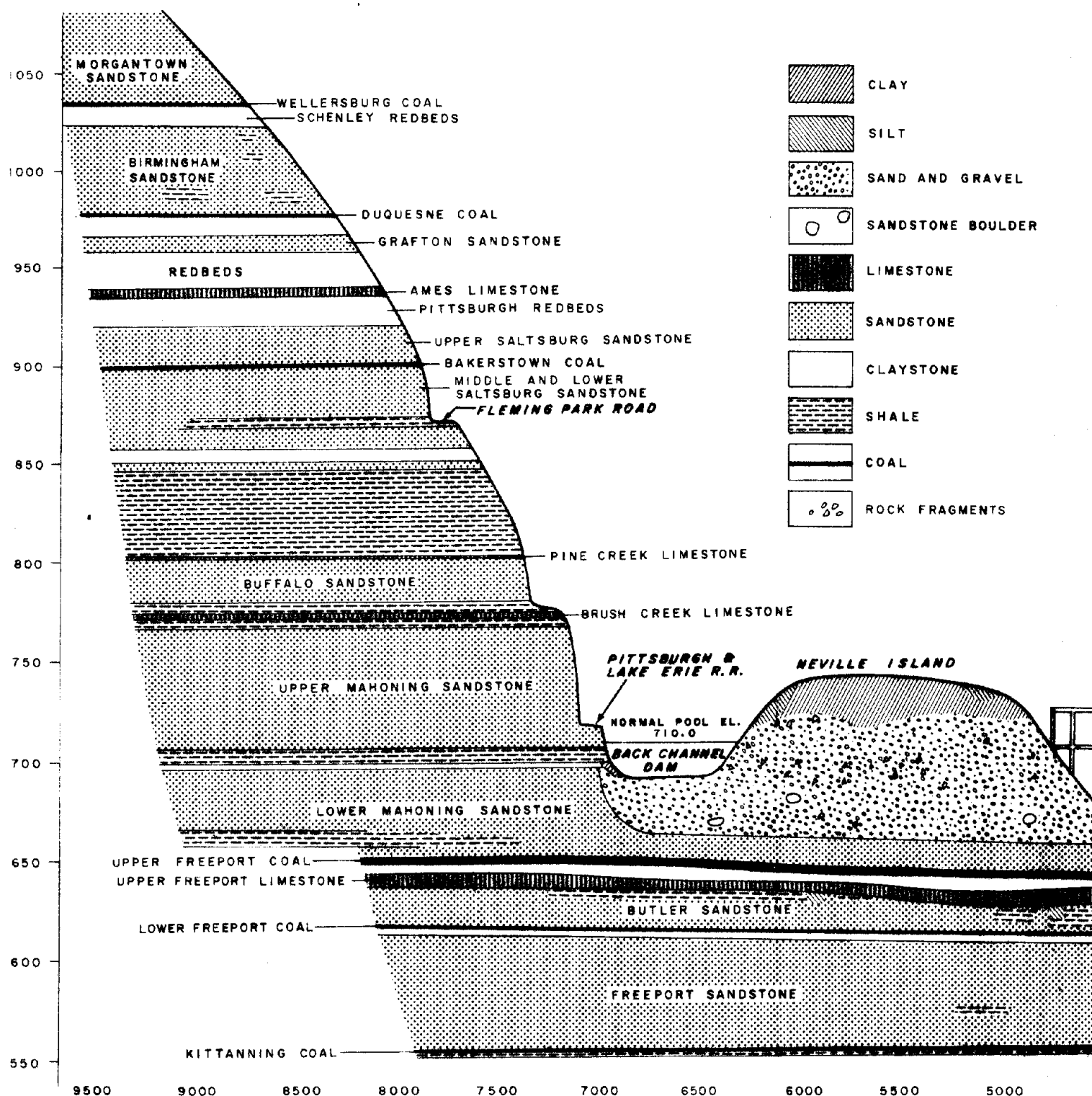
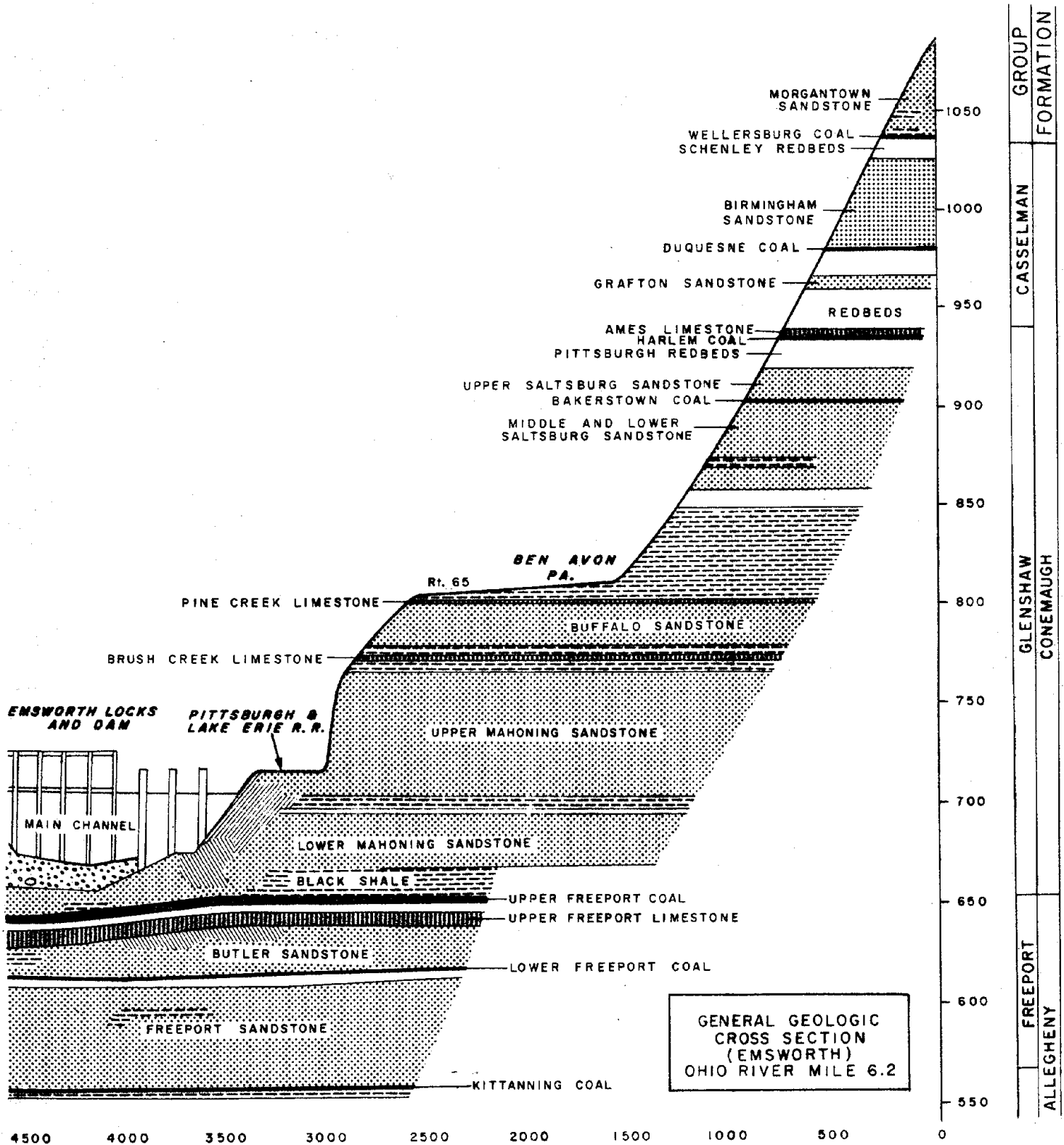


Figure 20



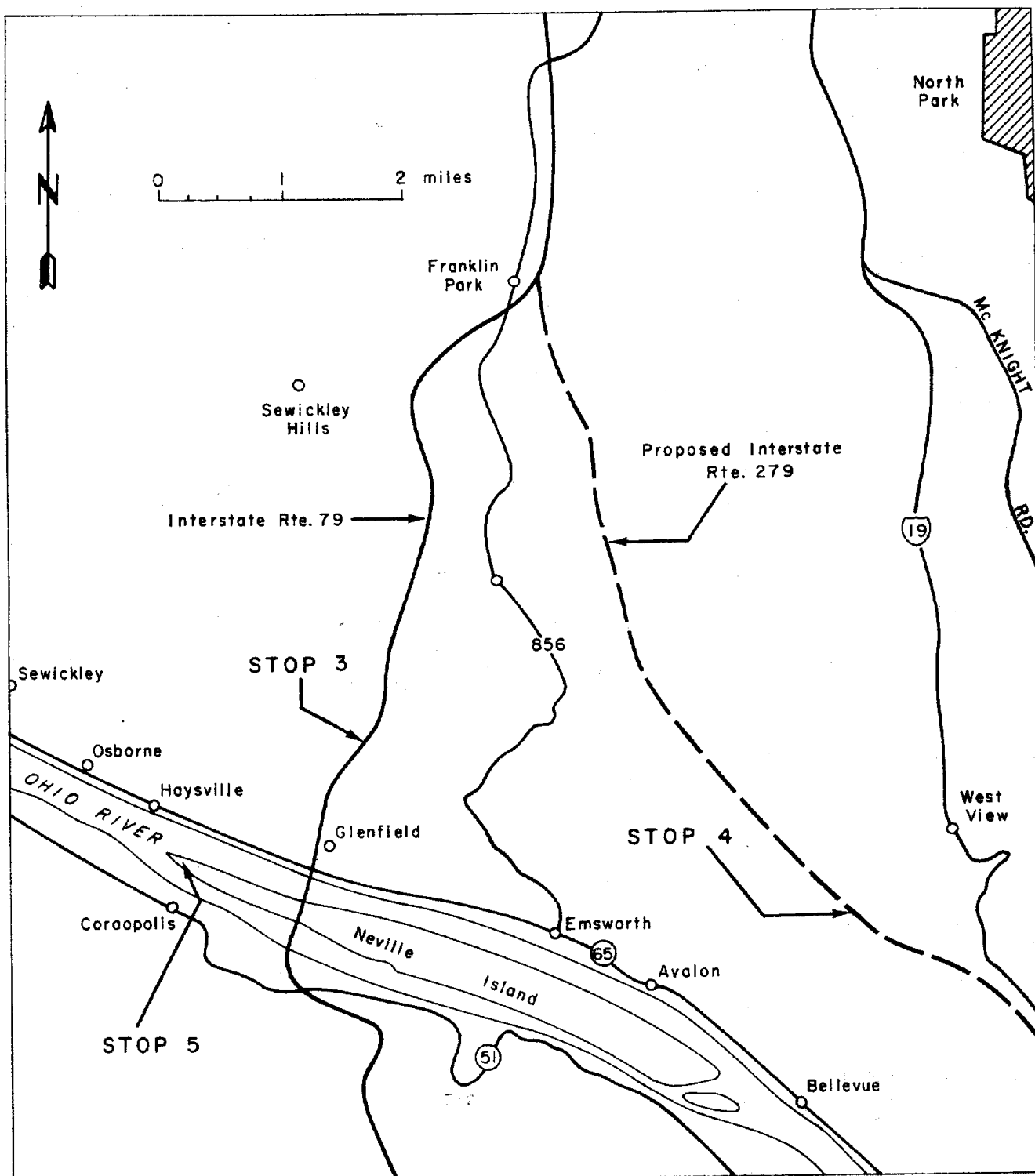


Figure 21. Index map for Stops 3, 4, and 5.

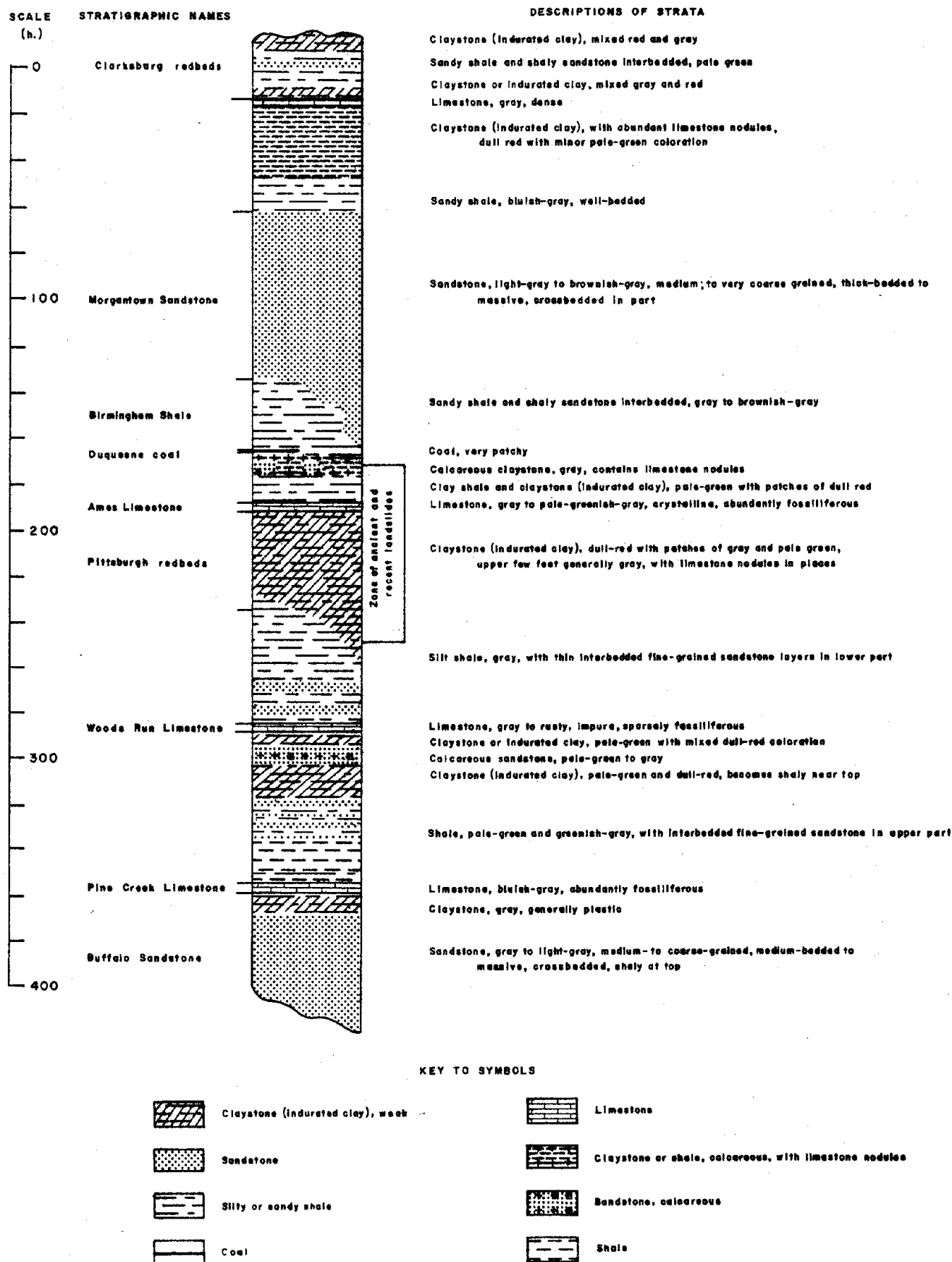


Figure 22. Stratigraphic section of the Glenfield area (modified from Hamel and Flint, 1969).

Construction began on this section of I-79 in the fall of 1968. The highway alignment here was chosen to avoid as many of the existing houses on the valley floor as possible, but the presence of ancient landslide masses was not recognized until the slides were reactivated during construction. As the east slope of Kilbuck Valley was being cut, several landslides were initiated along ancient slide surfaces (probably Pleistocene) in colluvial soil and rock masses. It is probable that these old slides developed in response to valley stress relief and high pore pressures during downcutting of the valley in the Pleistocene. For a description of valley stress relief see Ferguson (1967 and 1974). The original cut slopes at the level of the Pittsburgh red-beds were at 39° (1-1/4:1), but after landsliding occurred were flattened to 19° (3:1). At least one of the slide sites (the one we visit) still shows some movement, more than 10 years later. One indication of this are large tension cracks at the head of the slide that were not present when the site was surveyed in January, 1969. The history of the particular landslide we will see (Slide A) as described by J. V. Hamel (Hamel and Flint, 1969) is described below:

Construction began in the autumn of 1968 and slides began soon after slope excavation commenced. Excavation in the vicinity of Slide A began on November 26, 1968. The colluvium was excavated at an inclination of 1-1/4:1 or 39° . Tension cracks were reported above the cut slope between Stations 906+50 and 908+50 on December 4 (the buses are parked at about Station 910). This slide was first inspected by the writer on December 17 when excavation was down to about elevation 920. On December 17, the slide extended from Station 906+50 to Station 908+50. There was a 3-foot scarp about 100 feet back from the edge of the cut slope between Stations 907 and 908 and horizontal movement of three to four feet had occurred. A relatively planar sliding surface was exposed at the base of the scarp at Station 908. This surface consisted of red clayey colluvium and was slickensided from the slide movement. The surface dipped 35° to 45° west (in the direction of the slide movement). There were also many open fissures in the top of the slide mass parallel to the edge of the cut slope.

Movement in Slide A has continued to the present time (July, 1969). Surface-creep indications and new cracks have been observed at the rear of the slide mass since a warm period at the end of January. The slide outline shown in Figure 23 corresponds to late February, 1969. Slide material began falling to the bench at elevation 900 in appreciable quantities at that time. Other slides which were not studied in detail have histories similar to that of Slide A. Slope excavation began in the vicinity of Stations 917 to 928 on October 23-25, 1968. The first cracks were reported at Station 918 on November 4, and additional cracks were reported at Station 918 on November 20. Excavation began at Station 950 to 955 to February 14, 1969, and cracks were noted by the writer on March 7. Significant excavation began in the vicinity of Station 930 on February 21. Cracks were noticed by the writer on February 28, but the slide mass from 926 to

932 did not really begin to move until May 17; on May 24, there was a two-foot scarp in the haul road at Station 321.

All of these slides involved progressive failure to a certain extent. They were preceded by the development of tension cracks at some distance back from the edge of the cut slope and, if the slide masses were not excavated, they continued to move for periods of up to seven months. Most of the slides have also grown laterally from their initial configurations.

Figure 23 shows a map of pre-construction topography plus the February, 1969, limits of the slide area (Slide A) we will walk over in the field. Figure 24 is a geologic cross section of this landslide showing the original topography and the highway cut as designed before construction began. Figure 25 is a schematic cross section of the failure mass. The colluvium in the lower part of the slide mass is principally claystone derived from the Pittsburgh redbeds, whereas in the upper part there is considerable sandstone including boulder-size chunks of Morgantown Sandstone admixed with claystone. The failure surface of both the ancient and recent landslides is located at or near the base of the claystone zone of colluvium, that is, at the base of the Pittsburgh redbeds. This failure surface was studied by Hamel in test pits dug during construction. There was a shear zone consisting of a 2-inch seam of wet, soft, gray, silty clay underlain by a 3-inch zone of silty shale and claystone fragments in a silty shale matrix and then by in-place silty shale. The shear zone was overlain by about 6 inches of claystone fragments and silty clay, above which was fractured claystone colluvium. The shear zones of other slides along this section of I-79 were similar. They had three definite parts, the actual sliding surface consisting of 0.25 to 0.50 inch of damp to wet, soft to medium-stiff gray silty clay with a trace of sand located about mid-height in the shear zone. This was overlain and underlain by a mixture of silty clay and angular, sand- to gravel-size claystone and shale fragments. Each of these overlying and underlying zones was 2 to 3 inches thick, making the total shear zone about 6 to 7 inches.

It should be noted that the ground-surface profile along both the east and west valley walls provides geomorphic evidence of ancient landsliding. Although this profile has been destroyed by construction on the east wall, it can still be seen on the west side. There is a prominent bench developed at the stratigraphic level of the Pittsburgh redbeds. This bench is interpreted as the upper surface of an ancient landslide mass, most likely formed in Pleistocene time when a wetter climate prevailed. In Kilbuck Valley, these benches were chosen by early settlers as farm sites. Such benching signifies landsliding in other parts of the Pittsburgh area as well; not only at the Pittsburgh redbed horizon where it is most conspicuous, but also where other weak claystone units occur in the stratigraphic column (Schenley redbeds, Clarksburg redbeds, and Woods Run clay, for example).

At Glenfield the Pittsburgh redbeds are unusually thick. The average thickness in Allegheny County is about 30 feet, but at Glenfield they are 60 feet thick, close to the maximum thickness of this unit anywhere in the county. The thickness of this weak zone here was a contributing factor to landsliding, as was its high location on the valley wall.

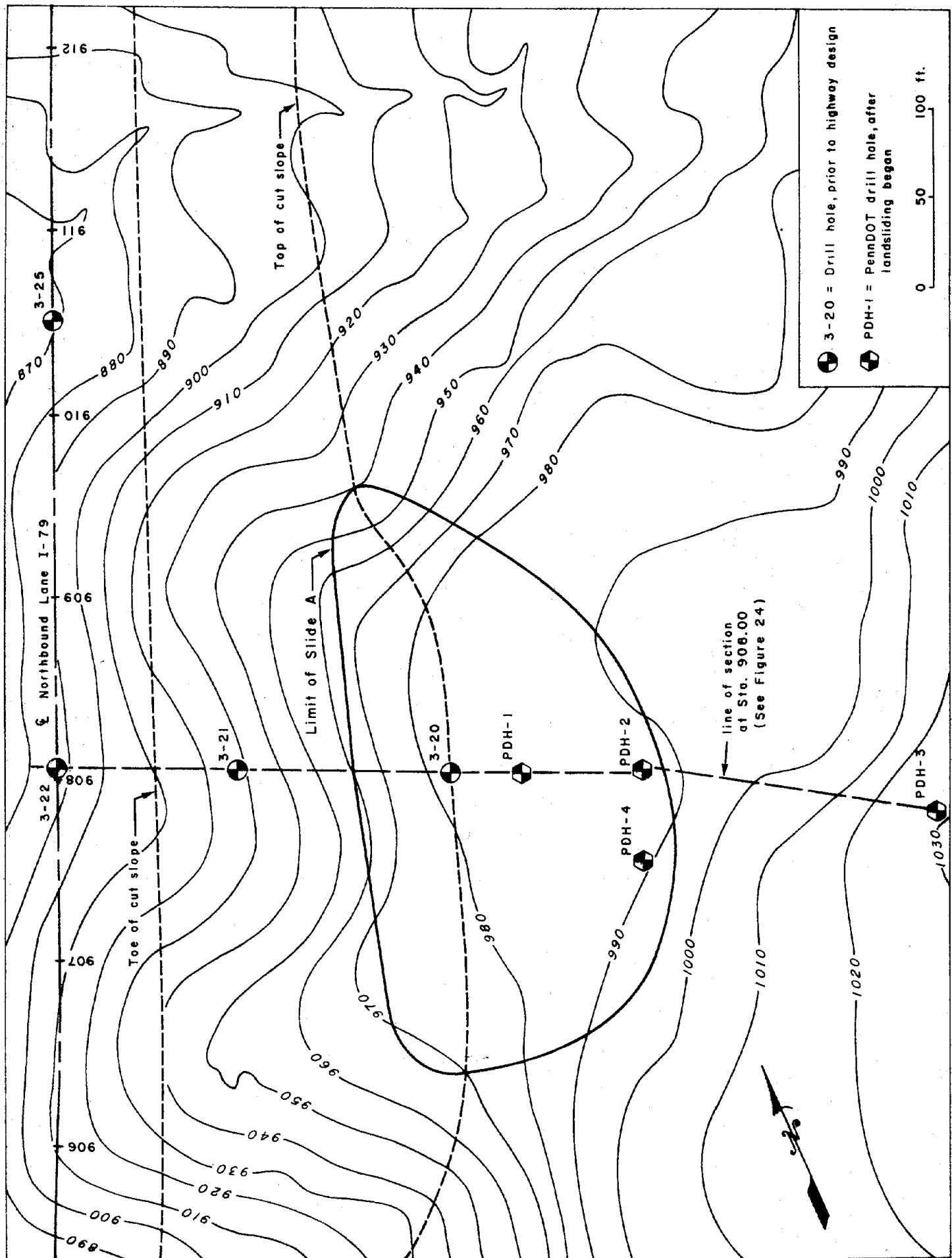


Figure 23. Pre-construction topography and outline of Slide A, I-79, Glenfield area.

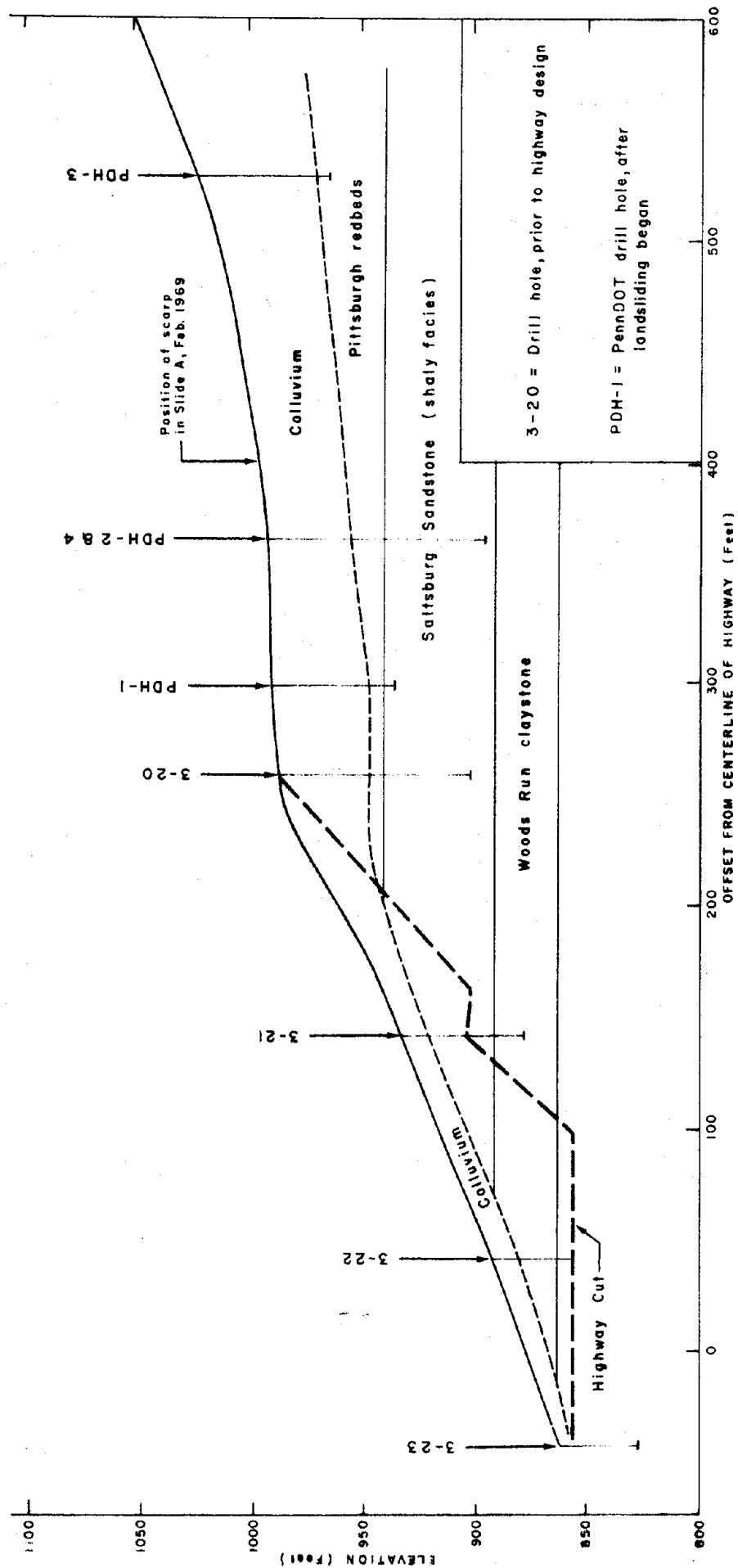


Figure 24. Geologic cross section at Station 908+00, Slide A, I-79, Glenfield area.

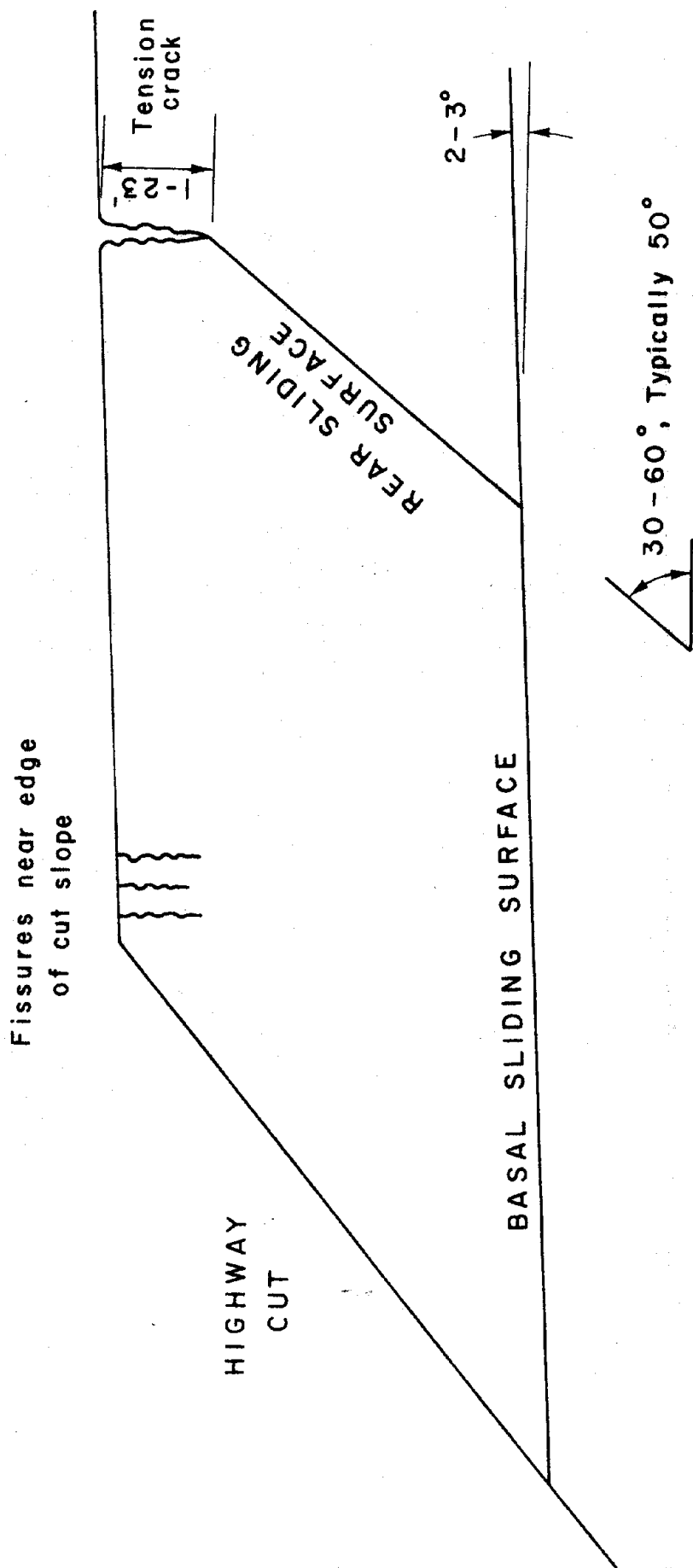
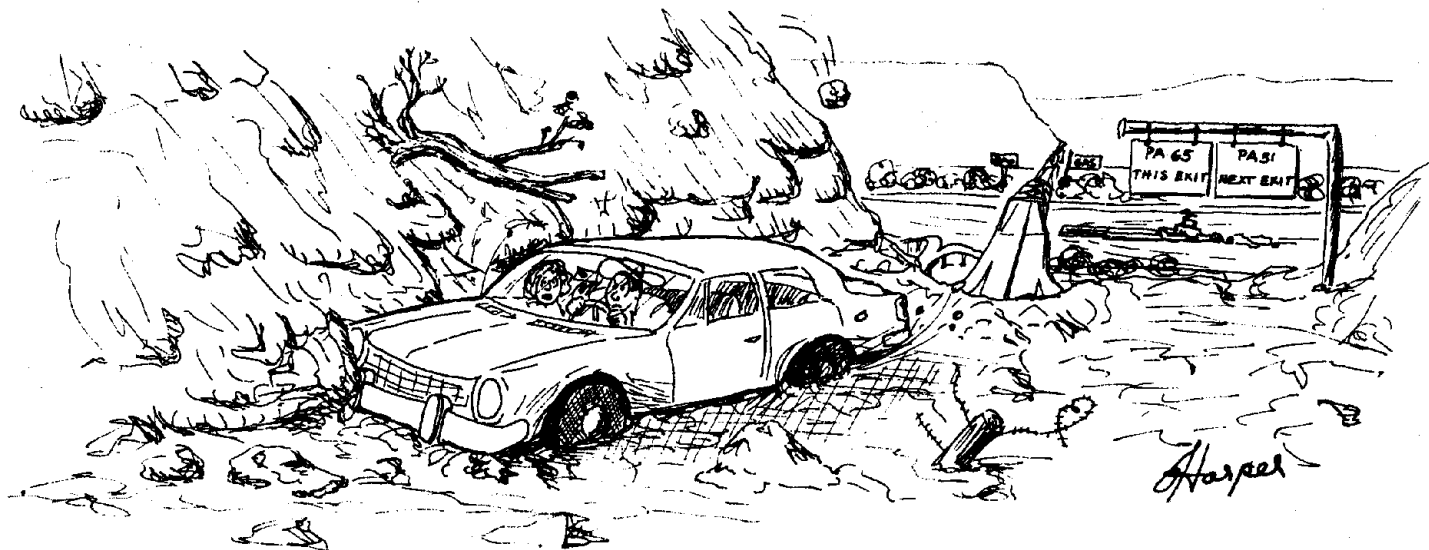


Figure 25. Schematic cross section of typical failure mass, I-79, Glenfield area.



But I'm telling you we are on the road, Herb! I saw a sign back down the hill just a bit ago!

Another factor in the landsliding was groundwater in a perched zone above the clay of the shear zone. Surface water that permeates through the Morgantown Sandstone appears at the surface as spring water, then slowly infiltrates the colluvium on the slope below, and develops a perched water zone there. Increased pore pressure resulting from this water buildup is a factor that promotes landsliding. Valley stress relief from the downcutting of the valley itself was also probably influential in causing the Glenfield slides. After the field stop, reboard the buses and proceed on I-79 northward.

- 0.5 28.4 Note slope area ahead (1 o'clock) on right at Station 945.
- 0.6 29.0 Roadcut on right shows small outcrop of Ames Limestone about 20 feet above road level.
- 0.1 29.1 BEAR RIGHT at Exit 20 on Yellow Belt.
- 0.3 29.4 TURN RIGHT on Mt. Nebo Road (Yellow Belt).
- 0.5 29.9 Cut on left at intersection of Mt. Nebo Road and McAleer Road exposes the lower part of the Pittsburgh redbeds and the upper part of the shaly Saltsburg Sandstone.
- 0.2 30.1 STAY STRAIGHT. Leave Yellow Belt. For the next 1.5 miles the route follows Bear Run valley. Interstate Route 279 will be built in this valley.
- 0.5 30.6 North Hills Raceway on right.
- 1.0 31.6 TURN RIGHT toward Ben Avon (Green Belt)

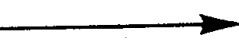
- 0.1 31.7 TURN RIGHT onto Lowries Run Road (Green Belt). Green Valley golf course on left. I-279 will cross Lowries Run and enter Bear Run valley here. Part of the golf course will be taken by the highway. Stratigraphically we are at the level of the Pine Creek Limestone (Glenshaw Formation).
- 0.5 32.2 TURN LEFT toward Ben Avon Heights on Bahl Hill Road. After making the turn, the Camp Horne drive-in theater is in view on right.
- 0.4 32.6 TURN LEFT on Gass Road.
- 0.1 32.7 STOP 4. Buses will unload here, proceed to a turn-around site, and reload later at the same site at the conclusion of the discussion.

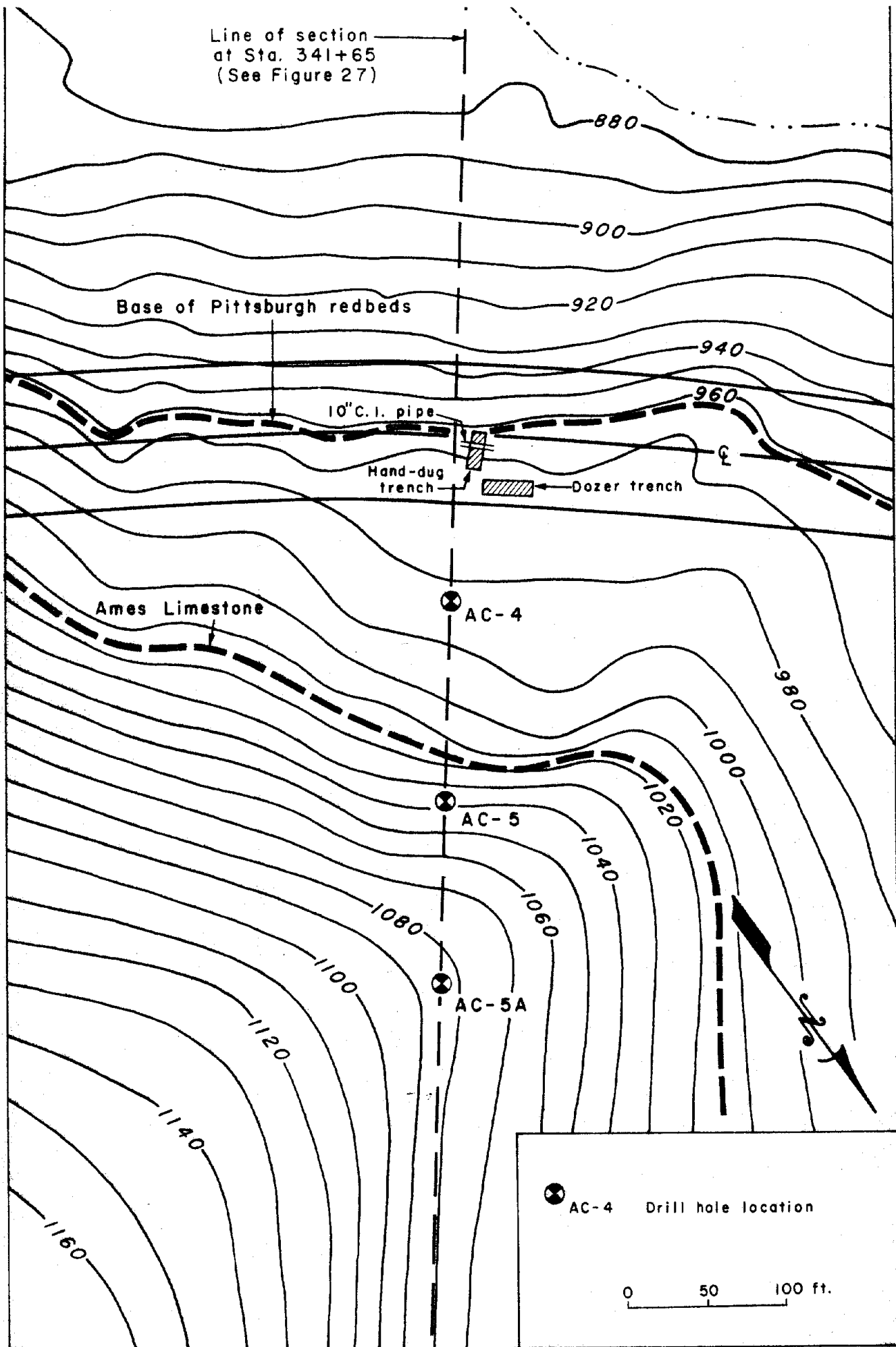
At this locality I-279 will cross Gass Road via a bridge and continue along the hillside on the north side of the valley. The purpose of this stop is to see topographic evidence of ancient landsliding in the Pittsburgh redbeds. The geologic setting is essentially the same as that at STOP 3 on I-79 where extensive landsliding occurred during construction. Because of a potential for landsliding on the originally designed cut slope here at I-279, the highway will be redesigned to avoid cutting into an ancient landslide mass. (Figure 21 shows the location of this site in relation to STOP 3. Figure 26 is a topographic map showing the original alignment of I-279 (northbound and southbound lanes, and the center line), the location of three core borings, a bulldozer trench, and a hand-dug trench. The outcrop trace of the Ames Limestone and the base of the Pittsburgh redbeds are plotted for stratigraphic reference. A geologic cross section is presented in Figure 27).

After identifying the ancient landslide mass on the basis of surface morphology, and after predicting the presence of a shear zone at the base of the Pittsburgh redbeds, an attempt was made to prove the presence of the shear zone by core drilling and to obtain samples from it for testing. This was followed by trenching, first with machinery and then by hand. The following account of drilling and trenching operations was modified from Elnaggar and Flint (1976):

Core Drilling

Core borings and Denison samples were made with standard skid rigs. Sampling of the colluvium was attempted at 3.5-foot intervals utilizing the method for Standard Penetration Tests. NX rock cores were obtained from the underlying shale formation. Once the contact between the colluvium and the shale was determined in Boring AC-4, Boring AC-4D was advanced by a roller bit to the predetermined depth of 21 feet. The 3.5-inch O.D., 24-inch long Denison sampler had a 2-3/8 inch brass liner. A Denison sample was attempted between 21 and 23.3 feet, but the contact material was washed away resulting in no recovery. AC-4D1 was then drilled, but only 12 inches of mud and cuttings was recovered from the inferred shear zone.

Figure 26. Topographic map at Station 341+65, I-279 site. 



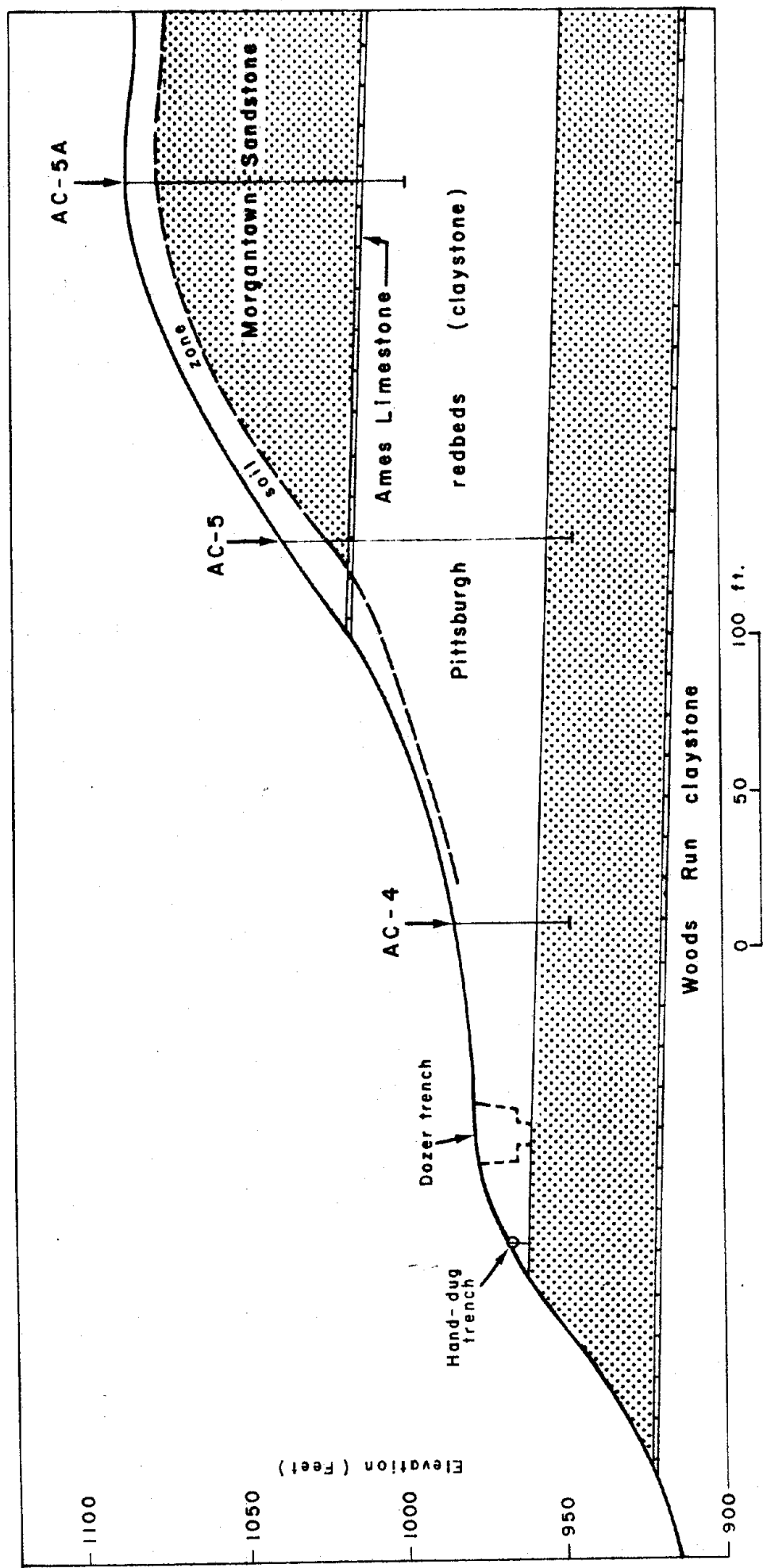


Figure 27. Geologic cross section at Station 341+65, I-279 site.

Boring AC-5 was located in what was thought to be the main scarp of an ancient landslide. However, due to the uncertainty in the location of the Ames Limestone, Boring AC-5A was added. The rocks encountered at this location consisted of sandstone to elevation 1054, and silty shale between elevations 1054 and 1025. An unnamed unit of claystone underlies this shale to elevation 1013. At the expected location of the Ames Limestone (elevation 1013) a rather thick layer of limestone (6.5 feet thick) was encountered in Boring AC-5A, followed by a 5.5-foot layer of silty shale. As stated earlier, the Ames is generally two to three feet in thickness and underlain by the well known Pittsburgh redbeds. Probably the abnormally thick Ames reported here includes some calcareous shale. The Pittsburgh redbeds have a thickness of about 57 feet, and their base elevation is 955.5. They overlie a silty shale unit.

Trenching

The first attempt at digging a trench for sampling purposes was made in the central position of a slump bench at approximately Station 342 + 00 in close proximity to the N.B. lane of the original alignment (see Figure 26 for trench location). The shallower part of this trench was dug by a bulldozer, and the deeper part by a backhoe. Caving of the walls was a problem throughout the operation, and although the bottom of the colluvial mass was reached at a depth of approximately 16 feet, the walls would not support themselves long enough to allow recovery of undisturbed samples of the one-foot layer of soft clay encountered at the bottom. Due to the large size of the trench, it was not possible to install wall supports to allow sampling.

From this trench, however, came evidence that the material through which it was dug is indeed colluvium. Several out-of-place blocks of Ames Limestone were encountered in the red claystone colluvium of the trench, the biggest of which was about 3 feet in diameter. The blocks were about 35 feet lower than their in-place position and about 125 feet from it horizontally.

After this unsuccessful attempt at sampling the bottom layer in this trench, another trench was dug at the edge of the slump bench (see Figure 26). This was of necessity dug by hand because a 10-inch gas pipeline near the edge of the bench precluded the use of machinery. This trench was begun at the exposed contact of the colluvium and underlying silt shale just over the lip of the bench, and was dug into the bench colluvium for a horizontal distance of approximately 15 feet. The trench was 3 feet wide for a distance of 11.5 feet and then widened to 5.5 feet at the inner end where the sampling was done. The maximum depth of the trench, at the inner end, was 11.5 feet. Plywood panels and 2" x 4" cross pieces were used to support the trench walls as it was being dug.

Sampling of Material for Strength Tests

As noted above, recovering samples from core borings was not possible, and trench sampling was the only feasible solution. After clearing the bottom and sides of the trench of all the loose material, muck and water, a distinct zone of clay was found at the base of the claystone colluvium in contact with the underlying undisturbed silty shale. This zone ranged in thickness from a minimum of 2 inches to a maximum of about 12 inches. The material consisted of yellow mottled clay with streaks of brown, soft plastic clay. The yellow material did not terminate at the top of this zone, but appeared in a "spotty" scattered manner for three to four feet above.

Six-inch diameter, 6- and 12-inch-long steel cylinders having a 7° cutting edge were machined for sampling the shear-zone material. The overlying colluvium was removed and the surface of the shear zone leveled. The cylinders were then pushed by hand until they either were filled or had reached bottom (shale). A steel plate was pushed under the cylinder, the material surrounding the cylinder was removed, and the sample lifted out. The cylinders were then enclosed in plastic bags and hand carried to the soils laboratory. Large block samples were also obtained from the shear zone material along with samples of the overlying claystone.

Test Results

Details of the strength tests of the shear zone material are presented in Elnaggar and Flint (1976). It was concluded from stability analyses based on the test results that the existing slope is stable, but that undercutting the toe of the slope or a change in either the groundwater level or external loading would result in an unstable condition. In addition to the strength tests, geochemical tests of the shear zone material and colluvium were made (Heinz Dehn, in Elnaggar and Flint, 1976). X-ray diffractometry showed that the yellowish-brown clay zone at the base of the colluvium was composed of a mixture of residual clay and non-crystalline, randomly interstratified colloidal material containing illite, chlorite, vermiculite, and kaolinite layers. The clay zone is impermeable, and therefore creates a perched water zone in the colluvium above. The gradational upper contact between the one-foot-thick clay zone and the red claystone above suggests to Dehn that the clay accumulated at the base of the colluvium after moving downward where it filled available pores forming the impermeable layer. It is reasoned that the clay would have been precipitated from colloidal solution higher up within the colluvium where "fresh" water of low ionic concentration from rainfall interacted with groundwater of higher ionic concentration. Dehn further suggests that perhaps the dilution of groundwater with increased amounts of newly added water during extended wet periods might cause re-solution or peptization of colloidal material in the clay zone, thereby decreasing its stability, and possibly be a landslide-triggering mechanism. Additional geochemical studies of shear zones may clarify some of these points. An alternative explanation of the origin of the one-foot clay zone is that it is primarily the result of

physical shearing. Laboratory direct shear tests show the development of a similar zone in small samples.

Return to buses and retrace route on Gass Road to Bahl Hill Road.

0.1 32.8 KEEP RIGHT onto Bahl Hill Road from Gass Road.

0.3 33.1 TURN LEFT on Lowries Run Road (also known as Camp Horne Road) at T-junction. The sandstone exposed in roadcuts at 33.4 and 34.0 is Buffalo Sandstone (Glenshaw Group).

1.5 34.6 Enter Emsworth Borough.

0.6 35.2 TURN RIGHT on Route 65 (Ohio River Blvd.).

0.6 35.8 Exposure on right is Buffalo sandstone (which we saw earlier).

0.7 36.5 Enter Glenfield Boro. Stay in RIGHT LANE.

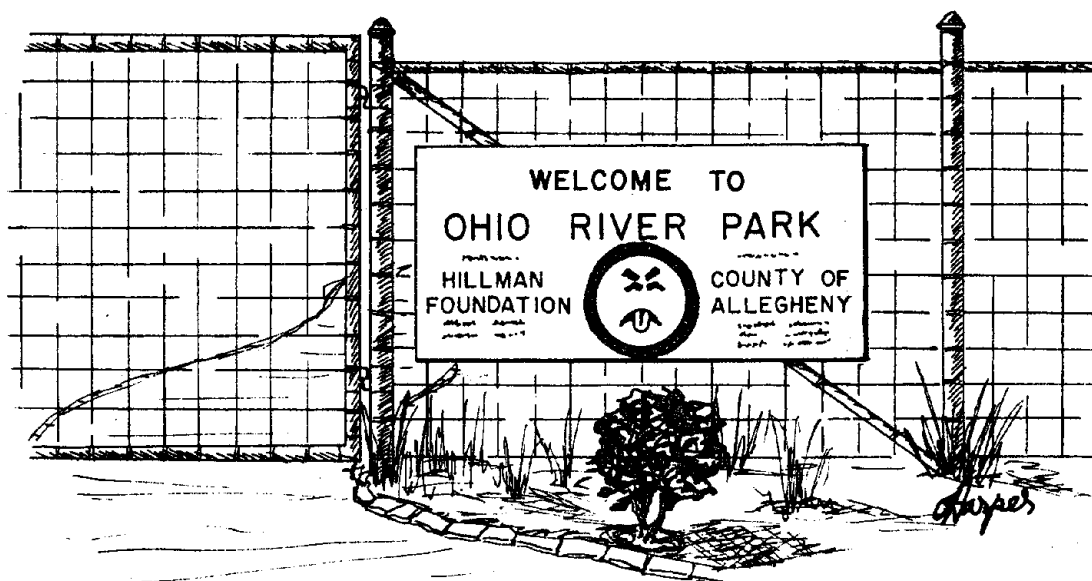
0.5 37.0 KEEP RIGHT on I-79 South toward Washington.

0.6 37.6 Join I-79 on approach to bridge over the Ohio River stay in RIGHT LANE.

0.4 38.0 Take Exit 17 toward Coraopolis (Route 51).

0.2 38.2 TURN LEFT on Grand Avenue toward Coraopolis. We are now on Neville Island. The island, a township in itself, is highly industrialized.

0.7 38.9 STOP 5. Ohio River Park (Neville Park) on right. This is the site where hazardous chemicals were dumped prior to the development of the park.



Case History: An example of how industrial waste disposal has conflicted with the development of a natural resource

by

Mary K. McGuire

The Monongahela, Allegheny and Ohio Rivers have supported the economic growth of the southwest Pennsylvania region since its colonization. The islands and the floodplains of these rivers were sites for industrial growth; however, past activities are now limiting their use for ours and future generations. A case in point is the recent abandonment of the Ohio River Park on Neville Island - a park that was developed but never officially opened because it had been the site of industrial waste disposal.

Setting of Neville Island

Neville Island, situated in the Ohio River five miles downstream of the Pittsburgh "Golden Triangle," is about 6.5 miles long and 0.75 mile wide with a total land area of about 868 acres. The main channel of the Ohio River flows along the north side of the island; the south side is bounded by the back channel and is not used as a commercial traffic route. The ill-fated Ohio River Park is located on the western tip of the island on about 35 acres of land.

The island is formed of alluvial deposits of layered sands, silts, and clays, with sands and gravels more dominant at depth. The basal sand and gravel unit is a valuable aquifer yielding up to 3000 gpm per well. The high yield is a result of the permeable sand and gravel and its direct recharge by the river. Many industries on Neville Island use the groundwater supply for their process water and the West View Water Authority has municipal wells on the eastern tip of the island.

Brief History

Neville Island was originally divided into individual farms. Around the turn of the century industries began to develop on the island partly because of the easy transport of supplies and finished products along the river. During World War II there were 22 industries on the island, and by the early 1950s, chemical and steel industries dominated the area producing coke, pig iron, cement, agricultural chemicals, synthetic resins, solvents, oil refinery products and reclaimed tin and scrap.

The undeveloped land on the western tip of the island, which was later donated to Allegheny County for a park, was owned by Pittsburgh Coke and Chemical (PC&C). During its existence, PC&C manufactured a variety of products. Immediately after World War II, PC&C began to manufacture pesticides, herbicides, and pigments for paint and dye-stuff in addition to coke and pig iron. Later, in the 1950s, parathion, an insecticide, was reportedly produced. There were several large settling basins on the property from which silted sludges were recovered, and the site is also believed to have been a disposal area for waste by-products from their chemical production. This hypothesis was strengthened by on-site investigations carried out in 1979. In addition, four acres

of the park site were reportedly used as a municipal dump from 1935 to 1945, and it is possible that other chemical companies may also have dumped wastes there. The origin and types of waste material at the park site is largely unknown.

Today, the physical character of the area has been documented by on-site investigation performed for the Allegheny County Health Department in order to evaluate the public health hazards after completion of park construction. This investigation, made by F. C. Hart and Associates, Inc. (FCHA), is the source of information on the historical land use of the park site and the extent of the chemical contamination of the land.

Discovery of a Potential Public Health Hazard

In 1976, the Hillman Company (owners of PC&C) donated the undeveloped land in question to Allegheny County for a park. Plans for the park (named the Ohio River Park) included picnic shelters, a walking trail, floatable swimming pools made from old barges, and a pleasure-boat marina. A preliminary soil reconnaissance report in June, 1977, and a subsurface soil investigation report in September, 1977, were prepared in order to provide the construction contractor with information on areas of possible construction difficulties and to help in locating an eighteen-inch oil pipeline.

Industrial waste, slag, tar, cinders, cement tiles, soaked wood chips, foundry sand, sawdust, bricks, coal, white chalk-like and paste-like materials, and sanitary waste were found at the site during test-pit excavation. Of the 50 test pits dug for general soil analysis, 45 contained various amounts of waste material and odors were reported in 6 test pits.

Clearing and grubbing of the site were performed during the fall of 1977 followed by construction of park facilities including picnic decks, roadways, parking lots, utilities and an administration building. During construction, over 12,500 cubic yards of undesirable material was undercut and buried elsewhere. The contractor encountered drums of unknown wastes which were drained and buried and it was reported that odiferous liquids, petroleum wastes, tars, and trapped groundwater were found during excavation. Several construction workers left the job site, apparently because of concern over their health. A telephone survey by the Allegheny County Health Department indicates that the workers had an unusually high rate of health problems ranging from eye irritation to blood in the urine. Out of 192 employees, 50 reported health problems while working at the park. Other symptoms included dizziness, light headedness, nausea, diarrhea, and shortness of breath. It should be noted that this survey did not include comparisons with other construction workers and that about 200 workers were not interviewed. Construction was completed by early 1979.

During the summer of 1978 concern arose that the fumes emanating from the park site could be a health hazard. This concern was probably heightened by the Love Canal incident in New York State. The Air Pollution Bureau (Allegheny County Health Department), finding little reliable information on the types and quantities of chemical waste deposited at the site, hired Hart and Associates in the summer of 1978. Their report on the potential public health hazards at Ohio River Park was presented to the County in July, 1979.

FCHA gathered background information in order to determine likely locations for buried waste and dug shallow test pits at known or suspected burial sites to collect waste samples for analysis. The toxicological aspects of the samples were assessed and the chemical wastes fell into four categories: pigments; coal tar residues; crystalline solids; leachates, sludges and liquid organics. The chemical wastes found within four feet of the surface included organic solvents such as benzene and toluene, pigments such as ferricyanide and ferrocyanide, tar, pitch, phenol, polycyclic aromatic hydrocarbons (PAH), phthalic anhydride, chlorobenzene, certain heavy metals such as mercury, arsenic and lead, and pesticides such as parathion.

Carcinogenic, mutagenic, and teratogenic chemicals were all found in solid, liquid and gaseous forms. Children and women of childbearing age are especially susceptible to the effects of these toxic chemicals. Highly flammable vapors such as benzene and other volatile organic compounds which are present throughout most of the site, when exposed to outdoor fires, charcoal grills, or even partially extinguished cigarettes could explode or burn. The consultant's toxicological assessment concluded that there is a public health threat at the site because of the possibility of skin contact with the contaminated soil and because of the fumes emanating from the soil from evaporating solvents.

On the basis of this first report, a subsequent study by FCHA was initiated to determine the cost of containing or removing the waste from the park, and in January, 1980, this second report was completed. It listed three options and their costs which Allegheny County could consider: first, to abandon the site forever as a recreational facility and to cover the ground with an impervious material such as clay at a cost of \$150,000 to \$250,000; second, to restore the park by digging up all the waste for proper disposal at an estimated cost of \$7 million to \$24 million and at a risk of subjecting the workers to exposure to toxic wastes; third, to develop only the eastern 14 acres where the land is safe as a smaller park area, costing approximately \$300,000 to \$430,000. The County Commissioners decided to negotiate with the Hillman Company to take back the park site. By May 1980, the County announced that the park site would be returned and that it would be reimbursed for expenses incurred in developing the site. As of June, 1980, the Hillman Company has accepted full return of the land. Their plans for it are still unknown.

Conclusion

We have seen an example of how accepted waste disposal practices in the past have contaminated a potentially valuable section of land. Because of the high cost of renovation, future recreational development of this area or the development of its groundwater resources are impractical. This case history also illustrates a growing awareness of industrial wastes and their effects on public health.

(Information for this article was obtained from the July 23, 1979, report by Fred C. Hart Associates and from newspaper articles published in the Coraopolis News Record.)

0.1 39.0 Cross Coraopolis Bridge (Neville Island Bridge) over "Back Channel" of the Ohio River. The following provides an interesting account of this history of this bridge taken from White and Von Bernewitz (1928):

Floating the Sixth Street Bridge to Coraopolis

Peculiar interest attended the removal of the old Sixth Street Bridge, because in two sections it was floated down the Ohio River 12 miles and re-erected over the back channel of that river at Coraopolis. The County engineers estimated that the removal of the bridge saved \$300,000 over what it would cost to build a new similar one at Coraopolis. The job was done by The Foundation Company of New York at a price of \$316,000. The bridge was of the through-truss bow-string type, pin-connected, with one end on rollers for expansion. Each truss was 440 feet in length, 44 feet in width, and 80 feet in height, and weighed, as prepared for removal, 1600 tons.

The bridge was closed to street-car and vehicular traffic on January 1, 1927. The two sidewalks were cut off; the concrete pavement was stripped off the deck and shore connections were cut. Before each span could be lowered vertically the masonry on which it rested had to be removed: but before this could be done, substitute supports for the bridge had to be provided and so arranged as not to interfere with the lowering of the bridge. To provide these, steel frames were fitted in the center pier and the two shore abutments. This procedure is opposite to what is currently seen in modern building construction. We see steel frames rising later to be filled in with masonry; in this instance, the steel frame was inserted into masonry already existing.

Although complicated in detail, the method used in lowering the bridge was simple in principle. It consisted in riveting to a lowering platform within the steel frame mentioned, 8 pairs of vertical steel straps, whose upper ends were arranged in such a way as to be slipped downward slowly. The straps were 47 feet long, 18 inches wide, and 1 inch thick. Each strap was punched with 26 holes, 7 inches in diameter and 15 inches center to center. They did not work singly but were paired so as to function like a sling or a loop. At the upper end of each loop was inserted a steel forged movable pin 38 inches long. By transferring this pin from one set of holes to the set above, the length of the loop could be lengthened 15 inches. The steel pin rested upon the plunger of a jack, which in turn rested on the steel tower. Eight 500-ton jacks, one for each loop, were used. Throughout the operation the jacks remained at the same elevation; as the bridge was lowered the length of the loop was lengthened 15 inches by shifting the movable pin to the set of holes above, and so on until lowered the full distance.

The jacks used in lowering the bridge consisted of a steel cylinder 12-1/2 inches in diameter and 15 inches in height into which fitted a tight plunger. A bleeder pipe led off from the bottom of the cylinder. The cylinder was filled with water and pumped to a pressure of 3,200 pounds per square inch. The lower end of the plunger rested against this water; and the bridge rested on the top end of the plunger. At a given signal, water was permitted to bleed away from the four jacks at one time; the four plungers gradually lowered and when they had moved downward their full distance, one end of the bridge had been lowered 15 inches. At another signal, the four jacks at the other end of

the bridge were bled, then that end of the bridge was lowered 15 inches; thus the bridge was tilted down end by end in steps of 15 inches for the complete distance of 18 feet. The total actual lowering period was 14 hours.

Each span was lowered on four steel coal barges each of 1000-ton capacity, two fastened side by side in front and two side by side in back. Special preparation was made on the barge float so that it would accommodate its unusual cargo. Steel stringers were placed cross-wise the float the same distance apart as the floor beams of the bridge. On each of these stringers (14 of them) three pyramids of wooden blocks were built up, making in all 42 points of support for the bridge. But the bridge did not rest directly on block pyramids. At each point of support was an ordinary 40-ton screw-jack which permitted the raising and lowering of the bridge at will, making it easier to load and unload.

When the bridge had been lowered onto the pontoon, it was gradually swung around and nosed down stream. Before it was started on its journey, it was anchored along the north shore, just east of the Manchester Bridge. There, workers dismantled about 27 feet from the top of the arch in order that the truss might clear the Manchester Bridge at the Point and the Ohio Connecting Bridge at Brunot Island. This disconnecting of part of the top chord is another reason why it was necessary to support the bridge under each floor beam. The Sixth Street Bridge is a bow-type truss; the string of the bow is made up of 16 eye-bar panels pinned together. As long as the bow is kept intact the structure is rigid, and could be moved by supporting it at its two ends, if necessary. But if the bow or the arch were cut the entire structure becomes unstabilized and requires support at every panel point throughout its length.

Two tug-boats were used to convey the bridge-laden pontoon to its destination. After passing under the two bridges mentioned, the structure arrived at the Government dam and locks at Emsworth, through which it passed easily. At the lower end of Neville Island the dismantled top chords were re-assembled and the barges were towed some distance below the end of the Island to prevent possible grounding; then they were backed up the channel to the site of the present bridge.

The operation at Coraopolis was just the reverse from that at Pittsburgh, but instead of lowering the bridge 18 feet it was necessary to raise it 32 feet. The same steel towers that were used at Pittsburgh were used at Coraopolis; the the bridge was elevated to its final position by the same straps and by the same jacks.

The "new" bridge is now in use.

0.3 39.3 End of bridge, TURN RIGHT on Yellow Belt (Route 51 North). Follow Yellow Belt.

0.1 39.4 TURN LEFT on Yellow Belt (Montour St.).

0.1 39.5 TURN LEFT on 5th Avenue (Route 51 South and Yellow Belt). Follow I-79 signs.

0.5 40.0 Buffalo Sandstone outcrop on right.

- 0.5 40.5 Enter Robinson Township.
- 0.2 40.7 KEEP RIGHT on I-79 South toward Washington. (Do not take Forest Grove Road).
- 1.0 41.7 Pittsburgh redbeds exposed in roadcuts on right.
- 0.9 42.6 A landslide and road failure occurred on the northbound lane at this site. A possible cause of the failure was the emplacement of fill on a preexisting roadbed and poor foundation soils.
- 1.5 44.1 Small sandstone quarry on right, probably in the Connellsville Sandstone (Casselman Formation).
- 0.8 44.9 Pass Crafton Exit.
- 1.0 45.9 Backfilled Pittsburgh coal strip mine on right.
- 0.2 46.1 Seepage in roadcut on left from Pittsburgh coal. Note bright-green algal growth along seepage zone.
- 1.0 47.1 KEEP RIGHT on Rte. 279 toward Pittsburgh.
- 0.4 47.5 Enter Rte. 279 (also U.S. 22 and 30 and Parkway West).
- 0.8 48.3 Concrete retaining wall on left near Rosslyn Farms exit ramp was constructed to stabilize slope where subsidence was occurring into rooms of an abandoned Pittsburgh coal underground mine.
- 0.5 48.8 Town of Carnegie on right.
- 0.7 49.5 Former Pittsburgh coal strip mine on left. Large quantities of fill have been dumped in former mine.
- 0.7 50.2 STAY RIGHT for Exit 3 from Route 279 to Green Tree.
- 0.8 51.0 TURN RIGHT at Exit 3.
- 0.1 51.1 LEFT onto Green Tree Road (Blue Belt) toward Crafton.
- 0.1 51.2 LEFT onto Route 121 North toward Crafton to Mansfield Ave. west.
- 0.2 51.4 LEFT onto Poplar St. toward airport to Mansfield Ave. west, then RIGHT onto Mansfield Ave. west.
- 0.2 51.6 RIGHT onto Holiday Drive to Holiday Inn headquarters.

END OF FIRST DAY

LOG OF ALTERNATE ROUTE
EXCLUDING ALLEGHENY RIVER SEGMENT

(See main road log for route from Holiday Inn headquarters to 31st St. bridge)

| Inc. Mil. | Cum. Mil. | |
|--------------|--------------|---|
| 0.0 | 11.0 | 31st St. and Liberty Avenue. Proceed straight ahead on Liberty Avenue. |
| 0.1 | 11.1 | LEFT onto 32nd Street, RIGHT onto Penn Avenue. |
| 0.2 | 11.3 | LEFT onto Butler Street. Proceed through Lawrenceville section of Pittsburgh. |
| 1.0 | 12.3 | Allegheny Cemetery on right. |
| 1.5 | 13.8 | 62nd Street bridge on left. KEEP STRAIGHT on Butler Street. |
| 0.4 | 14.2 | Slope on right shows evidence of slumping in colluvium associated with the Pittsburgh redbeds. |
| 0.3 | 14.5 | Highland Park on right at 2 o'clock. Pittsburgh's zoo is located in this park. |
| 0.2 | 14.7 | Highland Park bridge over Allegheny River on left. Lock No. 2 is just downstream from the bridge. |
| 0.3 | 15.0 | KEEP LEFT on Allegheny River Blvd. (Green Belt). The prominent hillside cut at one o'clock is known as Brilliant Cut. See Mile 8.6 of River Log, p. 65. |
| 0.6 | 15.6 | The slopes on right for the next mile or so show evidence of slumping and earthflow. The steep valley wall represents the undercut slope of the entrenched Allegheny River. Several weak claystone units occur in these slopes including the Woods Run claystone, the Pittsburgh redbeds and the Schenley redbeds. Abundant colluvial soil has developed from these units. Where sandstone beds are exposed in roadcuts, there have also been rock falls. |
| 2.1 | 17.7 | Intersection of Allegheny River Blvd. and Sandy Creek Road. KEEP STRAIGHT on Allegheny River Blvd. |
| 1.6 | 19.3 | Enter Verona. |
| 0.7 | 20.0 | Enter Oakmont. TURN LEFT on College Avenue and cross railroad track. TURN RIGHT on Allegheny Avenue. |
| 0.1 | 20.1 | TURN LEFT on Washington Avenue and proceed to end of street to Oakmont Yacht Club. |

0.2 20.3 Oakmont Yacht Club.

STOP 2. The highway cut across the river exposes the Conemaugh Group; beginning below the Woods Run claystone and extending up to the Clarksburg redbeds. See Figure 16 for photograph with various stratigraphic units identified. Turn around and retrace route on Washington Avenue.

0.3 20.6 LEFT on Allegheny Avenue. Here the route is on the "low-level" terrace deposits of Wisconsinan age.

0.9 21.5 LEFT on Hulton Road.

0.2 21.7 Hulton Bridge over Allegheny River. Twelve Mile Island is in view on right.

0.3 22.0 North end of Hulton Bridge. TURN RIGHT On Freeport Road (old Route 28).

0.2 22.2 Harmar mine of Consolidation Coal Co. on left. The Upper Freeport coal is mined for metallurgical coal. Mining is at a depth of about 300 feet. The complex of green buildings is a cleaning plant. Coal is loaded directly from the plant into barges at the mouth of Deer Creek.

0.9 23.1 LEFT at traffic light on Route 910 (Yellow Belt). Follow sign for Route 28 South.

0.2 23.3 RIGHT on ramp; enter Route 28 South.

0.7 24.0 Tailings pile from Harmarville coal mine.

0.3 24.3 Harmarville mine of Consolidation Coal Co.

0.2 24.5 North end of cut that extends for about one mile. Note minor slump mass at extreme north end of cut. The Saltsburg Sandstone in the lower part of cut shows channeling and a lenticularity which probably represents a crevasse splay deposit. The channel sandstone cuts down through the horizon of the Woods Run Limestone. The cut is benched to catch slump material and rock falls to prevent them from moving onto the highway.

0.9 25.4 Small valley on right is site of a large fill where material from the large cut was "wasted." A housing development is planned for the top of the fill area.

0.3 25.7 South end of long highway cut.

0.1 25.8 Two earthflows on slope to right. The original cut slope here had to be flattened because of movement at the level of the Pittsburgh redbeds. This necessitated the removal of houses which would have been spared, had not the landsliding occurred.

0.3 26.1 Bridge over Power Run Road.

- 0.5 26.6 Holiday Inn on left. For the next 3/4 mile Route 28 crosses a high-level Illinoian terrace underlain by about 50 feet of outwash sand and gravel. This is now the RIDC Industrial Park area, but formerly was the farm associated with the Allegheny County Workhouse.
- 0.8 27.4 Small valley on right (with ponded water) also contains a large volume of fill from highway excavation.
- 0.5 27.9 Bridge over Squaw Run.
- 0.1 28.0 Fox Chapel Exit.
- 0.5 28.5 On left, filter beds and water filtration plant of City of Pittsburgh.
- 0.2 28.7 Brilliant Cut again in view on left across Allegheny River.
- 0.7 29.4 Highland Park Bridge on left. Stay on Route 28.
- 0.2 29.6 Bridge over Guyasuta Run.
- 0.7 30.3 Bridge over Seitz Run. Highway cut for next half mile or more exposes Conemaugh Group from Saltsburg Sandstone up to Connellsville Sandstone. Sharpsburg Borough is on left. There is occasional flooding in Sharpsburg when the Allegheny River reaches flood stage.
- 0.7 31.0 West end of highway cut at exit to Route 8. STAY ON ROUTE 28 which crosses Pine Creek here. The Ames Limestone and Pittsburgh redbeds are exposed in the lower part of the cut. Etna Borough on right.
- 1.0 32.0 Shaler Township Waterworks on right. The steep slope on right for the next mile is one where periodic earthflows occur during rainy spells. The Pittsburgh redbeds occur near the base of the slope and the Schenley redbeds occur higher up. Colluvial soil from these, when water saturated, slowly flows down slope onto the highway and blocks the inside lane until the material is removed. Two recent landslides are visible, one at 32.4 and the other at 32.7.
- 0.9 32.9 Millvale Borough on right. The highway cut exposes strata from below the Ames Limestone up to the Birmingham Shale. Route 28 crosses Girty's Run here.
- 0.5 33.4 Washington Crossing Bridge (40th Street) on left. Stay on Route 28. See roadlog, page 58 for discussion of George Washington's crossing of the river at this site.
- 0.8 34.2 31st Street Bridge on left. Stay on Route 28 (E. Ohio Street). The Ames Limestone is poorly exposed in roadcut on right.

- 0.7 34.9 H. J. Heinz plant on left.
- 0.6 35.5 Intersection of East Ohio Street and East Street. Keep straight on East Ohio Street. The proposed route of Interstate 279 is along the East Street valley. There have been many delays in constructing this highway through Pittsburgh partly because of the activity of citizens groups to prevent it.
- 3.3 38.8 TURN RIGHT at IBM Building and circle to left.
- 0.3 39.1 Allegheny High School on right. This part of Pittsburgh is known as the North Side. It was formerly the City of Allegheny.
- 0.1 39.2 Buhl Planetarium on left. BEAR RIGHT and pass Pittsburgh Aviary (on right) in West Park. This was the site of a Union prison. Southerners captured at Gettysburg were kept here.
- 0.3 39.5 TURN LEFT on Brighton Road.
- 0.1 39.6 TURN RIGHT on Ridge Avenue. Allegheny Community College buildings on left and right.
- 0.2 39.8 Three Rivers Stadium in view on left at 8 o'clock. Across the Ohio River in the distance is Duquesne Incline, one of the two inclines that remain functional in Pittsburgh. This carries passengers up to Duquesne Heights.
- 0.4 40.2 TURN RIGHT on Route 65 and 19 (Reedsdale Street) to Ohio River Blvd.
- 0.2 40.4 RIGHT on Chateau Street (Route 65).
- 0.1 40.5 BEAR LEFT. Follow Routes 65 and 19.
- 0.4 40.9 STAY LEFT on Route 65.
- 0.2 41.1 Pittsburgh redbeds occur in slope on right. This poorly exposed claystone unit is gray in color and not red at this locality.
- 1.0 42.1 ALCOSAN sewage treatment plant, tall stack on left. This is in the Woods Run section of Pittsburgh where the stratigraphic name, Woods Run, originated.
- 0.3 42.4 The route here is on the Illinoian high-level terrace. Note toe of landslide on right.
- 0.1 42.5 McKees Rocks Bridge over Ohio River on left. KEEP STRAIGHT on Route 65.
- 0.5 43.0 Enter Bellevue Borough (leave City of Pittsburgh).

- 0.4 43.4 View of Neville Island at 11 o'clock.
- 0.6 44.0 Enter Avalon Borough.
- 0.8 44.8 Enter Ben Avon Borough.
- 0.6 45.4 BEAR RIGHT onto Brighton Avenue.
- 0.1 45.5 TURN LEFT onto Forest Avenue.
- 0.2 45.7 Emsworth Lock on Ohio River (for continuation of route, start at mileage 23.8 of main road log).

DAY 2

Saturday, October 4, 1980

| Int. mil. | Cum. mil. | |
|--------------|--------------|---|
| 0.0 | 0.0 | Mansfield Avenue at Holiday Drive entrance to Holiday Inn, Central (Green Tree), headquarters for the Field Conference. Leaving Holiday Drive, TURN LEFT onto Mansfield Avenue. |
| 0.25 | 0.25 | Intersection Mansfield Avenue and Poplar Street. TURN RIGHT and in about 150 feet TURN RIGHT AGAIN onto westbound entrance ramp to U. S. Route 22-30 (Penn-Lincoln Parkway, "Parkway West," I-279). |
| 0.15 | 0.4 | Join U. S. Route 22-30 (carefully; merging lane is short and traffic commonly heavy). Down this long hill, U. S. Route 22-30 essentially parallels the trace of the Nineveh Syncline. |
| 0.5 | 0.9 | Rook Yard of N&W Railway visible on right. |
| 0.4 | 1.3 | Crossing Whiskey Run, with Pittsburgh coal at about valley-bottom level. Site of extensive early mining activity. |
| 0.4 | 1.7 | Under N&W Railway high steel bridge. Built later as speculative competitor to the Pennsylvania Railroad (now Conrail), the "style" of the Wabash Road (now N&W) is in strong contrast to the style of the old Pennsy. The Pennsy's routes through this region chiefly wind along valley bottoms, whereas the Wabash pursued straighter lines with numerous cuts, fills, and tunnels and many notable steel-girder trestles, some about 2,000 feet long and as much as 200 feet above creek bottoms. The Wabash in a sense pioneered current transportation route practice. Rather than conform to the terrain, the terrain was altered. |
| 0.2 | 1.9 | Carnegie Exit. CONTINUE STRAIGHT on U. S. Route 22-30.. Formerly the Borough of Mansfield, its name was changed to Carnegie in return for the gift of a library building from steelmaker Andrew Carnegie, which still stands and is in use. |
| (2.0 - 2.3) | | Crossing over floodplain of Chartiers Creek, named for French trader and trapper, Pierre Chartiers, whose early 1700s trading post was several miles to the north. The busy mainline of Conrail to Weirton, Cincinnati, and points west is in this segment of the valley. The combination of accessibility to rail and Pittsburgh coal along the valley walls made this area an early center of industrial activity. |
| 0.9 | 2.8 | Rosslyn Farms Exit. CONTINUE STRAIGHT on U. S. Route 22-30. Concrete retaining wall beside this ramp now conceals formerly excellent outcrops of the Pittsburgh coal and adjacent rock, (another bone to pick with the highway engineers, along with crown vetch). |

- 0.3 3.1 Off ramp for Erie and Washington, Pa., via I-79. CONTINUE on U. S. Route 22-30, bearing gently left. Low roadcuts paralleling the ramp exhibit unevenly fractured layering, probably the result of subsidence over old Pittsburgh coal mine workings, here less than 50 feet below present road level.
- 0.6 3.7 Crossing Campbells Run and under I-79. At 4 o'clock about 1,500 feet from U. S. Route 22-30, visible through trees is Pennsbury condominium development, which has been plagued by slope-stability and mine-subsidence problems. Pennsbury developers provided a bit of unwitting ironic humor when they wrote in advertising, "Get one before they're all gone!"
- 0.6 4.3 On right in Campbells Run Valley is a large quarry in the sandstone of the Casselman Formation. This unit is identified by some workers as the Morgantown Sandstone, which commonly is about 150 feet below the Pittsburgh coal. Here the rock interval is appreciably less, about 60 feet to the top of the quarry, so the quarry rather may be in the Connellsville Sandstone. This is a good example of the uncertainty involved in tracing units between the sparse outcrops of the region.
- (4.3 - 7.0) U. S. Route 22-30 rises gently northwestward along Campbells Run as does the level of the Pittsburgh coal. The coal here was mined-out underground on both sides of the creek and was stripped along the outcrop in some places. Little evidence remains of this activity. However, at about Mile 6.9 on the cleared slope on the left, one wooded trench up the slope is a former mine entrance, and the slope has the slightly dimpled surface characteristic of long-past subsidence over mines. At about Mile 7.1, the highway passes from the Casselman Formation across the concealed coal outcrop, and into the overlying Pittsburgh Formation.
- (6.3 - 7.5) We are traversing the north end of the McDonald Oil Pool and its extension, the McCurdy Oil Pool. These pools form a continuous zone of oil production about 13 miles long by about 3 miles wide on the average, extending from about 2 miles north of U. S. Route 22-30 southwestward into Washington County. Discovered in 1886 and developed through 1892, the McDonald Pool was the second largest field in Pennsylvania, with cumulative production of 45 to 50 million barrels of oil. Modest production persists from some wells, such as that on the left skyline at about Mile 6.7. Production was chiefly from upper Devonian sandstone beds, the Gordon Stray, Gordon, 4th, and 5th sands, in a zone about 400 feet thick, the top of which lies about 2,000 feet below the Pittsburgh coal.
- 3.2 7.5 Following U. S. Route 22-30 signs, TURN OFF RIGHT at cloverleaf, turning through about 300°, and head west on U. S. Route 22-30.
- 0.2 7.7 On U. S. Route 22-30 heading west.
- 0.3 8.0 Exit to "old U. S. 22," the Steubenville Pike. CONTINUE STRAIGHT on "new" U. S. 22-30.

- (8.0 - 11.6) Throughout this segment, U. S. Route 22-30 parallels the generalized outcrop of the Pittsburgh coal and all outcrops are in the Pittsburgh Formation, mostly less than 100 feet above the coal. The coal has been mined out underground. Surface mining has taken place almost continuously along the coal outcrop on both sides of the ridge that U. S. Route 22-30 follows, but relatively little evidence of mining can be seen from the highway.
- 0.3 8.3 On the right, north, in the distance is a view of Greater Pittsburgh International Airport, a County-owned reserve of about 15 square miles developed in part on old surface-mine workings of the Pittsburgh coal.
- (8.1 - 8.9) We are travelling along the irregular edge of the McDonald Pool. Areas to the east and south generally were productive; areas to the north and west were nonproductive.
- 0.8 9.1 Oakdale Exit. CONTINUE STRAIGHT on U. S. Route 22-30.
- 0.8 9.9 Small gas pool producing from Gordon Stray, Gordon, and 5th sands.
- 0.2 10.1 Hankey Farms Exit. CONTINUE STRAIGHT on U. S. Route 22.30. In the residential development on the left there has been structural damage as a result of mine subsidence.
- (11.2 -11.5) Former strip mines on left.
- 1.5 11.6 U. S. Route 30 and Imperial Exit. CONTINUE STRAIGHT on U. S. Route 22.
- (11.6 -15.0) Segment continues in the Pittsburgh Formation.
- 0.8 12.4 Oil well on left.
- (12.6 -13.7) On right, long cut in lower Pittsburgh Formation; oil well.
- 0.7 13.1 Noblestown Exit. CONTINUE STRAIGHT on U. S. Route 22.
- (13.5 -13.8) On left, former strip mine.
- 1.5 14.6 On left, strip mine, active in March 1980.
- 0.4 15.0 Bridge over Pa. Route 980 and Montour Railway. At 8 o'clock, about 1,800 feet from U. S. Route 22 is the Champion coal cleaning plant of the Consolidation Coal Company. Run-of-mine coal from Consol's Montour #4 and Westland mines, 13 miles to the southeast and 10 miles to the south respectively, is carried here by rail for washing and sizing. Tailings are deposited in former strip mines, chiefly west of the plant. Clean coal is transported by rail directly to customers. Acid drainage has been an appreciable problem because of relatively high sulfide content of tailings. The plant is in the headwaters of Little Raccoon Creek, which drains into Raccoon Creek, then north into the Ohio River.

The plant straddles the Allegheny-Washington County line.

About 2 miles to the south, left, are large active strip mines.

This point is near the north edge of the Candor Gas Pool with chief production from the lower Mississippian 100-foot sand, about 1,800 feet stratigraphically below the Pittsburgh coal.

- 0.1 15.1 McDonald Exit. BEAR RIGHT onto exit ramp.
- 0.2 15.3 Stop sign at end of ramp. TURN LEFT, north, onto Pa. Route 980, paralleling Montour Railway amid much evidence of past mining. Railway cars with coal are marshalled here.
- (15.4 - 17.1) Pa. Route 980 follows Potato Garden Run downstream. On left and right are more or less continuous former surface mines, partially filled by tailings from Champion some years ago. Especially notable are masses of "red dog," burned mine refuse. In part, the massive remnants of red dog are results of a second mining, as red dog has been widely used as surfacing material for unpaved rural roads. These masses essentially are erosional remnants.

It is interesting to compare this area of relative desolation to those areas where mining activity has left generally unobtrusive results such as those seen from U. S. Route 22-30 and also with the virtual disappearance of all evidence of previous widespread mining in Pittsburgh and its suburbs. In addition to the presently required reclamation, urban development can also help to obscure industrial blight.

- 0.6 15.9 Intersection with paved road to right. CONTINUE STRAIGHT on Pa. Route 980.
- 1.2 17.1 Intersection. TURN RIGHT, east, uphill through mining-affected areas.
- 0.9 18.0 Intersection with road to right. TURN RIGHT.

STOP 6. Sanitary landfill operation.

This road is a public road which may be followed about 2 miles east to the village of Imperial on U. S. Route 30. However, its chief current use is as the access road to the large sanitary landfill operation of Browning Ferris Industries of Pennsylvania. (At the time of preparation of this field guide, the actual route and stop location within the disposal area could not be given, so no mileages or specific directions are supplied herein.)

The start of this operation was in 1964. Currently the site includes 4,500 leased acres, chiefly abandoned "orphan" strip mines in the Pittsburgh coal. By early 1980 about 400 acres had been reclaimed by disposal ("storage") of municipal and, to a minor degree, industrial wastes at the average rate of 5,000 cubic yards per day, 5 days per week.



Essentially all the City of Pittsburgh wastes are accommodated, as well as appreciable amounts of other wastes from BFI's own contract collecting services. City wastes are delivered by city Refuse Department trucks to a transfer station near Carnegie. At the station the wastes are compressed into large BFI semitrailers each capable of handling 18 to 20 tons (probably equivalent to about 100 cubic yards). These trucks then come here by approximately the same route we followed earlier.

On site, relatively impermeable clay is placed over outcropping coal and adjacent rocks. Wastes are distributed in 8-to 10-foot lifts and compacted. The lifts are covered by a minimum of 2 feet of earth and at the close of each day's operations. Groundwater quality is monitored in several observation wells. Ultimately the reclaimed ground will have potential recreational, agricultural, or light industrial capability.

Return to Intersection at Mile 18.0 and retrace route to U. S. Route 22, by proceeding south.

- 2.8 20.8 On right ramp to U. S. Route 22 west, CONTINUE STRAIGHT on Pa. Route 980.
- 0.05 20.85 U. S. Route 22 overpass.
- 0.05 20.9 Intersection with U. S. Route 22 ramps. TURN LEFT, east, onto U. S. Route 22, east ramp.
- 0.05 20.95 Intersection to right. CONTINUE STRAIGHT onto ramp to U. S. Route 22. Proceed east on Route U. S. 22, retracing earlier route.
- 4.75 25.7 Hankey Farms Exit. BEAR RIGHT, off U. S. Route 22.
- 0.2 25.9 Stop sign at end of ramp. TURN LEFT, south. The Pittsburgh coal outcrop line is at the approximate level of the road at Mile 25.9. Route then is stratigraphically downward through strata of the

upper Casselman Formation.

- 1.1 27.0 Intersection with road to left. CONTINUE STRAIGHT.
- 0.2 27.2 Intersection with Pa. Route 978 from right. Intersection approximates the northwest limit of the McDonald Oil Pool. Quarry on left is in Morgantown Sandstone of Casselman Formation. Bedding features are well exposed, and there are many fossil plant impressions. The Morgantown is a relatively impermeable sand. In areas to the south where it is under moderate cover, it yields only modest groundwater. Farther to the south under thicker cover, the Morgantown is only a spotty producer of natural gas, compared to sandstones lower in the Pennsylvanian, such as the Mahoning and Buffalo Sandstones (Glenshaw Formation) which have produced both oil and gas in Greene County. The Morgantown formerly was widely quarried for dimension stone, but now it is chiefly used for crushed aggregate.
- CONTINUE STRAIGHT, south, onto Pa. Route 978 along exposures in the Casselman Formation. Ridges on both sides are capped by strata of the Pittsburgh Formation, and the Pittsburgh coal was widely mined here. Oil wells are sporadically visible.
- 0.3 27.5 Oil well on left.
- 0.05 27.55 On left, quarry in Morgantown Sandstone.
- 0.55 28.1 Stop sign at T intersection. TURN RIGHT, south, following Pa. Route 978. Exposures here similar to those just passed.
- 0.5 28.6 Enter Borough of Oakdale.
- 0.2 28.8 The log cabin on slope to left is still in use at time of writing.
- 0.2 29.0 Center of Oakdale. Intersection with angled road from right. Yield to traffic and BEAR LEFT.
- 0.05 29.05 At intersection, Pa. Route 978 turns right. Do not turn, but CONTINUE STRAIGHT ahead, east, following route to Rennerdale along Noblestown Road.
- 1.15 30.2 TURN LEFT onto McGill Road and travel for about 2500 feet. Buses discharge passengers and turn around. This is the approximate southeastern edge of McDonald Oil Pool.

STOP 7. Subsidence features resulting from mining of the Pittsburgh coal, by William R. Adams, Jr.

This stop is located in Settlers Cabin Park, a regional park of Allegheny County. We will leave the buses at the intersection of McGill Road (road trending approximately northwest-southeast) and an unnamed dirt road trending in a northeasterly direction and walk in a northwest direction along McGill Road for approximately 750 feet.

On both sides of this roadway the Pittsburgh coal was stripped and then deep mined. Much of the southern portion of Allegheny County, particularly the southwestern portion, has been subjected to both of these mining techniques. Since most of this mining was done many years before any reclamation laws existed, the hummocky and often slide-prone slopes consisting of spoil dumped over the slope, the poorly drained strip benches, the nearly vertical highwalls, and the sinkholes in slopes above the coal are all too frequently seen.

Due to a joint reclamation project between the Pennsylvania Department of Environmental Resources and the Appalachian Regional Commission, there was some uncertainty at the time of this writing as to the exact location of this Stop. Reclamation was planned for this past summer on a portion of the southwest-facing slope east of McGill Road, involving the excavation of a trench near the top of the slope to intercept the surface water and prevent it from flowing over the slope and possibly infiltrating into the mines, thereby adding to the acid mine drainage (AMD) problems. The sinkholes on the slope were to have been backfilled allowing surface water to run off rather than flow into the sinkholes. The strip bench was also to have been graded so that the high point on the bench would be at the base of the highwall and the bench would slope down and out from that point. All of these measures should lessen the flow of AMD.

If the reclamation has not taken place, we will leave McGill Road and, after walking approximately 750 feet along it, head in a northerly direction. The strip bench will be encountered first and then the high wall. We will travel around the high wall near its northern end. The slope above the high wall contains sinkholes from mine subsidence. In some areas of this slope it is (or was) difficult to walk more than 20 feet from one sinkhole without encountering another one. These sinkholes are for the most part 10 to 20 feet in diameter and 5 to 15 feet deep.

If the reclamation has taken place, we will take approximately the same route except we will continue up the slope. At the hilltop one will be able to see what is probably subtle evidence of subsidence. There are shallow depressions a few tens of feet in diameter, but generally less than 5 feet deep. Continuing across the hilltop which most recently was a pasture (Watch Your Step), we will encounter a northeast-facing slope. A few feet down the slope sinkholes can be observed, the most prominent one is near an abandoned oil well (this old decaying derrick can be used as a point of reference when trying to locate the sinkholes). The density of sinkholes is significantly less on this slope than on the southwest facing slope.

These sinkholes have resulted from mining in the Pittsburgh coal (refer to Figure 2, page 5, for the stratigraphic position of this bed). This coal is the most famous seam in the world and mining is possible in approximately three fourths of the approximately 8,000 square miles over which it exists. It is a high volatile, bituminous coal and is an excellent coking coal. In Allegheny County the main bed, which may have one or more partings or binders separating different "benches" of coal, generally averages slightly over 5 feet thick. The Pittsburgh coal was by far the most important during the 200 years that coal has been mined in western Pennsylvania; however, recently it has given way to the Upper Freeport coal.

Detailed mine maps were not located for this site; however, those located for other areas within the Park indicate that the mining occurred during the period 1922-27 with retreat operations probably into 1928. In these nearby areas, as is probably true of this site, the room-and-pillar method of deep mining was used. With this method access, ventilation, and haulage ways are initially established by opening up a system of entries and cross entries ("butts"). These entries are generally driven to the farthest reaches of the property before extensive mining is initiated. Rooms, i.e. areas where coal is removed, are then driven off of the butts. A system of passage ways interconnect the entries, butts, and rooms (see Figure 9, p.29). This initial phase was followed by a second phase where mining would start at the furthest extent of the mine and then work back toward the entry removing the pillars of coal. Even when the second phase of mining takes place all the coal is seldom extracted.

Subsidence may be caused by either: collapse of the overburden into entries, rooms, and other voids; the pillars punching into the mine floors; or the pillars deteriorating or being destroyed by mine fires resulting in loss of support for the overburden. As with these sinkholes, the majority of subsidence events occur at sites with less than 100 feet of overburden above the mined-out coal. However, the old "rule of thumb" that you were safe from subsidence if the site was more than 100 feet over the mine and/or it was more than a year after mining is being disproven by recently documented events. With time and the exposure to air and water, the soil and rock in the overburden, the pillars, and the underclay or other rocks composing the mine floor deteriorate, increasing the potential for subsidence. Incidences of subsidence have been reported tens of years after mining and at sites several hundred feet above mines.

In areas subject to mine subsidence, several methods have been used to stabilize the site:

1. Over excavation and backfill - All soil and rock is excavated to a point below the coal and backfilled. This is generally restricted to sites with shallow overburden.
2. Complete filling - Can occur during mining or after by pumping sand, fly ash, crushed slag, or cement grout into the voids. This is an expensive technique and it is difficult to insure complete void filling if done after mining.
3. Drilled concrete piers or pile foundation - Holes are drilled to the mine floor or below, a steel casing is inserted (sometimes driven further into rock), and concrete is used to fill the casing. Generally this method is restricted to more shallow depths of overburden.
4. Piers constructed within mine - The cost of the technique is very dependent on ease of access to the mine and the need for stabilizing the mine roof for the workmen's safety.
5. Grout columns - A hole is drilled into a mine void and then cement, grout, and gravel is injected into mine void forming a truncated conical column. The cement grout is also injected into the rock

above the column.

Although the majority of subsidence events occur or have the potential to occur in undeveloped areas like this one and do not cause damage to property or pose a threat to cause damage, many do occur in developed areas. With the spread of suburban areas, the potential for damage is increasing. As it is, hundreds of thousands of dollars are spent each year to correct or prevent subsidence. These dollars are spent for reclamation projects, insurance claims, individuals (private and public) attempting to correct subsidence damage, and extra engineering and construction costs to stabilize an area.

As you travel through other areas of the park today, you will see other sinkholes and troughs formed from mine subsidence. Some of these have triggered landslides.

Return to busses and head northeasterly on Noblestown Road.

- (30.2 -33.0) Route parallels Robinson Run on its north side. Lower and middle valley wall strata are in the Casselman Formation. Upper slopes and ridgetops are in the Pittsburgh Formation. Sporadically visible in the valley to the right is the same Conrail main line mentioned at Mile 1.7. Completed in 1866 as the Pittsburgh, Cincinnati, and St. Louis Railway, this sinuous segment of railroad is an excellent example of the importance of topography on early transportation development, in strong contrast to the Norfolk and Western line constructed less than 40 years later, and of course to the Interstate Highway system that commonly overcomes topography rather than conforming to it. Dominating the skyline to the right is that "great golfball in the sky," a military missile-control installation (Mile 32.1)
- 0.7 30.9 Landslide area. Here Robinson Run impinges on the foot of the slope maintaining a slope steeper than most. Compounding the problem is the fact that the road is at the approximate stratigraphic position of the Clarksburg redbeds, a thinner unit containing materials similar to the Pittsburgh redbeds which were examined at Stops 3 and 4. The Clarksburg redbeds are in the Casselman Formation, 150 to 200 feet higher in the Conemaugh Group than the Pittsburgh redbeds.
- 0.05 30.95 Stop sign. Intersection, CONTINUE VERY SHARP RIGHT on Noblestown Road.
- 0.05 31.0 Restored log house on right.
- 0.7 31.7 Landslide area.
- 0.9 32.6 Enter village of Rennerdale.
- 0.4 33.0 TURN LEFT, north, onto McMichael Road. Keep watch, for this intersection is on a relatively straight downhill segment of Noblestown Road; it can easily be missed.

- (33.0 - 33.9) Rising through strata of the upper Casselman Formation.
- 0.9 33.9 Cross concealed outcrop of Pittsburgh coal.
- (33.9 - 37.1) Route through rocks of the lower Pittsburgh Formation. Most of the route is less than 150 feet above the level of the Pittsburgh coal. This area has been undermined.
- 0.8 34.7 Stop sign at Baldwin Road Intersection with poor visibility. CONTINUE HALF LEFT on McMichael Road, with caution.
- 0.9 35.6 Intersection with Ridge Road. TURN LEFT, west, on Ridge Road.
- 0.1 35.7 Approximate boundary of McDonald Oil Pool.
- 0.1 35.8 Road divides into one-way routes. KEEP STRAIGHT, avoiding right lane which is a turn-only lane.
- 0.1 35.9 On right, "wave pool." Top of old well derrick visible.
- 0.3 36.2 Oil well close on left.
- 0.1 36.3 On left, entrance to Settlers Cabin Park. TURN LEFT into Park.
- 0.5 36.8 Stop sign. TURN LEFT.
- 0.3 37.1 STOP 8. Lunch and rest stop.
- 0.8 37.9 Leave Park, TURN RIGHT, east, on Ridge Road.
- 1.7 39.6 Retrace route to intersection of McMichael Road and Baldwin Road (reference, Mile 34.7) TURN LEFT, east, onto Baldwin Road.
- (39.6 - 39.9) Route descends through Lower Pittsburgh Formation into upper Casselman Formation.
- 0.3 39.9 Crossing concealed Pittsburgh coal outcrop. Surface-mined area on left served an unusual purpose. It was headquarters for an auto-theft gang.
- 0.1 40.0 Intersection to right. TURN RIGHT, south, onto Scotts Run Road.
- (40.0 - 41.7) Route segment descends 200 feet in elevation but only 100 feet stratigraphically through the Casselman Formation, owing to downstream dip of strata. The Pittsburgh coal has been surface-mined essentially continuously along both slopes of Scotts Run valley.
- 0.2 40.2 Oil and gas well on left provided some excitement. An early producer from the upper Devonian Gordon Stray sand, a gamma-ray log run later indicated very high anomalous radioactivity at and above the producing horizon. This sparked interest in possible solution mining of radioactive minerals, and reportedly one or more wells were drilled to test for this purpose, without success. In the

end (according to George Leney, U. S. Department of Energy), tests demonstrated that the large gamma-ray "kick" resulted from long-term concentration of radioactive materials on and in the bottom of the well casing. The source probably was somewhat higher than normal, but still "trace" quantities from Gordon Stray oil and gas which "plated out" on the casing.

(41.5 - 41.7) Along east edge of abandoned meander of Robinson Run. Striking small meander core about 500 feet west of road, just behind white house.

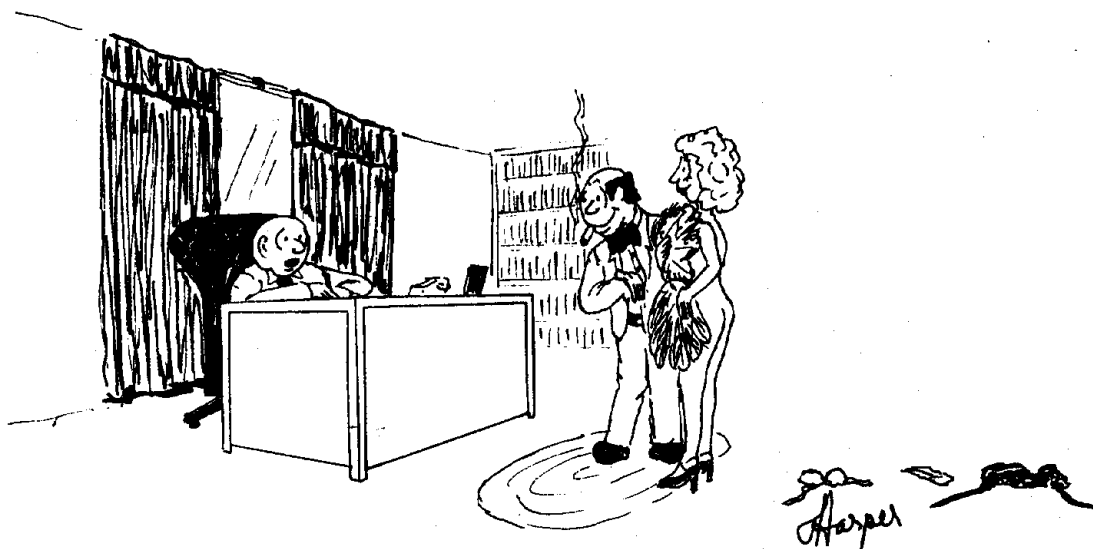
1.5 41.7 Stop sign at intersection with Noblestown Road. TURN LEFT, east. About 0.3 mile to the west, the massive Morgantown Sandstone quarries reportedly were the source of stone used in the architecturally famous Allegheny County Courthouse by H. H. Richardson.

(41.7 - 42.0) Route parallels Robinson Run.

0.35 42.05 TURN RIGHT, southeast, onto road leading to industrial area, including regional headquarters of Browning Ferris Industries and stop.

STOP 9. Maceral Strip Mine.

Disembark and walk to the intersection, TURN LEFT, and walk 100 feet. Cross to north side of Noblestown Road. CAUTION - there is fast, moderately heavy traffic on this road. Walk up unpaved road into Maceral surface mine.



Well, actually, that's not quite what I had in mind when I said I was interested in investing in a stripping operation!

The Maceral mine area extends for approximately 1 mile north-northwest to south-southeast along the east slope of the valley of Scotts Run. It is on property of the Nixon family of Carnegie, and much of the information below and permission to examine the property were provided by Charles Nixon. The mine lies athwart the common edge of Oakdale and Pittsburgh West 7.5-minute quadrangles.

Underground mining in the immediate area began with the Fort Pitt mine in the 1840s and this mine continued active for about 50 years. The most recent underground activity was at the south end of the property in 1917. The Pittsburgh coal in the mine area was approximately 6 feet thick. Underground mining, however, extracted mainly the upper 4 feet of blocky "breast" coal. The lower, more friable "bearing-in" coal largely was left in place, as were stringers of "roof" coal interlayered with shale.

Much early coal was coked close to the site in ovens on the slope above and paralleling the present Noblestown Road. At that time, the Noblestown Road was higher, only a wagon track along the slope at about mine-mouth level. Coal and coke were measured in bushels and were transported by wagon primarily to mills in Birmingham (now part of southside Pittsburgh) about 10 miles away.

With appreciable coal left underground, the site was attractive for surface mining, which was done in the late 1940s, leaving orphan, unreclaimed mine conditions. The current small-scale operation is aimed at land reclamation, based on higher recent prices of coal.

Exposed in mine faces are mine pillars, back-filled rooms, and subsidence of overlying layers. Near the south end of the property there are many small "sinkholes" over under-mined areas and relatively rare chimneys directly down into old workings.

One unusual facet of the area is its mine drainage. Most drainage from bituminous coal mines is acid to some degree. Here, however, the "Pittsburgh limestone," about 10 feet below the coal bed, reaches an unusual thickness and is cavernous. Water from the mine infiltrates the limestone and is neutralized.

Reboard buses. TURN RIGHT, east, from industrial road onto Noblestown Road.

- (42.0 -42.5) Route curves around abandoned meander scar of Robinson Run to right.
- (42.1 -42.3) High on slope to left were old Noblestown Road and coke ovens. Little evidence of the ovens remains; their bricks were taken for house construction.
- (42.5 -42.9) Through the village of Ewingsville and across Robinson Run. Road becomes divided highway.
- (42.9 -43.0) On right a large roadcut. The fenced bench of the cut is at the level of the Pittsburgh coal, here mined out. Visible above the bench are fractures in overlying strata attributable to overburden collapse into mine workings. In effect the Pittsburgh horizon

here is partly "squeezed shut."

0.95 43.0 TURN LEFT, north, onto entrance ramp to I-79 southbound.

(43.5 -43.9) Long, high roadcut on right, essentially a right-angle continuation of the cut at Mile 42.9 - 43.0. At the very beginning of the cut the Pittsburgh coal is visible at the base. The cut exposes more than 200 feet of section entirely in the Pittsburgh Formation.

At the high point of I-79 in the cut (Mile 43.8) the distinctive thick layer 40 feet above road level is the Benwood Limestone (or carbonate; in many places it is chiefly dolomite) which in recent stratigraphic nomenclature is an informal unit within the Sewickley Member of the Pittsburgh Formation. The layer of dark shale immediately beneath the Benwood is the Sewickley coal horizon, here very thin or absent, but of mineable thickness in Greene County, about 50 miles to the south. The base of the Benwood is approximately 120 feet stratigraphically above the Pittsburgh coal.

This roadcut was excavated in the late 1960s, at a steep angle without benches. The face of the cut was essentially planar. Between the shoulder of the highway and the base of the cut was a broad trench about 5 feet below road level. Erosion of the face has filled this trench at least twice (it has been cleared more than once, and was mostly full again in March 1980). Large blocks of rock have bounced onto the roadway. The face of the cut now has the more expectable profile, with shale units on somewhat more gentle slopes than resistant units such as the Benwood. Spalling from the face continues. It is a reasonable speculation that average retreat of the cut may be more than 4 feet since excavation.

Layering here dips gently southeast, forming an oblique over dip situation at the cut. Accordingly, groundwater resurges along many layering interfaces, especially noticeable during winter, when large masses of ice accumulate on the face. These conditions accelerate erosion.

(44.0 -44.3) On a massive fill, I-79 crosses an abandoned meander of Chartiers Creek. Abandonment was artificial, brought about during 1930s reconstruction of the Washington Pike (Pa. Route 50, subparallel to I-79 a short distance east) in order to avoid construction of two bridges.

The Pittsburgh coal is exposed in the steep meander walls on the west. At 4 o'clock, west, deposits of iron oxides are evidence of outflow from former mine workings. Above the meander are extensive grounds and buildings of Woodville State Hospital.

1.6 44.6 I-79 crosses Thoms Run Road. At 2 o'clock, southwest, is a new channel constructed by the Army Corps of Engineers. This channel, approximately 1 mile long, cuts across the neck of a loop of the generally northward-flowing, meandering Chartiers Creek. Its pur-

pose is to provide a release to floodwaters and so avoid extensive flooding along approximately 3.3 miles of the natural course of the stream.

The Pittsburgh coal is exposed in the wall of the channel. The visible portion of the channel approximates the trace of the Ninevah syncline, and layering is essentially horizontal.

0.5 45.1 BEAR RIGHT off I-79 at Kirwan Heights, Exit 12.

0.6 45.7 At end of connecting ramp, keep in left lane and, signal permitting, TURN LEFT, north, on Washington Pike (Pa. Route 50).

0.55 46.25 On left, the Neville House. Historical marker reads:

Neville House. Known as Woodville. Built 1785 by Gen. John Neville; later occupied by his son, Col. Presley Neville. Refuge of Gen. Neville's family when some Whiskey Rebels burned his home at Bower Hill, July 17, 1794.

Difficult topography isolated western Pennsylvania from the rest of the young nation. Grain grown here could not be transported eastward economically. Whiskey made from the grain, however, could be transported relatively cheaply, and it was imposition of taxes on this whiskey that brought about the Whiskey Rebellion, which centered in Washington County, just to the south. The Rebellion probably was the most serious early challenge to the authority of the Nation's government after the War for Independence.

0.05 46.3 Signal at intersection with Thomas Run Road from left. CONTINUE STRAIGHT on Washington Pike. On left, I-79 passes over Thomas Run Road and the flood-water channel (reference, Mile 44.6). On right, the channel joins Chartiers Creek. From this point downstream through Carnegie, the creek has been canalized for flood protection. The loop upstream to the other end of the flood-water channel has not been canalized.

(46.4 -46.9) On right, channel of Chartiers Creek relocated in artificial abandonment of meander (discussion, Mile 44.0 - 44.3).

0.5 46.8 Signal at intersection from left with shopping center road. CONTINUE STRAIGHT on Washington Pike.

0.1 46.9 Signal at intersection from right. TURN RIGHT onto Greentree Road. Grade crossing is on the former Pittsburgh, Chartiers, and Youghiogheny Railroad, now a low-density Conrail line. Underpass is through a high fill on the Norfolk & Western.

0.1 47.0 Other wells of Woodville field to left.

0.15 47.15 Traffic signal. CONTINUE STRAIGHT on Greentree Road.

- 0.2 47.35 Visible in distance on left is large I-79 cut (discussion, Mile 43.5 - 43.9).
- 0.5 47.85 Signal at 5-point intersection. TURN RIGHT, following Swallow Hill Road up hill. At intersection, 11 o'clock, foundation of Denny's Restaurant was excavated to level of Pittsburgh coal, here about 30 feet below ground surface, in order to avoid potential subsidence problems. At 8 o'clock, Pittsburgh coal is exposed on north side of Hope Hollow Road.
- (47.85-48.05) On right, slope rising to Nob Hill apartments suffered landsliding during construction, now largely stabilized.
- 0.7 - 48.55 At bottom of hill, curve right to stop sign. TURN RIGHT onto Scrubgrass Road.
- (48.55-49.05) On slope to left, Grouse Drive runs parallel to Scrubgrass Road ranging approximately 40 to 80 feet up the slope. Foliage permitting, one can see evidences of slumping in many of the back yards facing Scrubgrass Run.
- 0.2 - 48.75 On left, operating gas well.
- 0.1 - 48.85 On right, operating gas well.
- 0.2 49.05 "Backyard" landslide site.

STOP 10. Disembark and climb slope to right, north, to cut bench about 20 feet above road. Look south across Scrubgrass Run. Scrubgrass Run has an upstream drainage area here of about 0.6 square mile, much of it armored by chiefly residential and commercial institutional development. Across the stream on the slope rising to the house above (1314 Grouse Drive) are scar and debris of a landslide.

It is emphasized that this landslide is not of itself unique in this region. Rather, it is of an all too common type. This particular site was selected for this conference for two chief reasons: it was convenient to the rest of the tour; but, mainly it is one of the few of its type that exposes the entire feature at a glance. In most such phenomena, a coherent, photographable view is precluded by other houses, foliage, and the terrane.

This is a "hands off" stop. We do not have permission to climb on the mass itself. Indeed, the live weight of as many as 150 visitors, 10 tons or more, might have further unfortunate consequences. If, after the discussion you wish a closer view you may take a look at its toe in the valley.

Informally categorized as a "backyard" landslide by geologists in the region, this landslide and its brethren are a predictable result of the impress of the topography on development practice. Briefly, level ground is relatively rare, so hill slopes are developed, creating a bench along the slope by cutting upslope and emplacing excavated material on the downslope. A road is then placed along the axis of the bench and houses are constructed on either

side. Depending on steepness of original and resulting slopes, the character of slope and fill materials, hydrologic conditions, and "engineering," such development practice may or may not prove successful.

Aerial photographic inventories have identified numbers of such landslides, and it is estimated that, considering housing density, several thousand would be recognized by detailed on-the-ground study, ranging from incipient, to active, dormant, or past, and from mere nuisances to damaging occurrences, appreciably more serious with respect to property damage than this one.

This particular landslide has a history longer than many. The house was constructed in 1958 or 1959, and was acquired by the current owner in the Fall of 1969. In the following December, the backyard "fell away," most of the movement occurring in one night. After this event, the owner found that similar, but probably smaller, movements had occurred as little as 8 months before the purchase. The previous owner seemingly had modest cosmetic remedial work done and got out from under. One can't blame him, but certain questions arise concerning the real-estate broker who handled the sale and the VA who inspected the property and guaranteed the mortgage for this now unsaleable, essentially valueless property. Most likely the realtor and the VA had not the knowledge to recognize an incipient problem of this sort. However, that appears little excuse, considering how common landslide problems are in this area.

In 1972, the VA arranged for the dumping of some 400 tons of slag on the slide, which is now visible as the gray material in the approximate middle of the slope. This only served to make matters worse, for prior to this activity the house apparently had suffered no structural strain, owing to its deep foundation (20 to 30 courses of block below the level of the basement floor). Since then, much noticeable cracking has occurred, but no other "remedial" measures have been taken. In 1975, a few more feet of backyard remained at the garage door, visible on the left, although the situation at the back door on the right was almost as you see it.

The landslide must be described as still active, for the scarp is spalling actively and has propagated modestly to the left (east) and appreciably to the right (west), as evidenced by the undercut trees on the adjacent undeveloped property.

Remains of cribbing can be seen in the rubble of the landslide, probably relics of the cosmetic, pre-1969 sale repairs. Like the victims of most similar occurrences, the owners are in modest circumstances, and there is no landslide insurance or other financial support. The result is that no detailed studies have been made, and there are no good estimates of costs of viable remedies. In a case similar both geologically and in areal extent about 3 miles to the south, 6 properties were directly affected and remedies were estimated to be \$175,000 to \$225,000 in 1979 dollars.

The crown of the landslide scarp is at the 975 foot elevation, stratigraphically at the approximate level of the Sewickley coal (which is thin to absent in the immediate vicinity) and about 140 feet stratigraphically higher than the Pittsburgh coa. Scrubgrass Run at the base of the landslide is at elevation 895 feet, about 65 feet higher than the Pittsburgh.

The stratigraphic position of the Fishpot Limestone (Pittsburgh Formation) is 25 to 30 feet below the crown of the slide, and adjacent strata are general-also significantly calcareous. In addition, the Benwood Limestone, which commonly is argillaceous, crops out above the level of site. These units weather to a clay residuum, classified by the U.S.D.A. Soil Conservation Service as Guernsey soil, which is characterized as unstable on moderate slopes. These unstable soil conditions often result in colluvium of variable thickness covering slopes at and below the levels of these bedrock units.

The geologic structure at this point dips generally northwesterly out of the affected slope at a gentle 45 feet per mile, an oblique overdip condition. Overdip slopes have been demonstrated to be preferred sites of groundwater resurgence.

It is reasonable speculation that this landslide may be a result of the following factors in ill-defined and varying degrees:

- (1) Naturally steep slope;
- (2) Unstable characteristics of weathered material on the slope (low shear strength);
- (3) Seeps or springs on the slope (increasing hydrostatic pressures);
- (4) Thick fill apparently chiefly composed of the same type of generally unstable soil that mantled the natural slope (low shear strength);
- (5) Oversteepened developed slope (increased shear stresses);
- (6) Stream cutting toe of slope (increased shear stresses).

These factors resulted in the sudden large-scale failure of December, 1969. One wonders why it took so long.

In many residential developments it is likely that there was an essential lack of "engineering" during placement of fill. Relating to the numbered factors above, operations that may not have been done include:

- (1) Proper clearing or grubbing of slope.
- (2) Proper cutting or benching into slope to establish stable foundation for fill.
- (3) Proper surface and subsurface drainage.
- (4) Proper compaction of fill and establishment of proper embankment slope angle.
- (5) and (6) Proper slope protection.

Return to buses which will have reversed headings.

Retrace route to intersection of Swallow Hill Road and Greentree Road (reference Mile 47.85).

- 2.35 51.4 Signal at T intersection with Greentree Road. TURN RIGHT
- 0.4 51.8 At Virginia Manor Shopping Center on right and Colony Restaurant facing, Greentree Road bears left. Follow it up through residential area into business area.
- 2.5 54.3 Signal - turn left, follow signs to Mansfield Avenue and Holiday Inn
- 0.6 54.9 Holiday Drive on RIGHT. Turn up.

END OF FIELD TRIP

References for both Day 1 and Day 2

(See also references in contributed papers)

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