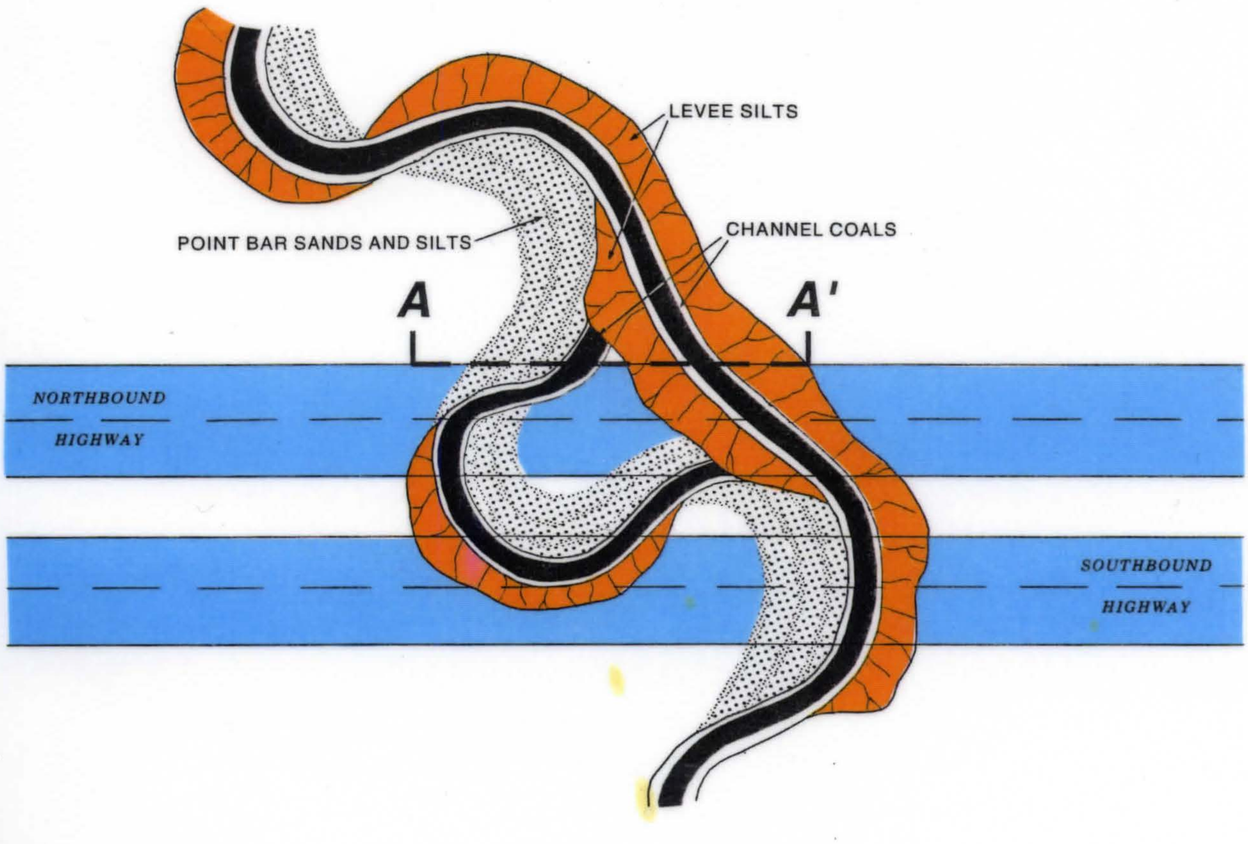

PITTSBURGH GEOLOGICAL SOCIETY
GOLDEN ANNIVERSARY (1945 - 1995)
FIELD GUIDE BOOK
1995

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GOLDEN ANNIVERSARY (1945 - 1995)
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Cover Drawing by V. Skema, Day One, Stop 2

THE PITTSBURGH GEOLOGICAL SOCIETY
GOLDEN ANNIVERSARY (1945-1995)
FIELD TRIP

Peter J. Hutchinson, The Hutchinson Group, Ltd.
Field Trip Coordinator and Editor

This year we are celebrating the Golden Anniversary of the Pittsburgh Geological Society and in honor of this occasion the Board of Directors is sponsoring this three-day event. The idea for the field trip originated nearly one year ago and with diligent efforts we have prepared what we hope will be a learning adventure for all attendees. The original intent was to present as much information as possible in a one-day field trip; however, we soon found that western Pennsylvania had too many features to package into a one-day field trip. With job constraints and other commitments, we felt that three one-day field trips would be the best solution for all of our members' busy schedules.

Each day focuses on one topic of geology, and in a different portion of the Pittsburgh area. The first day examines economic geology and includes a quarry, a stratigraphic analysis of coal, and a visit to a gas storage field all in Westmoreland County. The second day presents geotechnical and engineering geological solutions for several unusual projects. This trip concentrates on the west side of Pittsburgh and examines Little Blue Run dam, the new Pittsburgh International Airport Mid Field Terminal, a stabilized slide, and coal-mine seals. The third day will combine interesting stratigraphic analyses with some of the geotechnical hazards associated with these units. This trip will also provide some of the better fossil collecting localities in the Pittsburgh area.

I would like to personally thank the coordinators of each field trip for the enormous effort they have expended to produce the Golden Anniversary Field Trip: Ray Follador, Viktoras Skema, Karen Rose Cercone, Chris Ruppen, Charles Shultz, John Harper and Judy Neelan. They have worked together to produce a wonderful set of field trips, that we know you will enjoy.

Acknowledgments

The Pittsburgh Geological Society would like to thank Mr. George Hospedar and the Davison Sand and Gravel Company for granting permission and arranging a tour of the Torrance Quarry and Mr. John Graham and Mr. Thomas Sokol of the Pennsylvania Turnpike Commission for granting permission for stopping along the Amos K. Hutchinson highway (new Route 66) to view outcrops. The Society would also like to thank Mr. Rick Lynch and the Consolidated Natural Gas Transmission Company for granting permission and arranging a tour of the Oakford Storage facility. A special thanks goes to IUP for supplying hard hats and Mr. Dale Cunningham and Halliburton Services for supplying ear protection. A final thanks goes to the Hutchinson Group, Ltd. for donating the drinks.

Geology of Western Pennsylvania

John A. Harper, Pennsylvania Geological Survey

Introduction

Southwestern Pennsylvania lies within the Appalachian Plateau Physiographic Province, an area having a generally level surface at an altitude great enough to permit erosion of deep valleys by streams. This level surface results from the essentially flat-lying nature of the bedrock near the earth's surface. The area around Pittsburgh, including Allegheny, Beaver, and most of Westmoreland counties, is assigned to a subprovince called the Pittsburgh Low Plateau Section. The topography in this section is characterized by a relatively small amount of relief. The hilltops in this area stand at about the same elevation, approximately 1,100-1,300 ft (335-400 m) above sea level, or about 350-550 ft (105-165 m) above the level of the rivers. By comparison, relief in the neighboring Allegheny Mountain Section to the east (eastern Westmoreland and Cambria counties) commonly exceeds 1,500 ft (460 m) in the vicinity of the prominent high ridges that characterize that section, Chestnut Ridge and Laurel Hill. Most of the hilltops of western Pennsylvania are the remnant of an ancient, relatively broad, relatively flat surface that has been highly dissected by numerous antecedent streams, many of which became established during the Mesozoic or Cenozoic. This surface sloped very gently toward the northwest, toward the area of the present-day Great Lakes. At least the larger streams probably meandered in broad, shallow valleys cut only a little deeper than the surrounding landscape. Once this drainage pattern was established, the topographic relief gradually increased as the streams cut down into the rocks of the plateau, until the present-day relief of western Pennsylvania became established.

Stratigraphy

Most of the surface rocks in the Pittsburgh area belong to the Conemaugh Group (Figure 1). The rock record in this area has many gaps owing to erosion or non-deposition that took place in the myriad depositional environments present between and 315 and 290 ma. Figure 1 represents a composite stratigraphic section prepared by piecing together many smaller sections exposed at different localities around the tri-state area. This figure is highly generalized -- although each rock unit in the section is shown as though it had a specific thickness and vertical distance from every other unit, in reality these are just averages. Real changes in thickness and interval are too variable to be shown in a single illustration.

The Conemaugh Group is the thickest sequence in the Pennsylvanian System of western Pennsylvania, commonly containing more than 600 ft (180 m) of sandstone, mudrock, limestone, and coal. Coals consist of a few thin seams that are mined only in limited areas. The top of the Upper Freeport coal and the base of the Pittsburgh coal form the boundaries of this group. The top of the Ames Limestone Member divides the Conemaugh Group into

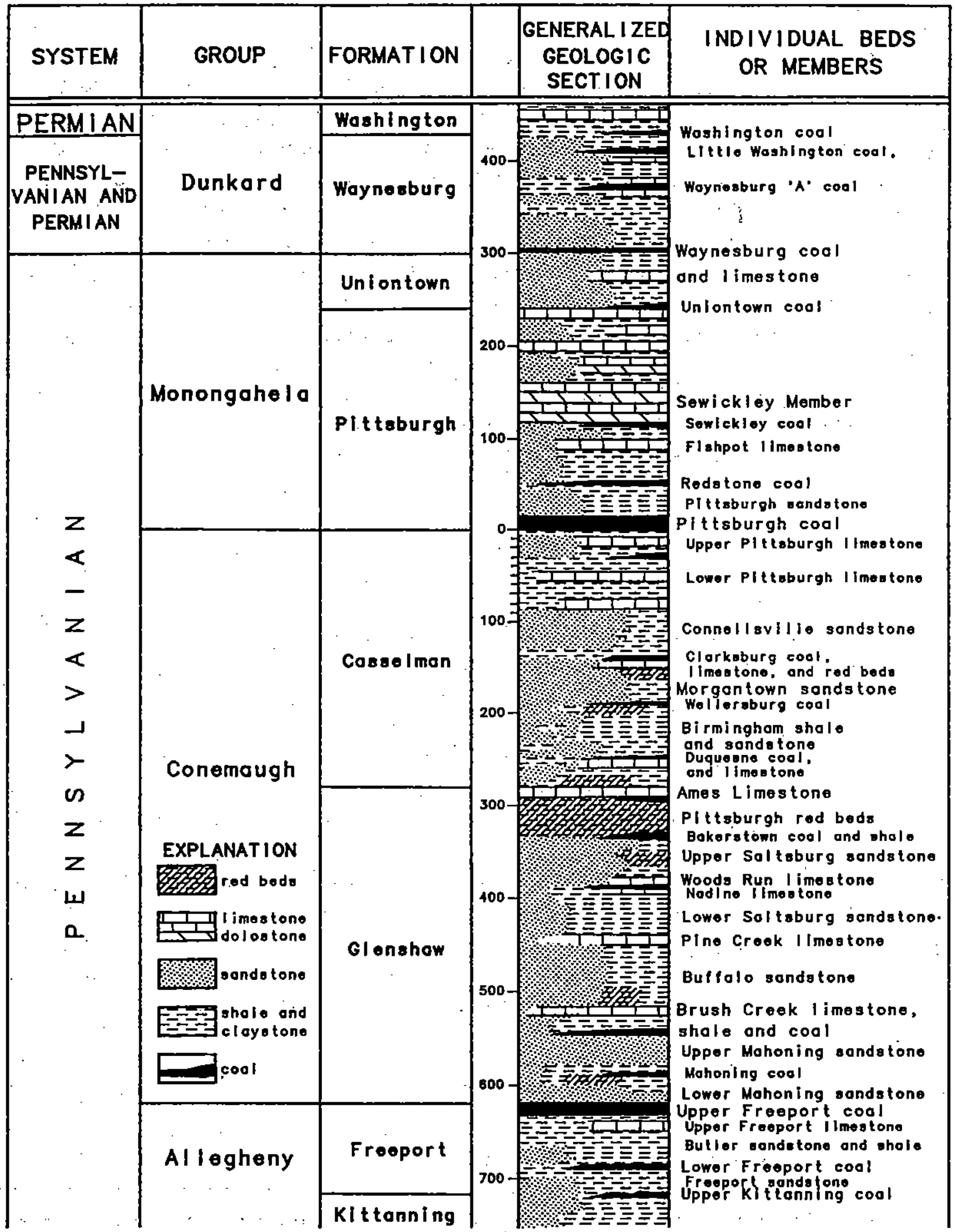

Figure 1 Generalized geologic column of the exposed rocks of Allegheny County (from Harper, 1990).

two formations, the older Glenshaw Formation and younger Casselman Formation. Each of these formations is about 300 ft (90 m) thick, dividing the group into two roughly equal subdivisions.

The Conemaugh Group underlies almost all of the Pittsburgh area, but because of regional dip to the southwest, the Conemaugh crops out mostly in stream valleys in the southern half of Allegheny County (Figure 2). The Glenshaw Formation is well exposed north of the Allegheny and Ohio Rivers whereas the Casselman Formation is best seen south and east of the two rivers. Although no one has seen a complete, uninterrupted section of the Conemaugh from top to bottom, there are places in the county where large portions of it can be seen in a single outcrop or roadcut. Notable examples include: 1) along Route 51 on the southwest side of the Ohio River, across from Sewickley, exposing an almost complete section of the Glenshaw Formation, from thick Mahoning sandstone at the bottom of the roadcut to the Ames Limestone Member near the top; 2) the extensive roadcut along Route 28 southwest of the Harmarville exit, that exposes the section from the Lower Saltsburg section (Middle Glenshaw) to the Connellsville sandstone (upper Casselman); and 3) in excavations behind stores lining approximately 1.5 mi (2.5 km) of Banksville Road (US 19) between the Parkway West and Wenzell Avenue that expose the middle Casselman to the lower portion of the Monongahela Group (Morgantown sandstone to the Pittsburgh coal).

Depositional Environments

During the much of the Pennsylvanian Period, western Pennsylvania was situated close to the edge of an epeiric sea. Climate shifts at the poles created alternating periods of glaciation and global warming which, in turn, led to periodic episodes of eustatic sea-level rise and fall. As such, western Pennsylvania became subject to periodic shifts of the coastline. At any particular time during the Pennsylvanian, northern Allegheny County could be: 1) several tens of feet below the surface of an ocean teeming with a myriad of fish and shellfish; 2) a swampy tropical rainforest of fern-like trees and scouring rushes up to 100 ft (30 m) high; 3) a large lake filled with calcareous phytoplankton and the almost microscopic crustaceans that ate them; 4) an alluvial plain with large, exotic amphibians and reptiles scampering after prey along the banks of a sluggish meandering stream; or 5) a vast delta of steaming swamps and distributaries, home to foot-long cockroaches and dragonflies the size of falcons. It was the shifting and intermixing of these environments that was responsible for the repetitious sequence of rock types that compose western Pennsylvania.

Structure

Southwestern Pennsylvania lies within the Pittsburgh-Huntingdon Synclinorium (also referred to as the Dunkard Basin) because the axis of the structure trends northeast-southwest between Huntington, West Virginia and Pittsburgh (Figures 3 and 4). Most of

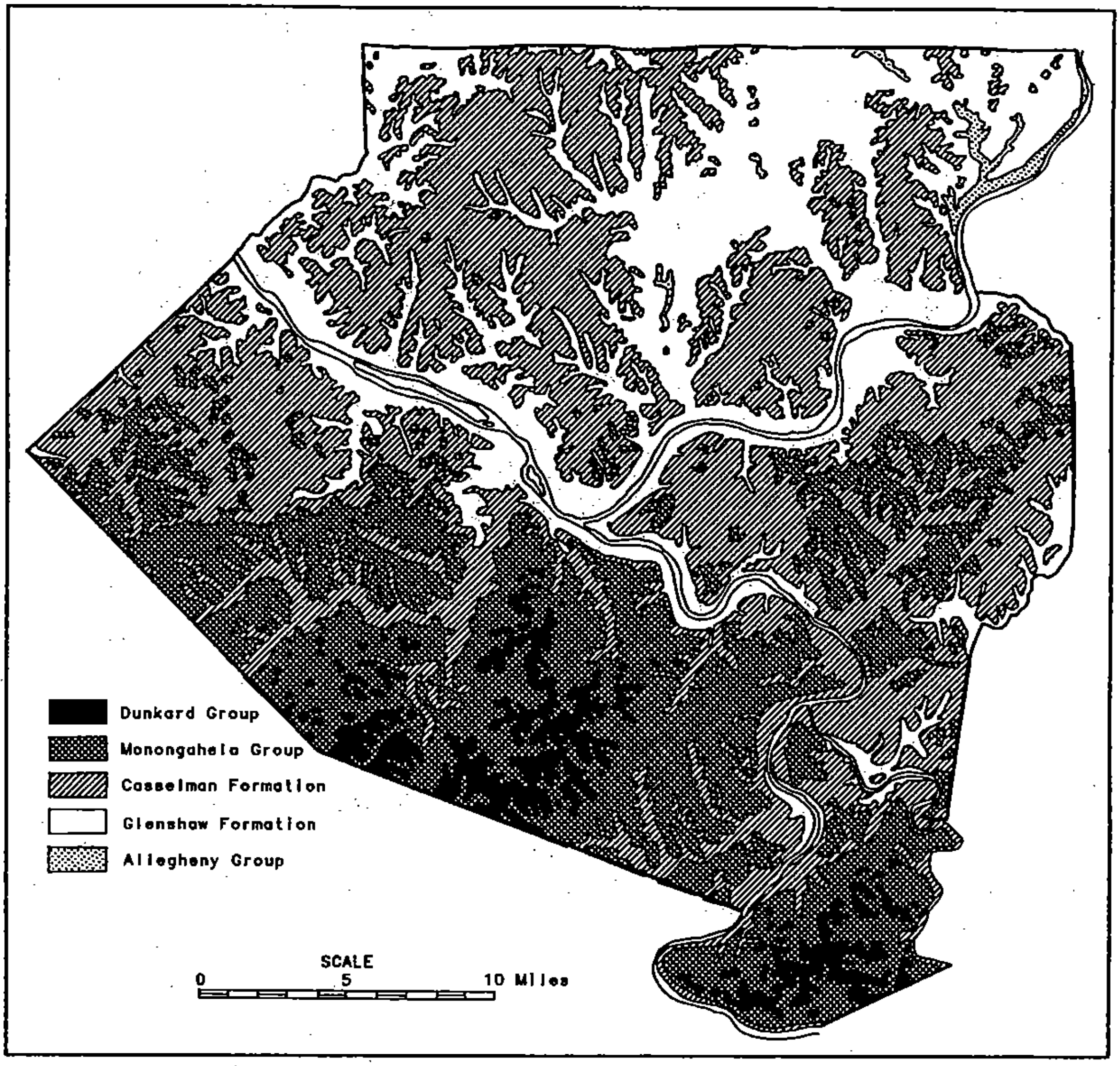

Figure 2 Geologic map of Allegheny County. The combined Casselman and Glenshaw formations comprise the Conemaugh Group.

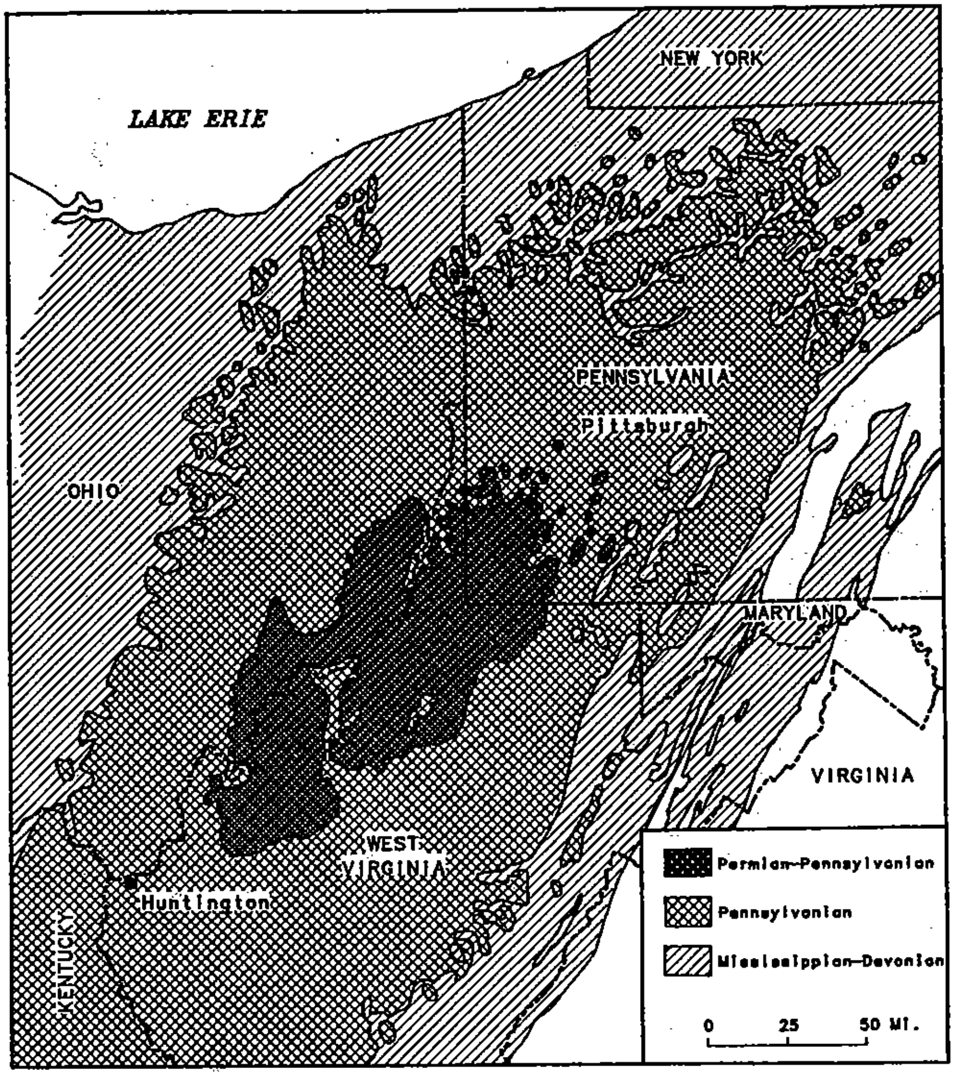

Figure 3 Generalized regional geologic map of the tri-state area. The configuration of rocks defines the Pittsburgh-Huntington synclinorium or Dunkard basin.

the strata in the basin dip gently toward this axis. The Permian System occupies the center of the basin, and progressively older rocks crop out towards the basin margins.

The strata of southwestern Pennsylvania are very gently folded, with axes trending approximately N35E (Figure 4). The anticlines typically have flanks dipping less than 20 ft/mi (3.75 m/km), although some of the "more pronounced" folds in the Pittsburgh area have dips in the neighborhood of 200 ft/mi (38 m/km), an amazing 2° slope! The typical fold tends to curve horizontally as well as vertically, resulting in serpentine structures marked by very gentle domes and saddles. Westward from the center of the Dunkard basin the folds become open and discontinuous. Eastward from the basin center the rocks become increasingly distorted by both folding and faulting, and the folds have more steeply dipping flanks and higher structural relief. Outstanding among these are Chestnut Ridge, Laurel Hill, and Negro Mountain anticlines. The principal surface fold axes in Allegheny County are shown in Figure 5, and a cross section illustrating the relation of structure to topography (at a GREATLY exaggerated scale) has been included as Figure 6.

Jointing is very common in southwestern Pennsylvania outcrops. The preferred orientations of the two principal joint sets, as measured in shales and sandstones, range from N10E to N40E and N50W to N80W (Nickelsen and Hough, 1967). Vertical joints lie nearly at right angles to bedding planes. Joints also form approximately parallel to valleys, regardless of valley orientation as a result of the release of stress. We will have the chance to see some of these valley stress-release joints during the field trip, especially along I-279 (Day Three) where the roadcuts are still fairly fresh. In addition, two well-developed vertical and intersecting cleat sets have develop in the local coals. The face cleat, which formed perpendicular to the regional fold trend, is the best developed, whereas the butt cleat, formed parallel to the regional fold trend, is less well developed. Joints have influenced the surface drainage patterns and subsurface water accumulations. Although the major drainage pattern in western Pennsylvania is dendritic, many of the streams in the region have long, straight segments that are oriented northwest-southeast or northeast-southwest, the same orientation as the major joint sets. A good example of this phenomenon is the Ohio River which flow in an almost straight channel from downtown Pittsburgh to Beaver. Jointing in the rocks created an easily eroded pathway that the rivers followed as they cut down into the folds. Jointing also plays an important role in landsliding by separating large blocks of rock, some the size of buildings, from the main bedrock layer on unstable slopes. Once gravity takes over, a rockfall is inevitable.

Faulting is not a common feature of the surface rocks of southwestern Pennsylvania, but faults do occur as we shall see. Normal faults are the most common fault type present in the surface rocks of southwestern Pennsylvania. Good examples of these occur at numerous localities around the Pittsburgh area; Wagner et al., (1970, figs. 3 and 37) illustrated normal faults with a considerable amount of displacement along Banksville Road and in a railroad cut across the Youghiogheny River from McKeesport. Most, if not all, of these faults occurred penecontemporaneously with deposition as glide planes of slump

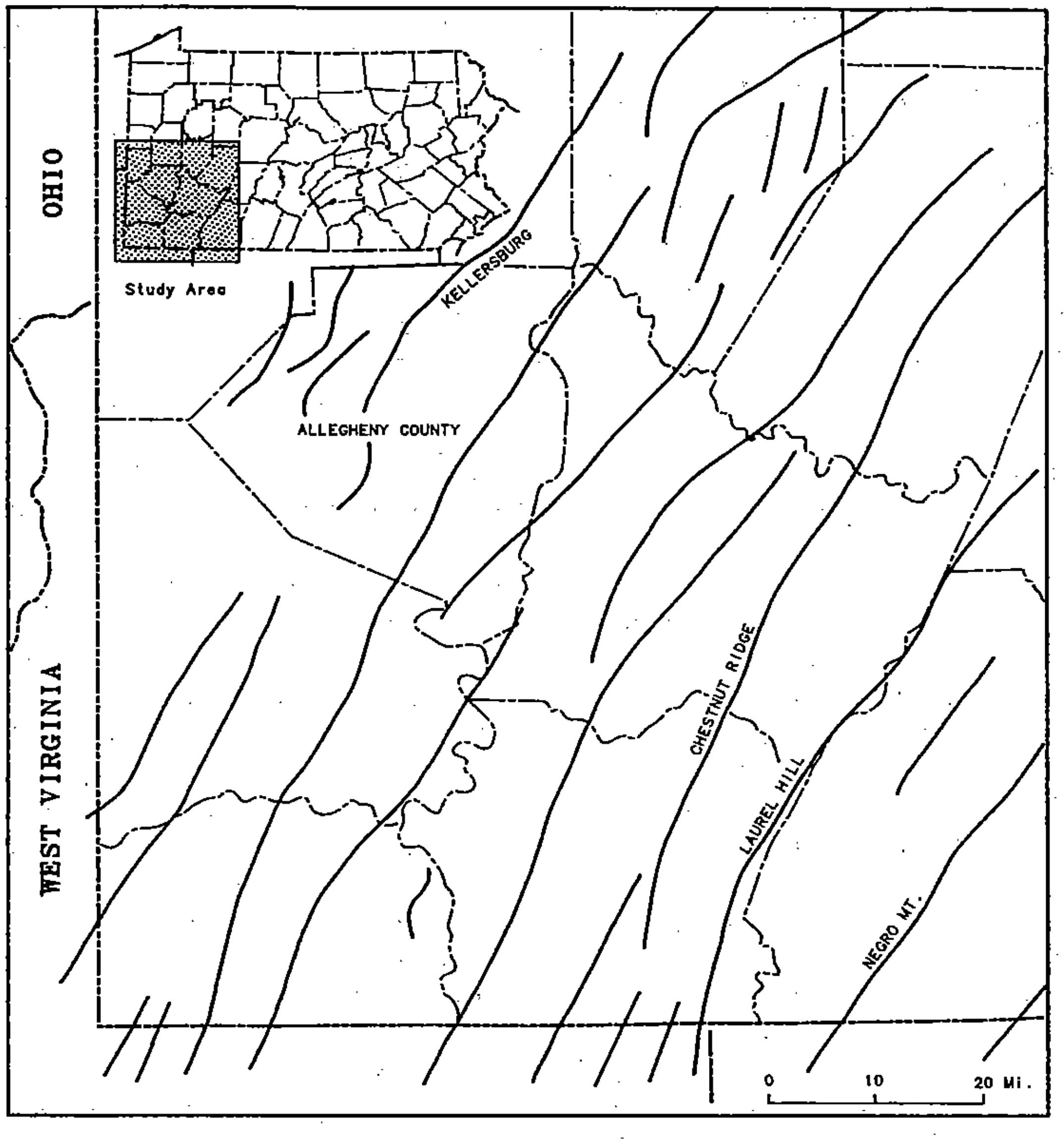

Figure 4 Map of southwestern Pennsylvania showing the trends of the major anticlinal axes. The three most prominent, Chestnut Ridge, Laurel Hill, and Negro Mountain anticlines, form high, deeply dissected ridges.

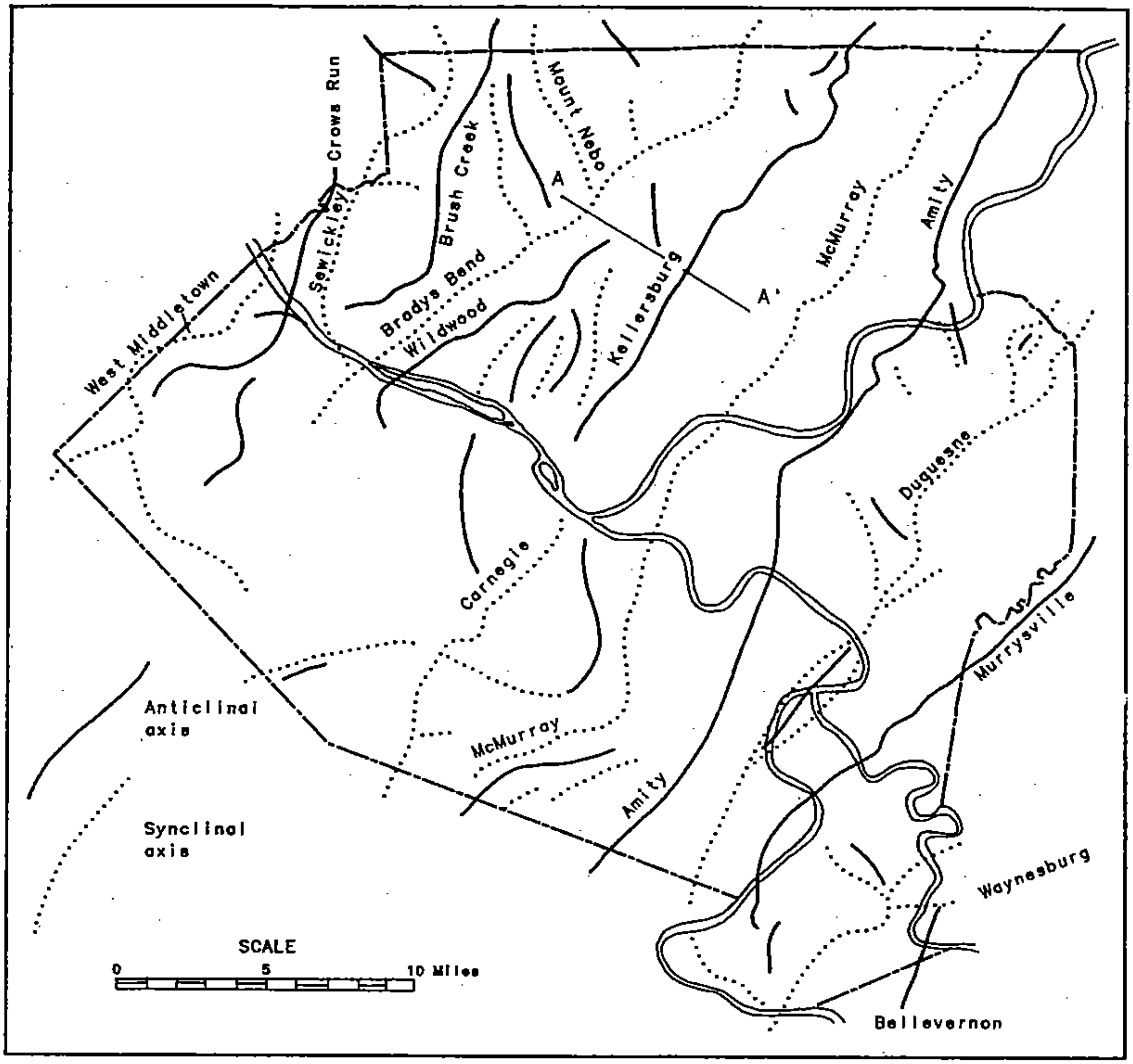

Figure 5 Map of Allegheny County showing structural axes (compiled from Dodge, 1985). Cross section A-A' is shown in Figure 6.

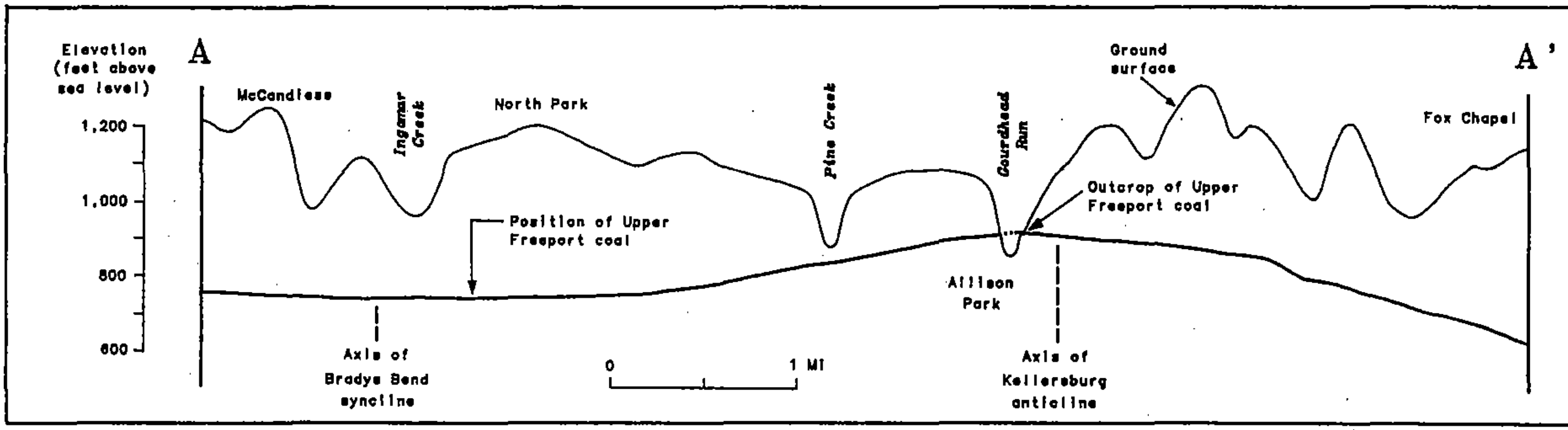

Figure 6. Cross section A-A' across the Bradys Bend syncline and Kellersburg anticline in northern Allegheny County. See Figure 5 for location.

blocks associated with stream-bank landslides. Several small normal faults cut the Ames Limestone Member in a roadcut along Route 28 near Creighton, creating a small graben. Reverse faults are far less common in southwestern Pennsylvania than normal faults,except in the more highly distorted rocks to the east. One good example can be seen in the roadcut along the southbound ramp to and from Route 28 at Tarentum where a portion of the Mahoning sandstone has been thrust upwards.

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Greater Pittsburgh Region Structure Contour Map, Penna. GS Map 43

Greater Pittsburgh Region Oil and Gas Fields Map, Penna. GS Map 44

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APPENDIX 1

Foundation Treatment for Little Blue Run Dam

Thiers, G. R.; Lobdell, L. W.; and Mihalcin, B. M.; "Foundation Treatment for Little Blue Run Dam", Proceedings, Rock Engineering for Foundations and Slopes, Vol. 1, ASCE Specialty Conferenc Boulder, Colorado, August, 1976.

FOUNDATION TREATMENT FOR LITTLE BLUE RUN DAM

By Gerald R. Thiers[1], L. W. Lobdell[2] and B. M. Mihalcin[3]

ABSTRACT

Methods of abutment and foundation treatment of high earth and rockfill dams are as many and diversified as are the dam sites themselves. The exploration, planning and execution of this work at the site of a 420-foot high sloping-core dam founded upon sedimentary rocks in western Pennsylvania are discussed, considering the influences of site topography, geology, and hydrology. Hydraulic pressure testing of diamond drill holes during the subsurface investigation was utilized to determine permeability variations. Settlement, sliding and special seepage analyses were carried out to guide the design of the foundation treatment. The grouting program was modified during construction to meet special conditions and was continually evaluated by pressure testing before and after grouting along centerline exploratory borings. Additional foundation preparations utilizing air and water jets, hand cleaning, dental concrete, slush grout, and a grout cap were used to insure a satisfactory bond of impervious core material to rock. Special consideration was given to the problems associated with the presence of "country bank" coal mines in the abutment areas. A variety of techniques and materials were used to backfill the mines. Backfill materials included fly ash-cement and sand-cement grout. The adequacy of the backfilling operations in critical areas was later checked using water pressure tests. An assessment of final performance of the dam must await its completion in 1976.

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[2]Project Director, Dravo Corporation, Pittsburgh, Pennsylvania.

[3]Project Engineer, GAI Consultants, Inc., Monroeville, Pennsylvania.

Introduction

For a 420-foot high sloping-core, rock-fill dam, located on sedimentary rock strata in southwestern Pennsylvania, the following foundation conditions were encountered:

1. A shell of highly fractured rock formed by the valley walls and floor, resulting in a 20- to 30-foot deep weak zone with permeabilities of the order of 10^{-3} to 10^{-4} centimeters per second.

2. Order of magnitude variations in compressibility and permeability between adjacent horizontal rock strata.

3. A variable core-rock contact surface involving weatherable shale and fractured sandstone with existing rock slopes as steep as 0.5 horizontal to one vertical.

4. A series of country bank coal mines penetrating as far as 110 feet into the abutments.

Foundation exploration, analyses and treatment procedures required to accommodate the conditions encountered are described herein.

Location and General Situation

Particulate matter and sulfur dioxide in stack gases at the Bruce Mansfield Power Station, located near Shippingport, Pennsylvania, will be removed by wet scrubbers and treated with a solidifying additive (CALCILOX)*. The resulting sludge will be transported via pipe line (Fig. 1) and deposited in the reservoir formed by Little Blue Run Dam. As the solid portion of the sludge settles out, the supernatant remaining above the solid surface will be maintained at a minimum depth of 10 feet. On this basis, the reservoir has a 30-year capacity. At the final embankment crest elevation (1100 feet), the reservoir surface will be approximately 11,000 feet long and 8,200 feet wide (maximum width).

Elevations in Little Blue Run Valley vary from about 650 feet above sea level at the mouth of the stream to a maximum of 1,380 feet at the southern limit of the watershed. The lowest point along the downstream

*CALCILOX is a proprietary additive developed by Dravo Corporation.

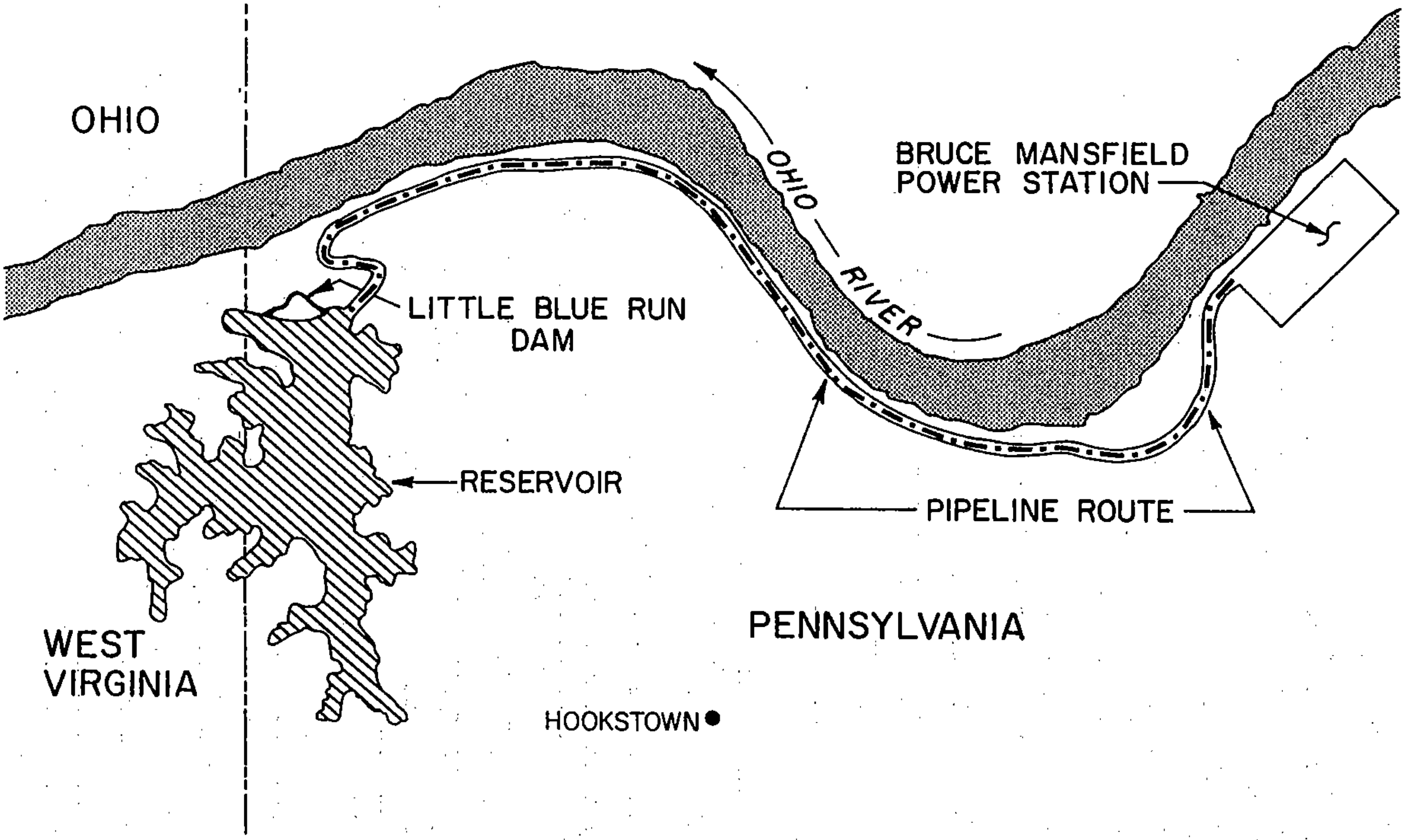


FIGURE 1 - LOCATION MAP

toe of the dam is at elevation 680; the final crest length will be approximately 2,200 feet. The 8,000,000 cubic yard embankment will be one of the highest earth- or rock-fill dams in the eastern United States. Construction began in April 1974, and by January 1976, approximately 4,000,000 cubic yards of material had been placed. Additional details regarding construction of the embankment have been presented elsewhere (5).

The particular location and geometry of the embankment centerline were selected to maximize the storage volume of the reservoir and to minimize the embankment volume (Fig. 2). (The design cross-section is shown in Fig. 3.) The design is based on the comprehensive subsurface investigation described below.

Subsurface Investigation

The subsurface investigation was designed to determine:

1. The types and distribution of soils at the location proposed for the embankment;

2. Strengths and permeabilities of the rock strata at the proposed dam site.

Investigative techniques included the following:

1. In soil: Machine dug test pits and borings;

2. In rock: Core-boring and field permeability tests in bore-holes (packer tests, Ref. 7).

In the preliminary phase of the investigation, borings were spaced approximately 400 feet apart along the initially proposed centerline and along the axis of the valley (Fig. 2). Because relatively impermeable rock strata were encountered above elevation 420, the deepest borings were terminated at approximately this elevation (270 feet below the top of rock in the valley floor).

Data from the 15 preliminary borings and the preliminary geologic study indicated that the proposed site was acceptable. Therefore, the detailed phase of the study was initiated. Additional borings were drilled in this phase, between the preliminary borings and at other locations, (as shown in Fig. 2), resulting in a total of 121 borings. Six borings in the valley walls were inclined at 60 degrees (roughly normal to the valley walls) to better evaluate joint spacing. A plot of joint strike frequency indicates that most jointing is from stress relief, i.e., normal to the valley walls (2,3).

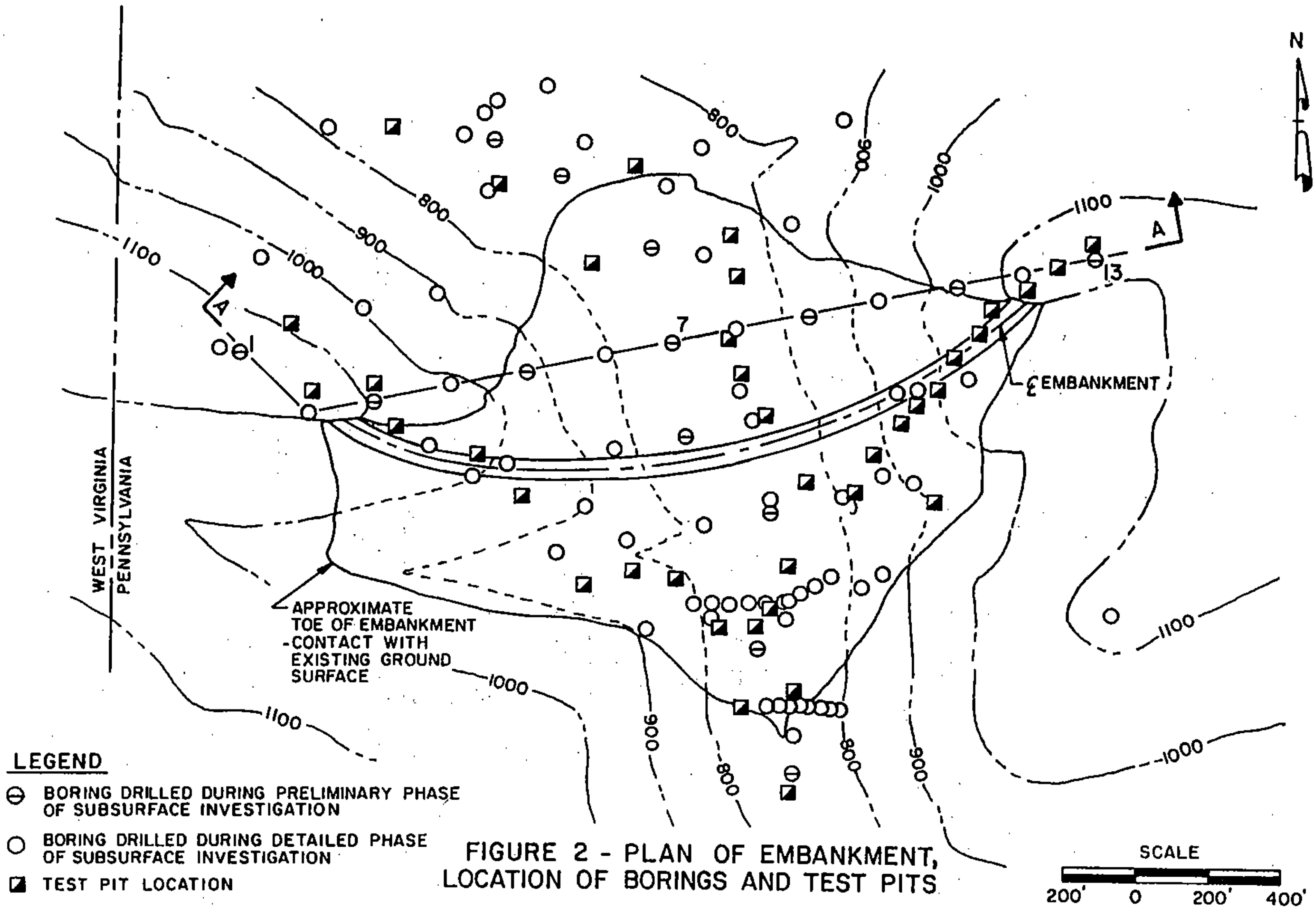


FIGURE 2 - PLAN OF EMBANKMENT, LOCATION OF BORINGS AND TEST PITS

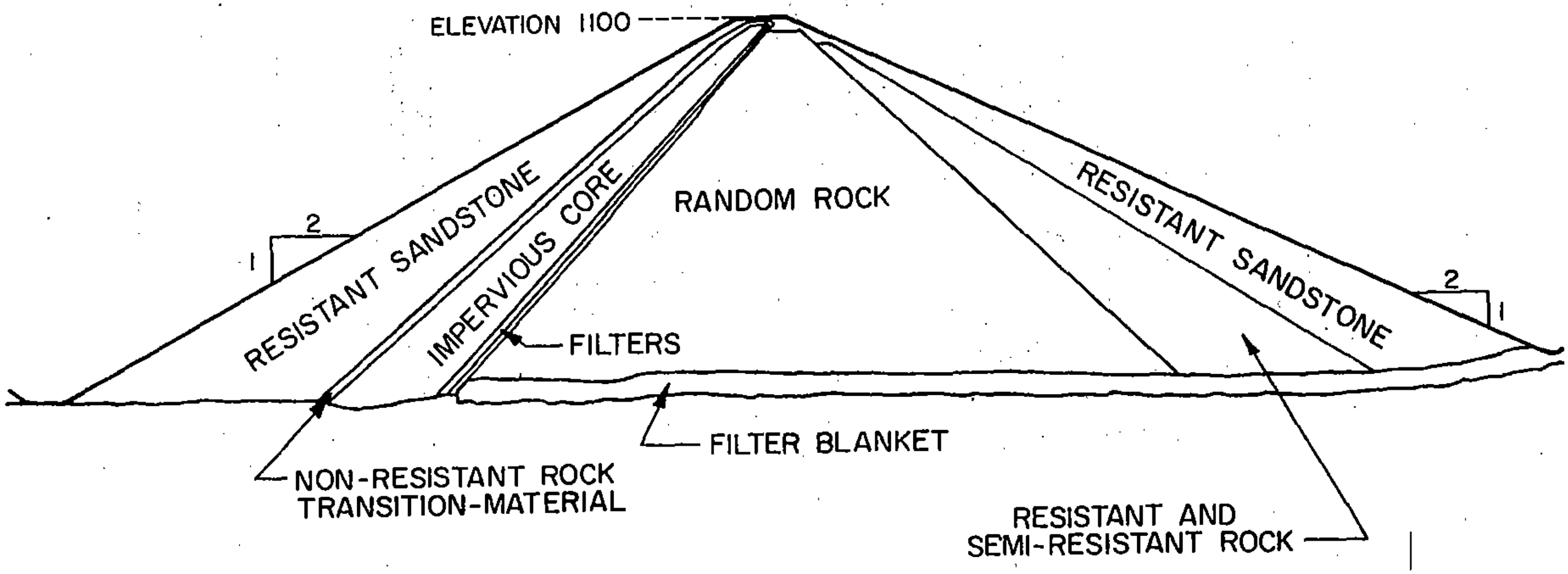


FIGURE 3 - EMBANKMENT CROSS SECTION

Soil depths ranging from 3 to 30 feet were encountered in the borings and test pits, as shown in Fig. 4. A relatively thin veneer of fine-grained colluvial soils (mostly sandy and clayey silt with some silty clay) was found on the valley walls. Thicker deposits of silty sand and gravel with occasional thin lenses of clay were present in the valley bottom. Because of the variability in thickness and composition of the natural soils throughout the embankment area, it was decided to eliminate the differential settlement and stability problems related to foundation soils by founding the dam directly on rock.

Essentially flat-lying sedimentary rocks (sandstone, siltstone, shale, coal, claystone, and occasionally limestone) varying in thickness from less than an inch to 60 feet were encountered (Fig. 4). Rock hardness varied from soft to hard, indicating that order of magnitude variations in modulus and compressive strength could be expected. Of particular interest were the claystone seams shown in Fig. 5. The compressibility and strength of these seams were considered as discussed below.

Packer permeability tests were carried out in 31 of the borings, generally in 5-foot intervals. A water pressure of 1 pound per square inch per foot of depth below the top of rock was used in the subsurface investigation. The packer test data indicate that rock permeability varies with the extent of jointing and brokenness of the rock more than with rock type. Because breakage decreases with depth below the top of rock, permeability also decreases with depth. For analysis purposes the rock strata were divided into the following three permeability zones as shown on Fig. 4:

Zone A: Upper 20 to 30 feet of rock; 10^{-3} to 10^{-4} centimeters per second permeability.

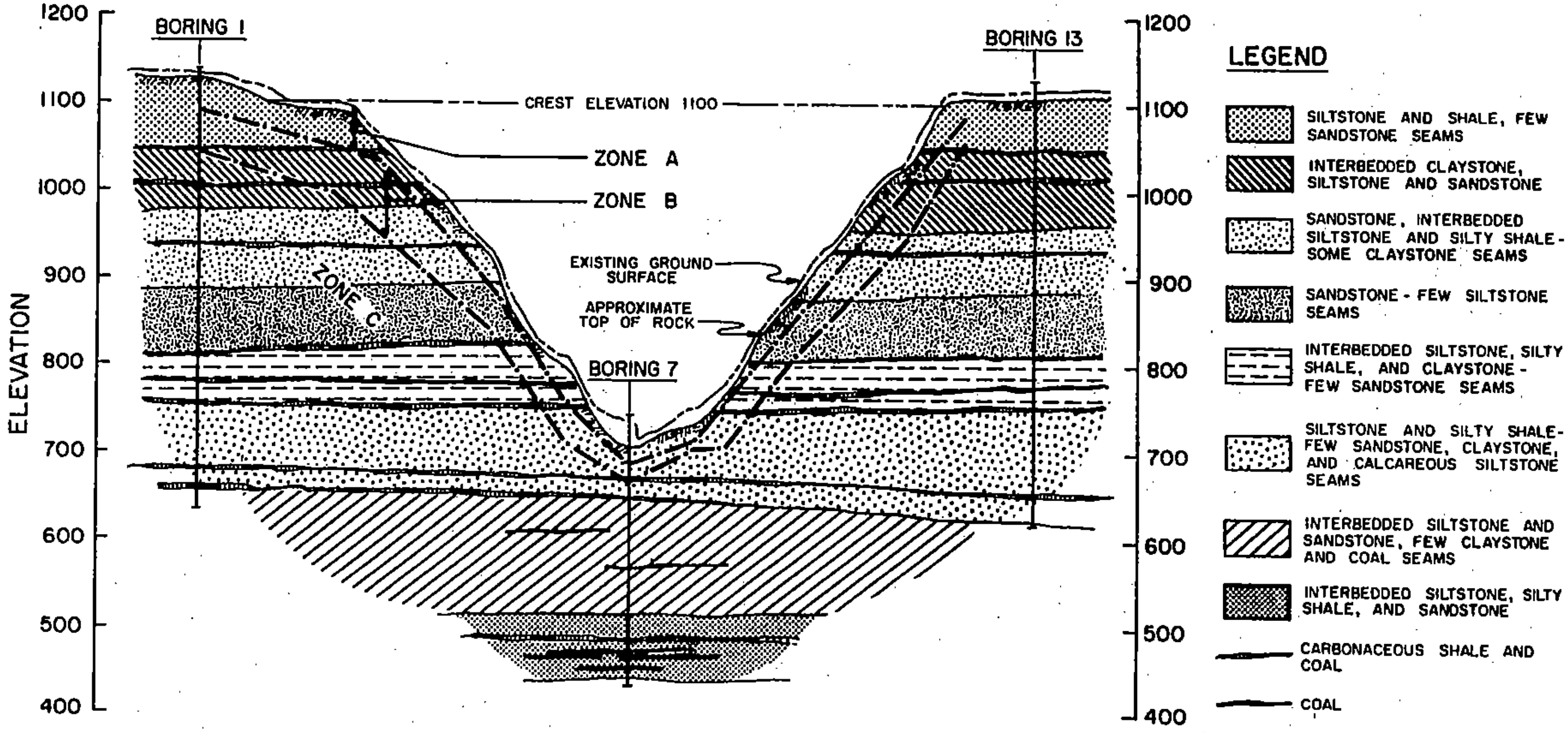
Zone B: 40- to 50-foot thick zone starting at the base of Zone A; 10^{-4} to 10^{-5} centimeters per second permeability.

Zone C: Lower zone starting at the base of Zone B; permeability less than 10^{-5} centimeters per second.

(Frequency of jointing determined from the inclined borings correlates well with these zones.) These permeabilities were considered in the analyses described below.

Settlement, Sliding, and Seepage Analyses

Settlement analyses indicated that foundation



SECTION A - A

GENERALIZED ZONES OF PERMEABILITY

ZONE A = 1×10^{-3} CENTIMETERS/SECOND
ZONE B = 1×10^{-4} CENTIMETERS/SECOND
ZONE C = 1×10^{-5} CENTIMETERS/SECOND OR LESS

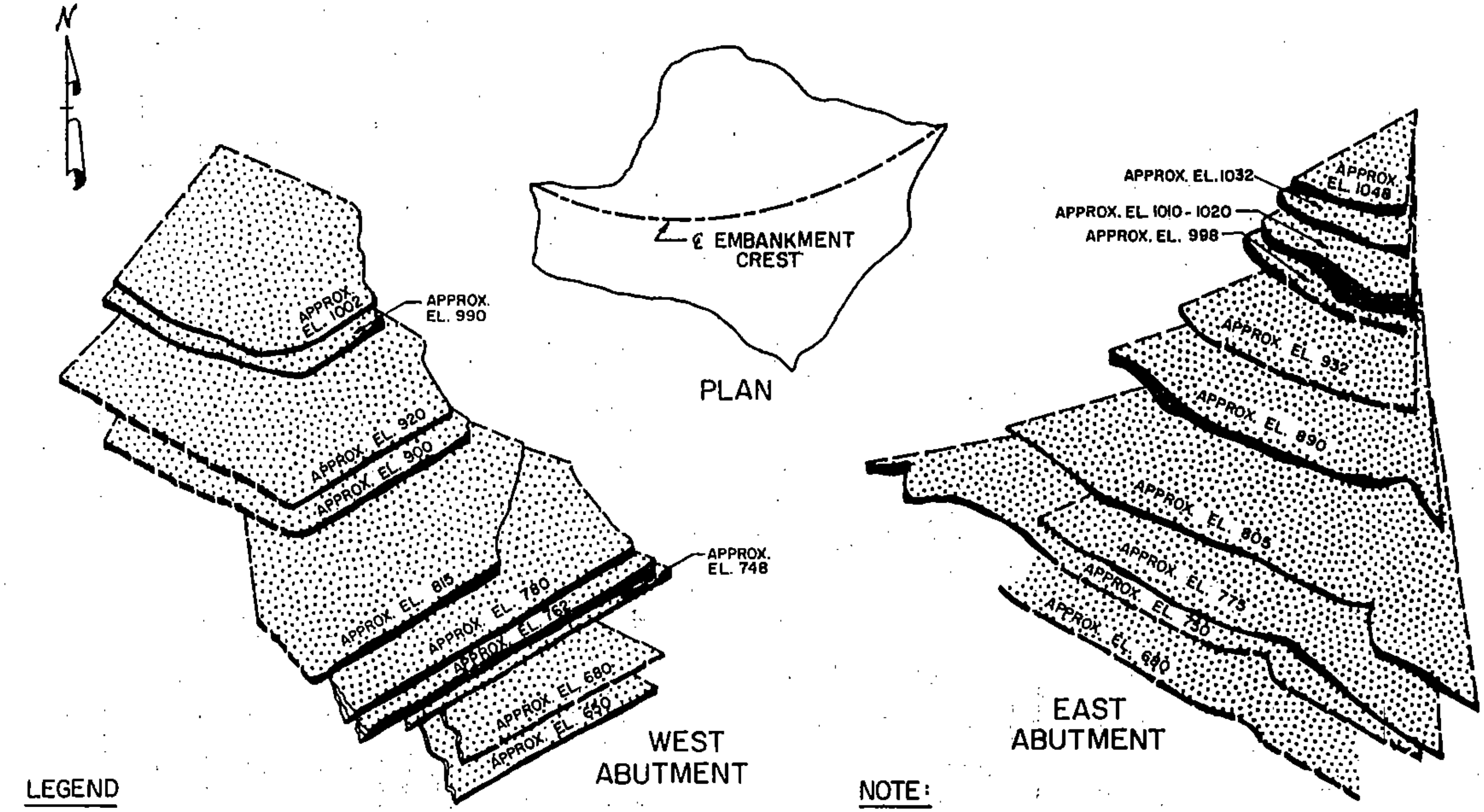
NOTE:

FOR LOCATION OF SECTION AND BORINGS SEE FIGURE 2

HORIZONTAL SCALE

200' 0 200' 400'

FIGURE 4 - GENERALIZED GEOLOGIC CROSS - SECTION



LEGEND

– – – INFERRED STRATA

▬▬ OUTCROP OF CLAYSTONE SEAMS

NOTE:

THE STRATA AS INDICATED ARE MAPPED FROM CLAYSTONE CORE RECOVERY, INDICATIONS OF SLICKENSIDED SURFACES IN SILTSTONE CORE RECOVERY, AND CLAYSTONE TRACES ASSOCIATED WITH CORE LOSSES.

FIGURE 5 - ISOMETRIC VIEW OF CLAYSTONE LAYERS

settlements would be less than 0.1 percent of the height of the embankment and therefore would be acceptable. Sliding of the embankment was checked on several of the claystone seams shown in Fig. 5. For preliminary analyses, low strength parameters were assumed for these layers ($c = 0$, $\phi = 12$ degrees) (4). On this basis, calculations indicate sliding will not be a problem unless unusually high pore pressures develop. Therefore, 7-inch diameter, 50-foot deep relief wells were installed on 50-foot centers, 100 feet downstream of the core-rock contact below elevation 750 (Fig. 10), to reduce pore pressures, and piezometers were installed at various locations to check on the pore pressures actually developed in the claystone seams. Unless excessive pressures are measured, additional foundation treatment related to the claystone seams is not required.

Seepage analyses involved the following considerations: All seepage from Little Blue Run Reservoir is to be collected and tested for water quality. If the water quality is objectionable, the water collected will be pumped back into the reservoir. To avoid excessive pumping costs the maximum acceptable seepage rate has been set at 1,000 gallons per minute.

For the impervious core at Little Blue Run, field permeability tests (well permeameter method, Ref. 7) gave permeabilities of the order of 10^{-6} centimeters per second. With this permeability seepage through the core will be approximately 35 gallons per minute at final pool level. Because this value is small compared to the acceptable limit, only seepage through the foundation has been considered in subsequent analyses.

Prediction of seepage rates through the foundation at Little Blue Run involves the following complicating factors:

1. Rock permeability depends both on rock integrity (jointing and brokenness) as well as rock porosity. Thus, a flow net based on the assumption of only 3 permeability zones is only approximate.

2. The foundation surface forms a valley with a narrow bottom and moderately steep sides. Thus, a flow net defined by a vertical section along the valley axis will not be representative of conditions encountered at most sections along the centerline of the dam.

Factor 1 could be accounted for by using available computer solutions. However, the available solutions are only two-dimensional, so that factor 2 cannot be accounted for accurately unless a three-dimensional solution is developed. Therefore, it was decided that hand-drawn two-dimensional flow nets would be used to provide an order-of-magnitude estimate of seepage rates, and computer solutions used only if further refinements were required. The effects of factors 1 and 2 above were approximately accounted for as follows:

1. Flows through the individual layers in Zone B were calculated using the permeabilities measured in the packer tests and neglecting the effects of three-dimensional flow.

2. Horizontal flow nets were drawn for several typical seams, each sandwiched between layers of low permeability. Following Twelker (6) revised flows were calculated and used to correct the flows calculated in 1, approximately accounting for the effects of three-dimensional flow.

3. The flow net defined by a vertical section along the valley axis was used with the total flow calculated in 2. to estimate the equivalent uniform permeability for Zone B (3×10^{-4} centimeters per second). This value was used in subsequent calculations.

4. Flow nets were drawn as if permeability were constant, and then modified in zones other than Zone A by increasing the number of head drops in a given zone by the ratio k_1/k_2, k_1 being the permeability of Zone A (10^{-3} centimeters per second) and k_2 being the permeability of the given zone.

Using the procedures outlined above, the seepage rate corresponding to the maximum pool with an untreated foundation was calculated to be 2,000 gallons per minute. Because this rate exceeds the acceptable limit, foundation treatment was necessary. Consideration of various treatment procedures is discussed below.

Consideration of Foundation Treatment Alternatives

The basic purposes of foundation treatment are the following:

1. To insure adequate foundation strength and stiffness.

2. To prevent the development of excessive seepage rates and excessive uplift pressures downstream from the core.

3. To prevent piping of fine-grained material.

4. To insure adequate bond between embankment and foundation.

Adequate bond was made possible by carefully cleaning the foundation surface. Strength and stiffness did not appear to be a problem for most of the foundation; however to insure strength and stiffness beneath the core, blanket grouting was carried out in this critical area.

Assuming blanket grouting to the bottom of Zone A, and a permeability of 10^{-5} centimeters per second for the grouted zone (the upper bound for values reported for grouted rock in the literature, Ref. 1), the estimated rate of seepage for the maximum pool level is 750 gallons per minute. This is less than the acceptable limit, indicating that additional foundation treatment (such as deep curtain grouting) is not absolutely necessary. As added insurance, however, the following procedures were also carried out:

1. Coal seams and large cracks in the bedrock surface below the upstream rock shell (between the core and the upstream toe of the dam) were sealed using clayey soil, slush grout and dental concrete. [The area upstream of the dam will be covered with low permeability sludge ($k = 10^{-6}$ centimeters per second), so that sealing permeable areas between the core and the upstream toe forces seepage from the reservoir to pass through the contained sludge mass, thereby reducing the total seepage which passes beneath the embankment.]

2. A number of the grout holes along the centerline of the core-rock contact zone were drilled to a depth of approximately 80 feet, packer tested to verify the depth of Zone A, and used to place grout in excessively permeable portions of Zone B. These holes were called exploratory grout holes. This procedure essentially guided the choice of the depth of blanket grouting, and to a lesser extent decreased the permeability of Zone B.

In addition to reducing seepage to an acceptable level, the procedures outlined above will tend to prevent the development of excessive uplift pressures downstream of the core. For added insurance a filter blanket is being installed over all portions of the foundation downstream of the core (Fig. 3). This will tend to relieve any uplift pressures developed in this area. Prevention of piping of fine-grained material should be accomplished by the blanket grouting and dental work.

Implementation of Foundation Treatment Procedures

Using dozers and scrapers, the bulk of the soil was removed from beneath all portions of the dam. The core-rock contact area required additional cleaning in the following two stages:

Before grouting, hand cleaning with picks and shovels was used to remove enough of the rock rubble and soil left by the dozers and scrapers to permit subsurface grouting.

After grouting had been completed, a second more careful cleaning of the core trench was performed in small increments. The second cleaning involved primarily additional hand-cleaning (Fig. 6) and the use of light machinery and air or water jets (Fig. 7), depending on rock type-air for shale, water for sandstone. Each increment extended no more than five to seven feet above the adjacent fill surface. Each interval of core trench surface treatment was followed by a corresponding interval of fill placement.

In cleaning a particular interval of core trench, a group of workers, commonly three or four but sometimes as many as a dozen, removed any soil and loose rock left after the first cleaning using picks and shovels. A front-end loader often worked in conjunction with the workers, scraping the rock surface with a "back-dragging" motion of its bucket. The loader was particularly effective in preparing shale slopes but was less effective in sandstone, owing to its harder and more irregular surface. Scraping shale with the front-end loader resulted in a rather smooth surface that required only a minimal amount of sweeping with a straight broom to render it acceptable for placement of clay. Preparation of sandstone was generally more involved than that of shale and varied markedly with the character of the sandstone itself. The sandstone ranged from thin bedded to massive, and jointing varied from hairline cracks to openings twelve or more inches wide. In the lower half of the valley walls, the degree of jointing tended to diminish with distance from the valley centerline. For example, sandstone some distance removed from the centerline could often be prepared merely by hosing with water, while elsewhere extensive hand cleaning was often required. A loader, and less frequently a dozer was employed to remove large, loose blocks, while workers with picks and shovels removed the smaller ones. Presplit blasting techniques were used in one 40-foot interval of

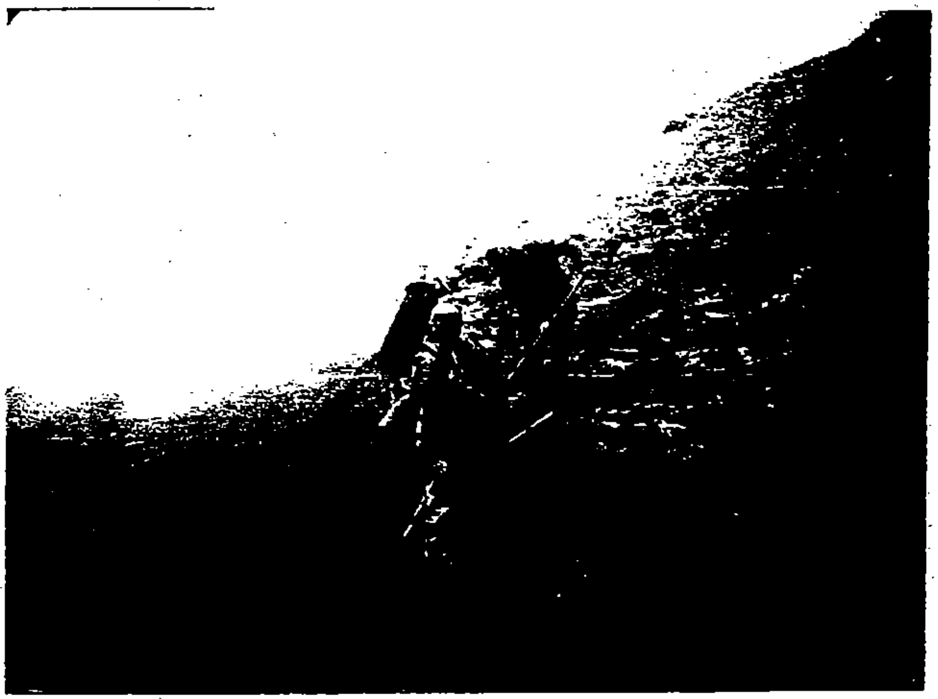


FIGURE 6 - CLEANING CORE AREA WITH BROOMS

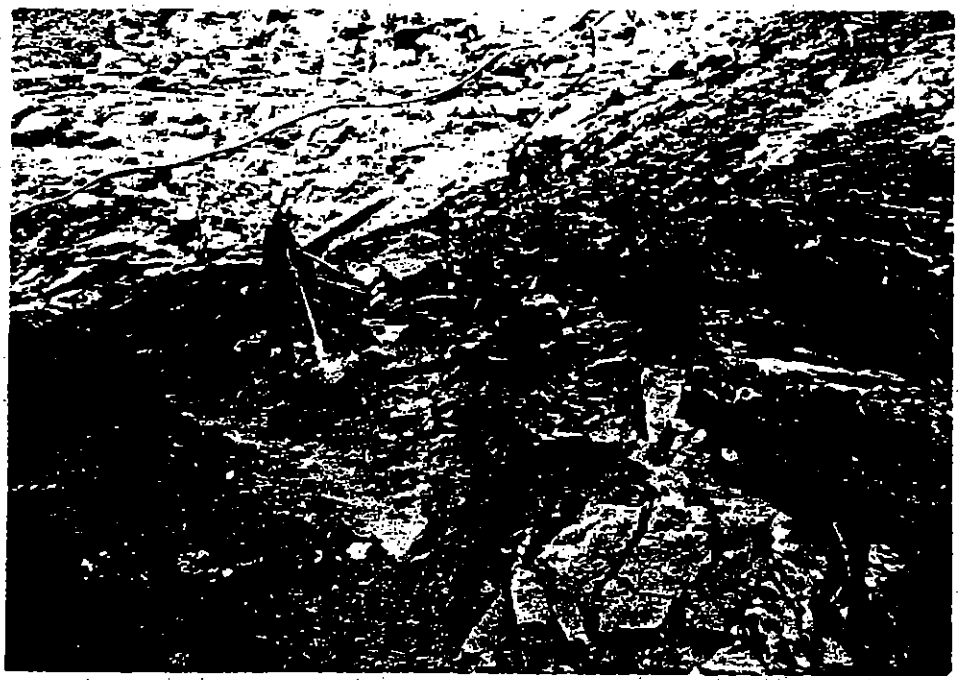


FIGURE 7 - HOSING JOINTS IN CORE AREA

sandstone, reducing the quantities of machine and hand labor required to prepare the rock surface.

Once a sandstone surface was essentially free of loose rock, the rock was hosed off with water, thereby removing any remaining soil and chips of rock (Fig. 7). At the same time, joints were cleaned out to a depth on the order of three times their width. Joints open several inches were cleaned out with picks and shovels and then flushed out with water (Fig. 7). Joint-filling invariably consisted of silt, many times along with broken rock. Joints too narrow to clean with tools were merely flushed out with water.

Water was not used to clean shale or shaley siltstone owing to the rather high tendency for these rocks to break down when wetted. In a few instances, final cleaning of rock surfaces was successfully accomplished by use of a blowpipe operated from an air compressor.

The rock in the valley bottom was primarily weatherable shale and siltstone. To protect this material from weather and vehicular traffic in the core area, an 8-inch (minimum) thick concrete grout cap was placed on the freshly exposed rock from station 9+00 to 13+00 (Figs. 8 and 9). The grout cap was placed before grouting began and served as a platform for subsequent drilling and grouting in the valley bottom. Foundation treatment outside the valley bottom is described below.

"Dental concrete," a four-sack, sand-cement mixture supplied by a local redi-mix distributor and brought to the site in mixer trucks, (Fig. 10), was used to fill large open joints, to seal jointed rock and erodible seams (coal and underclay) (Fig. 10), and to fill overhangs in which compaction of fill would be difficult. (Filling of overhangs was resorted to only when the overhang could not be eliminated by trimming.) The mixture was transported from the mixer truck to the rock face in the truck chute (Fig. 10) or a shallow pan suspended from a mobile crane. Laborers spread the material on the rock surface, smoothing it with the backs of their shovels. Where a rock surface was highly jointed, slush grout, formed by diluting the dental mixture to the consistency of milkshake, was poured over the surface from the carrying pan (Fig. 11). Laborers spread the slush grout with shovels and brooms, developing a coating nominally one-eighth to one-quarter inch thick.

As soon as possible after the second cleaning and the placement of any required dental concrete or slush grout, a layer of highly plastic contact clay was placed against the prepared foundation and compacted with heavy, rubber-tired construction equipment. Prompt placement of clay served to protect the exposed rock,

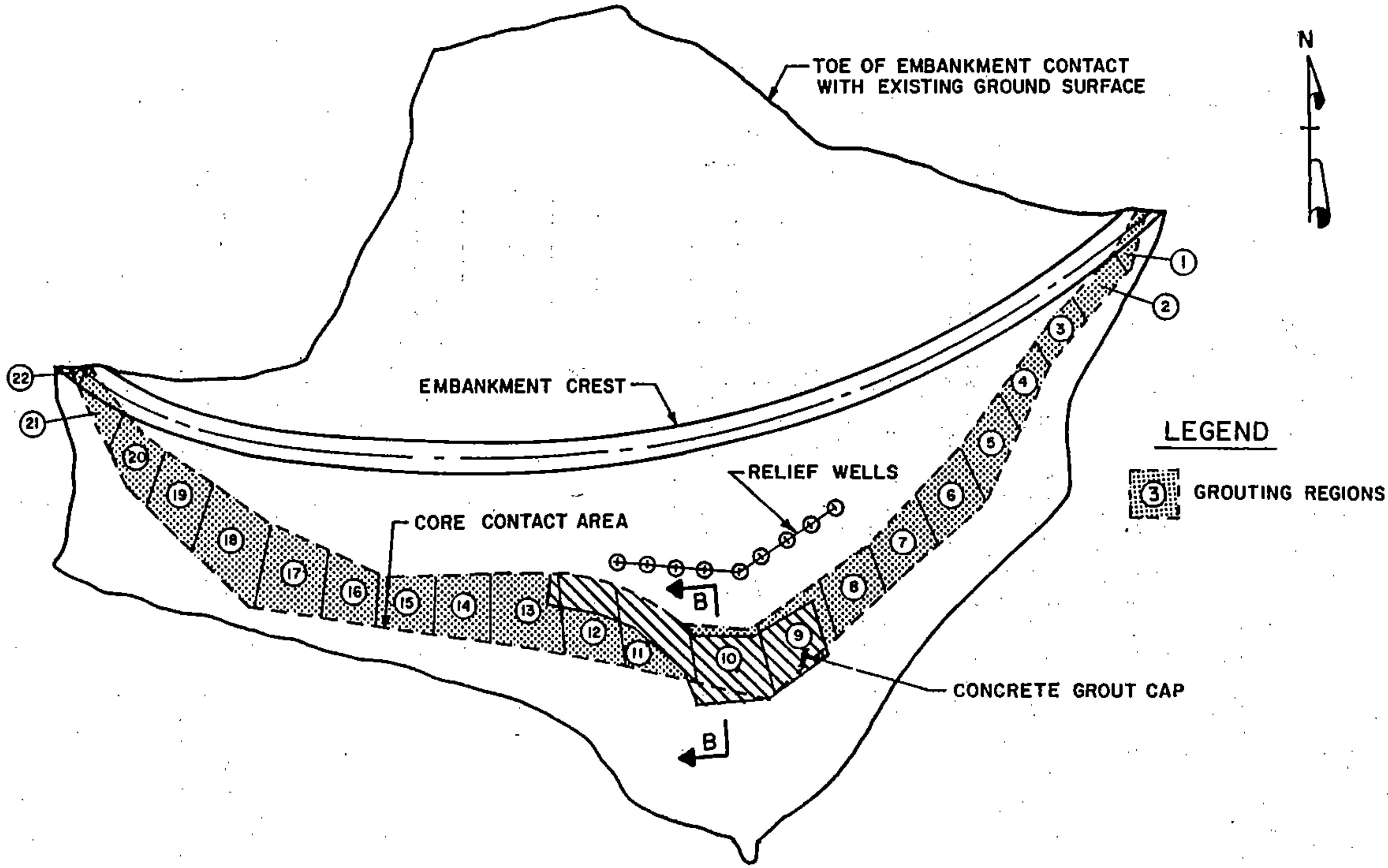


FIGURE 8 - CORE CONTACT AREA, GROUT CAP, RELIEF WELLS AND GROUTING REGIONS

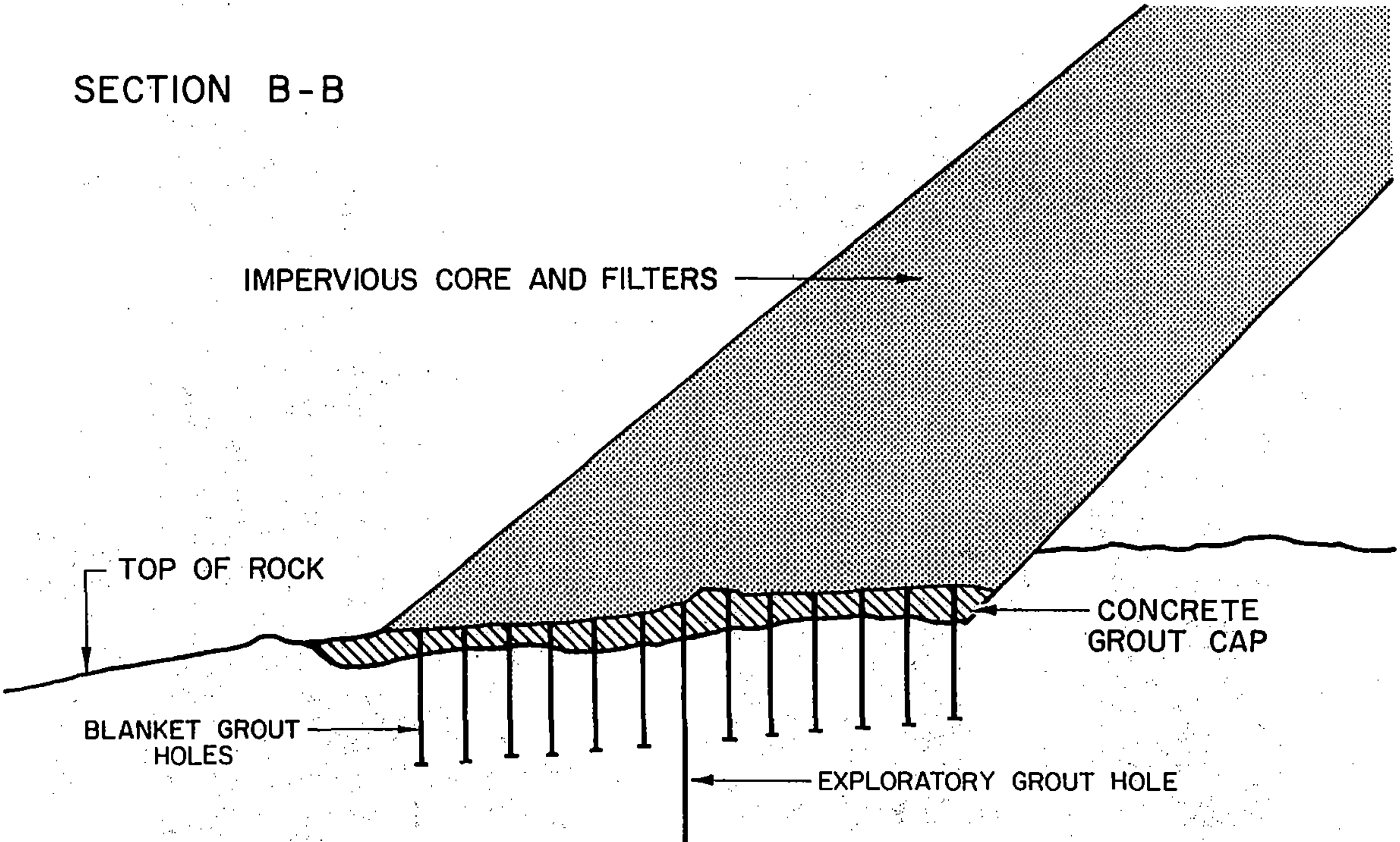


FIGURE 9 - SECTION VIEW OF GROUTING

FIGURE 10 - SEALING COAL SEAM WITH DENTAL CONCRETE

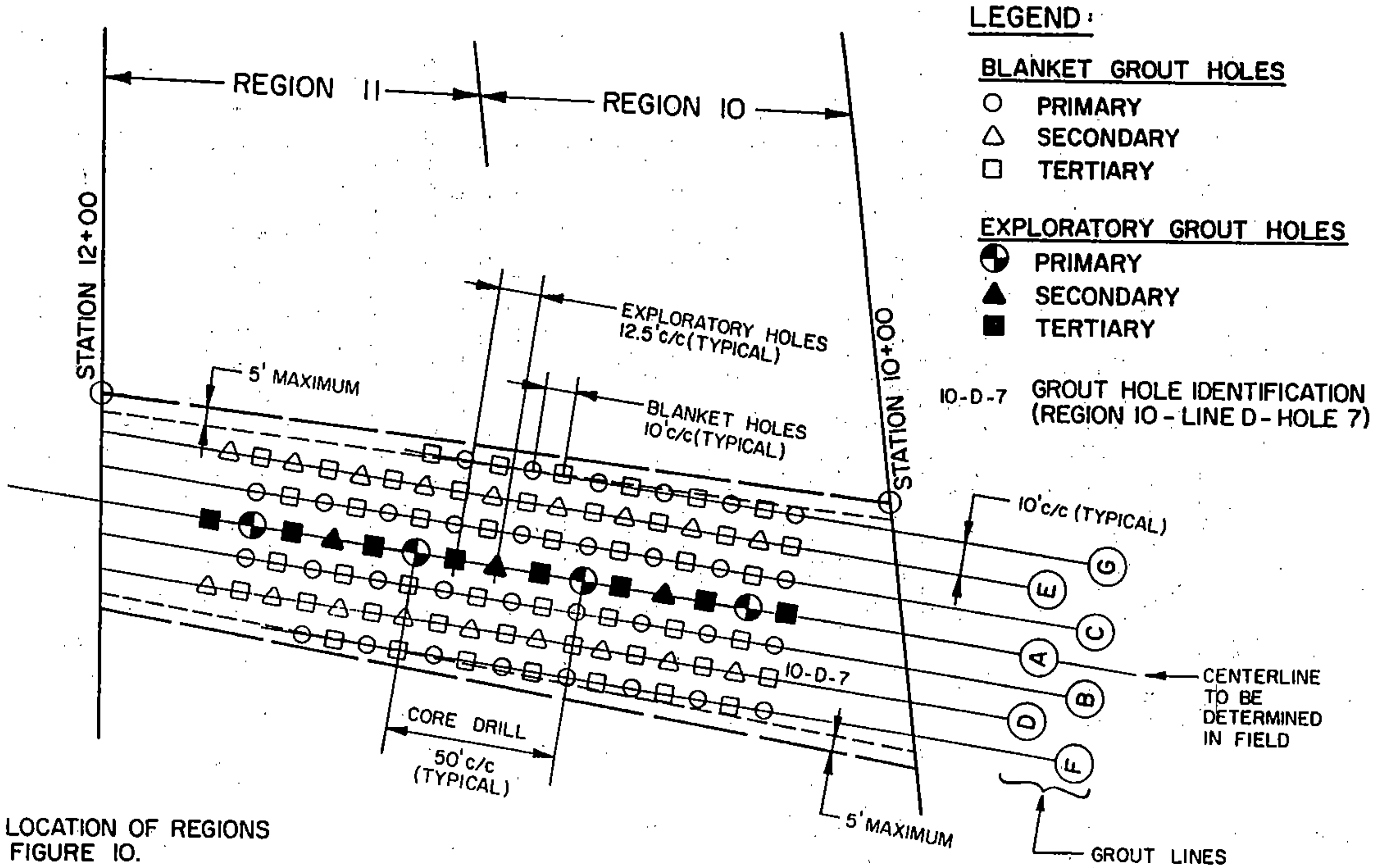
FIGURE 11 - SEALING JOINTS WITH SLUSH GROUT

eliminating unnecessary recleaning. Compaction with rubber-tired equipment kneaded the plastic clay into any remaining surface irregularities.

During construction a number of country bank coal mines were discovered in the abutments. Most of these extended only 25 to 30 feet into the valley walls. Mines downstream of the core were filled with filter material to insure good drainage. Small mines upstream of the core were backfilled with concrete and in some cases pressure grouted. The largest mine, located in the right abutment, extended 110 feet into the hillside in the core area. The mine was entered and surveyed visually. Several seven-inch-diameter vertical holes were then drilled from the ground surface into the roof of the mine, the entrances were sealed, and the mine was backfilled by injecting a mixture of fly ash, cement and water through the holes. After backfilling, the entire area was pressure grouted and packer tested. The packer tests indicate that the mine was successfully backfilled and that rock permeability has been reduced to acceptable levels.

Blanket grouting beneath the core (Figs. 10 and 11) followed the pattern shown in Fig. 12. The primary exploratory holes in a given area were drilled first (50-foot centers along the centerline of the core-contact area), and packer tested to check on the local depth of Zone A, ($k > 10^{-4}$ centimeters/second), the zone to be blanket grouted. (In general, the depth of Zone A was 20 to 40 feet.) Because of the critical nature of the core zone, pressures were limited to a maximum of 0.75 pounds per square inch per foot of depth, and survey points were initially monitored to detect any tendency for foundation uplift. The exploratory holes were extended to a depth of approximately 80 feet to be certain no important permeable zones were missed. Pressure grouting was then carried out below Zone A in each exploratory hole. (Zone A was left ungrouted in these holes until after additional testing as described below.) (Pressures were limited as noted above for packer testing.) When the grout take in a given hole exceeded 0.15 bags per lineal foot of grouted hole, the adjacent secondary exploratory holes were also drilled, tested, and grouted (grouting in Zone B only). However, grout takes in the lower portions of the primary exploratory holes were generally less than 0.15 bags per foot, so that few secondary and tertiary exploratory holes were drilled.

After the lower portion of a given exploratory hole had been grouted, the surrounding primary blanket holes were drilled (to the bottom of Zone A) and grouted. If the grout take in a given hole exceeded 0.15 bags per lineal foot of grouted hole, the surrounding



NOTE:

FOR LOCATION OF REGIONS
SEE FIGURE 10.

FIGURE 12 - TYPICAL GROUT HOLE PATTERN

secondary holes were also drilled and grouted, etc. Once acceptable takes were observed around a given exploratory hole, the hole was packer tested again. (In some cases grout from other holes had entered the exploratory hole and it was necessary to redrill the hole using a slightly larger bit.) The packer tests confirmed the adequacy of the blanket grouting as described subsequently. After a hole had been retested, the upper portion of the hole was pressure grouted as a final step.

Evaluation of Grouting

As outlined above, after completion of grouting around a given exploratory hole, the hole was retested to evaluate the adequacy of the blanket grouting. The results of packer tests carried out before and after grouting are presented in Figs. 13-15. In general, permeabilities of the order of 10^{-3} to 10^{-4} centimeters per second were reduced to 10^{-5} to 10^{-6} centimeters per second. For a more detailed evaluation, a line corresponding to $k = 10^{-5}$ centimeters per second has been drawn on each plot, defining zones of $k < 10^{-5}$ centimeters per second and $k > 10^{-5}$ centimeters per second. (A permeability of 10^{-5} centimeters per second was determined to be suitable for the grouted zones.) The total depth of rock having $k < 10^{-5}$ centimeters per second exceeds the total depth having $k > 10^{-5}$ centimeters per second. Thus, the permeability assumption for grouted rock used in the seepage analyses ($k = 10^{-5}$ centimeters per second) is conservative, and the grouting program has accomplished its intended goal. A more critical assessment of the grouting program in conjunction with the other foundation treatment procedures will be made as the reservoir is filled and final seepage rates and pore pressure levels are measured.

Summary and Conclusions

To provide a reservoir for containment and solidification of sludge collected by a wet scrubber system, a 420-foot high, sloping-core, rock-fill dam is being constructed in southwestern Pennsylvania. A comprehensive subsurface investigation involving 121 borings, 35 test pits and a large number of bore-hole (packer) permeability tests was carried out to determine the soil and rock characteristics involved. Due to the extent of jointing and rock breakage, permeability decreased with depth below the top of rock as well as with rock type. Settlement and sliding analyses indicated that the foundation would be acceptable, provided unusual pore pressures did not develop. Therefore, piezometers and relief wells were installed. To insure strength and stiffness beneath the core,

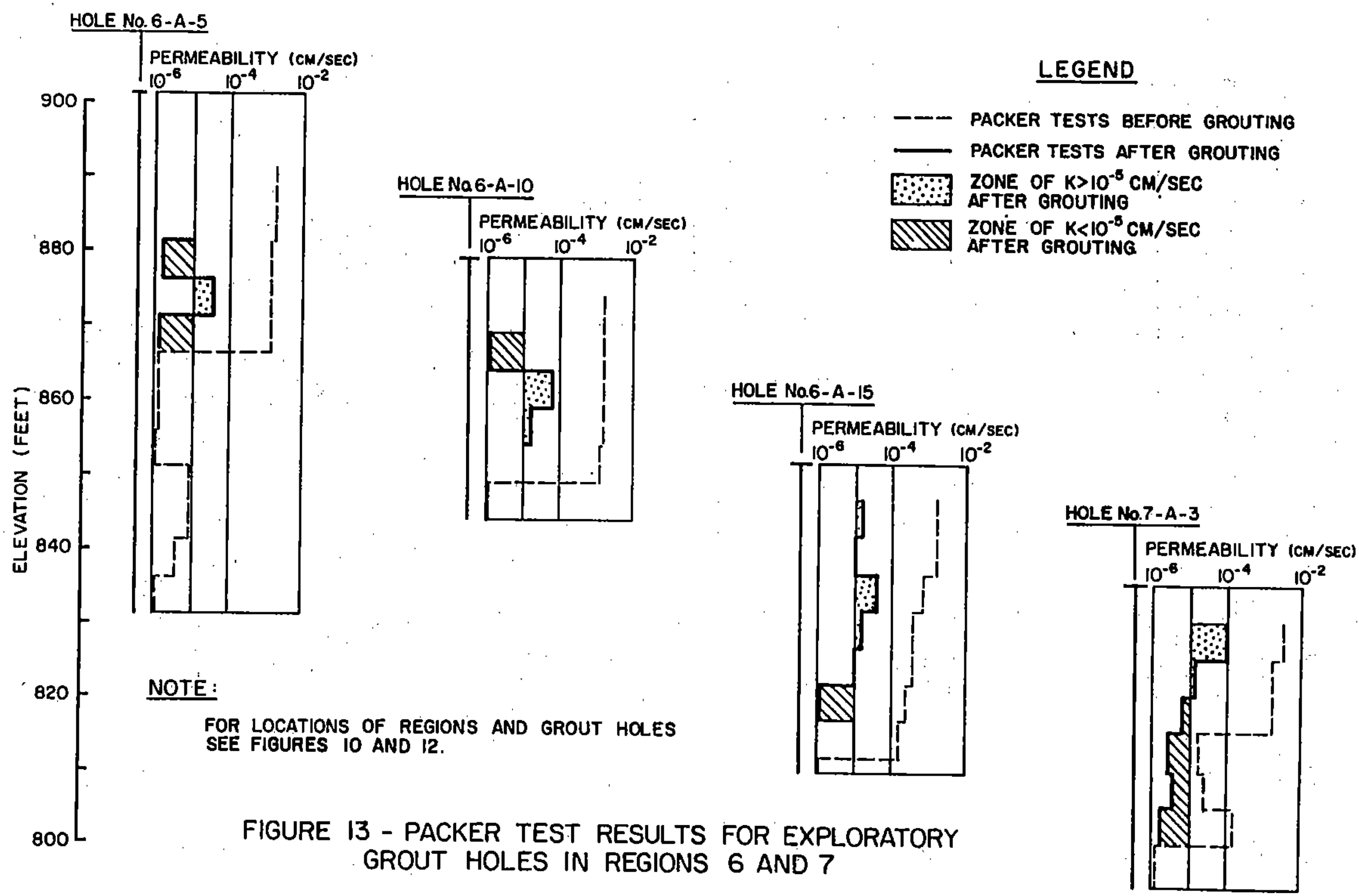


FIGURE 13 - PACKER TEST RESULTS FOR EXPLORATORY GROUT HOLES IN REGIONS 6 AND 7

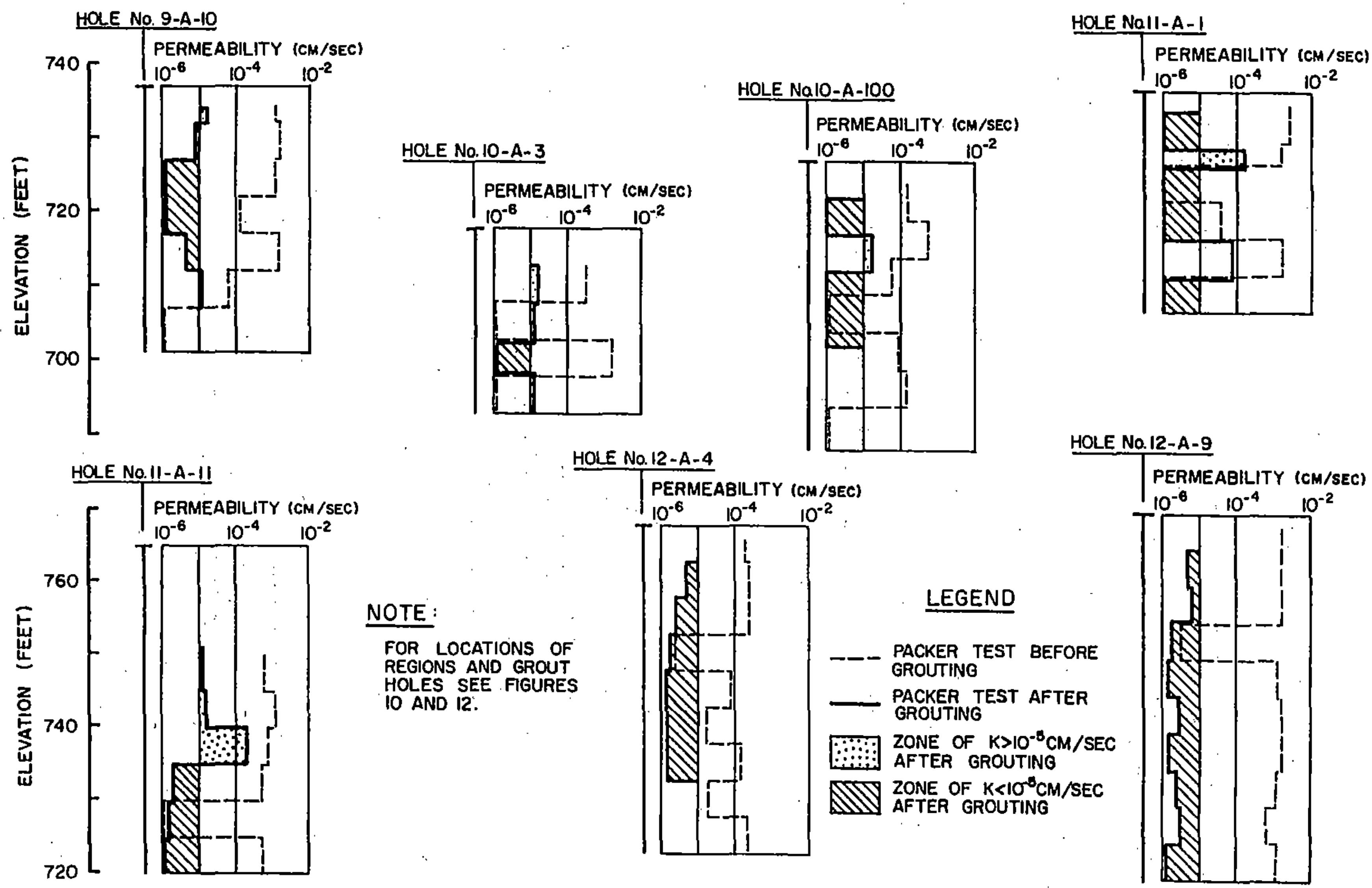


FIGURE 14 - PACKER TEST RESULTS FOR EXPLORATORY GROUT HOLES IN REGIONS 9 THRU 12

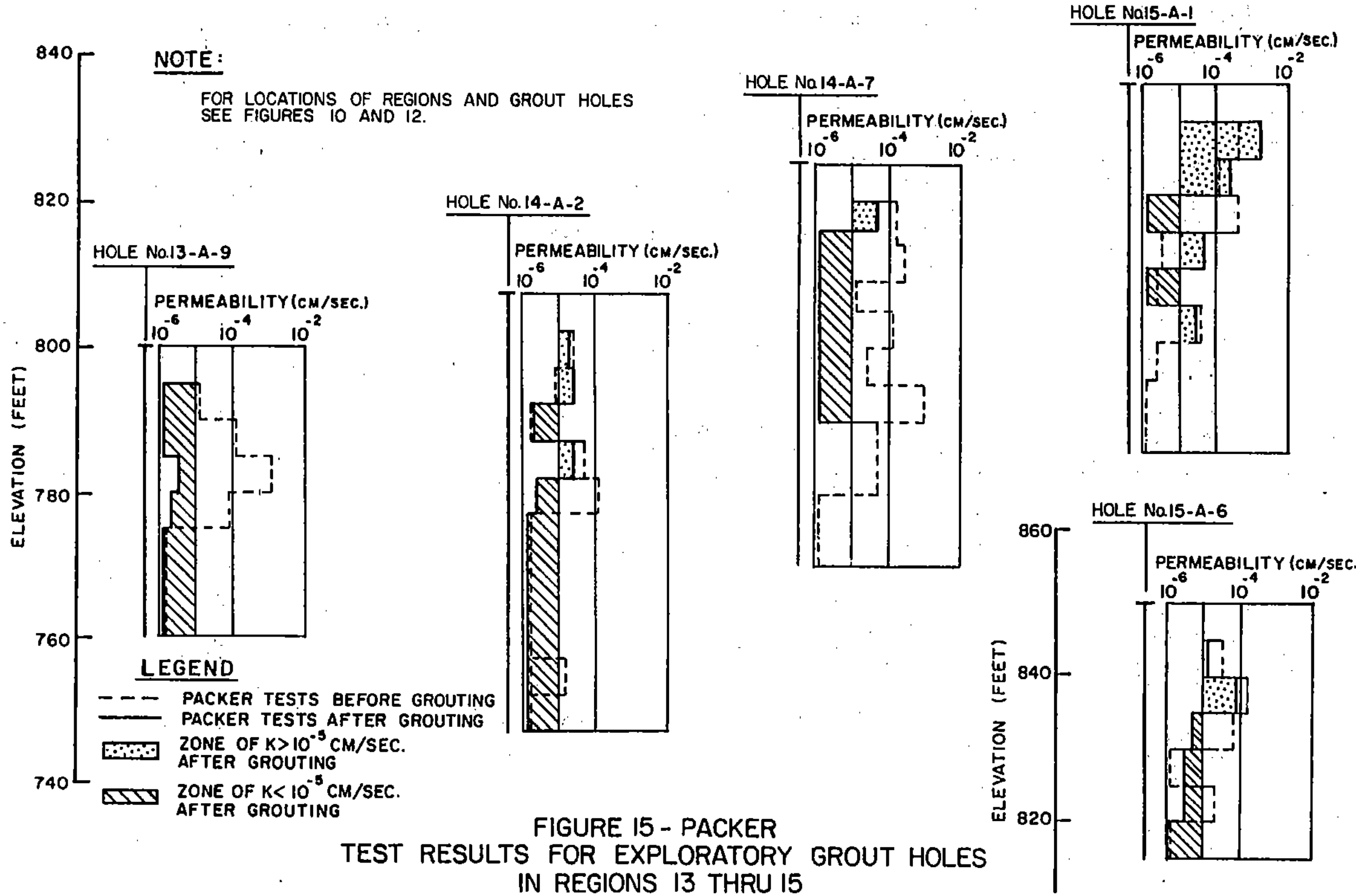


FIGURE 15 - PACKER TEST RESULTS FOR EXPLORATORY GROUT HOLES IN REGIONS 13 THRU 15

blanket grouting was conducted in this critical zone. Special seepage analyses were carried out accounting for variations in rock permeability and the three dimensional nature of the flow. The analyses indicated that the blanket grouting would reduce seepage to an acceptable level.

Soil was removed from beneath all portions of the dam, and the bedrock surfaces below the core and below the upstream rock shell were subjected to additional cleaning and sealing. A number of country bank coal mines in the abutments were also sealed. Additional exploratory holes were drilled and packer tested as part of the grouting program. The results of these tests and observation of grout takes guided the final selection of grouting depths and hole spacings. A preliminary evaluation of the grouting program was developed using packer tests carried out after completion of the work in a given area. In general, permeabilities exceeding 10^{-4} centimeters per second were reduced below 10^{-5} centimeters per second, the value assumed in the analysis of grouted zones. Thus, the foundation treatment implemented appears to be adequate. Pore pressures and seepage rates will be monitored during and after construction, as a further check on the adequacy of the foundation treatment.

Acknowledgements

Little Blue Run Dam is part of the Scrubber Sludge Disposal System for the Bruce Mansfield Power Station. The overall system was designed by Gibbs and Hill, Inc., and will be owned and operated by the Pennsylvania Power Company for the CAPCO group. Mr. Thomas M. Leps served as a consultant on the design of the dam.

APPENDIX I - REFERENCES

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6. Twelker, N. H., "Analysis of Seepage in Pervious Abutments of Dams," Proceedings, Fourth International Conference on Soil Mechanics and Foundation Engineering, Vol. 2, 1957, pp. 389-393.

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Day One
Friday, May 19, 1995

ENERGY AND MINERALS

Trip Leaders:
Raymond Follador, Angerman Associates, Inc.
Viktoras W. Skema, Pennsylvania Geological Survey
Karen Rose Cercone, Indiana University of Pennsylvania

Meeting Point: Monroeville Mall Park and Ride lot (In front of Lazarus Dept. Store).
Meeting Time: 8:00 AM to 8:30 AM. **DISEMBARK at 8:30 AM PROMPTLY.**

Mileage		
Interval	**Cumulative**	**Field Trip Itinerary**
0.0	0.0	Monroeville Park and Ride Bus Shelter, Monroeville Mall, Monroeville, PA.
1.0	1.0	Turn right onto Mall Boulevard and continue to Business Route 22 east. Continue east towards Murrysville.
4.5	5.5	Enter municipality of Murrysville at traffic light (near McDonalds). The approximate axis of the Murrysville anticline is located here. Historical Marker for Murrysville Gas Well on right of highway.
3.7	9.2	Approximate axis of Irwin syncline located at the intersection of Route 22 and Harrison City Road.
4.1	13.3	CNG Transmission Co. Oakford Gas Storage Facility on left side of highway. The approximate axis of the Grapeville anticline is located here.
5.9	19.2	Current road construction on Route 22 has included the stripping of coal.
10.9	30.1	Exit Route 22 at Blairsville (Torrance Hospital exit) and follow Route 217 south through the town of Blairsville and across the Conemaugh River. At this point we are traveling along the east flank of the Fayette anticline from which Chestnut Ridge anticline can be viewed from a distance on the left side of the highway.

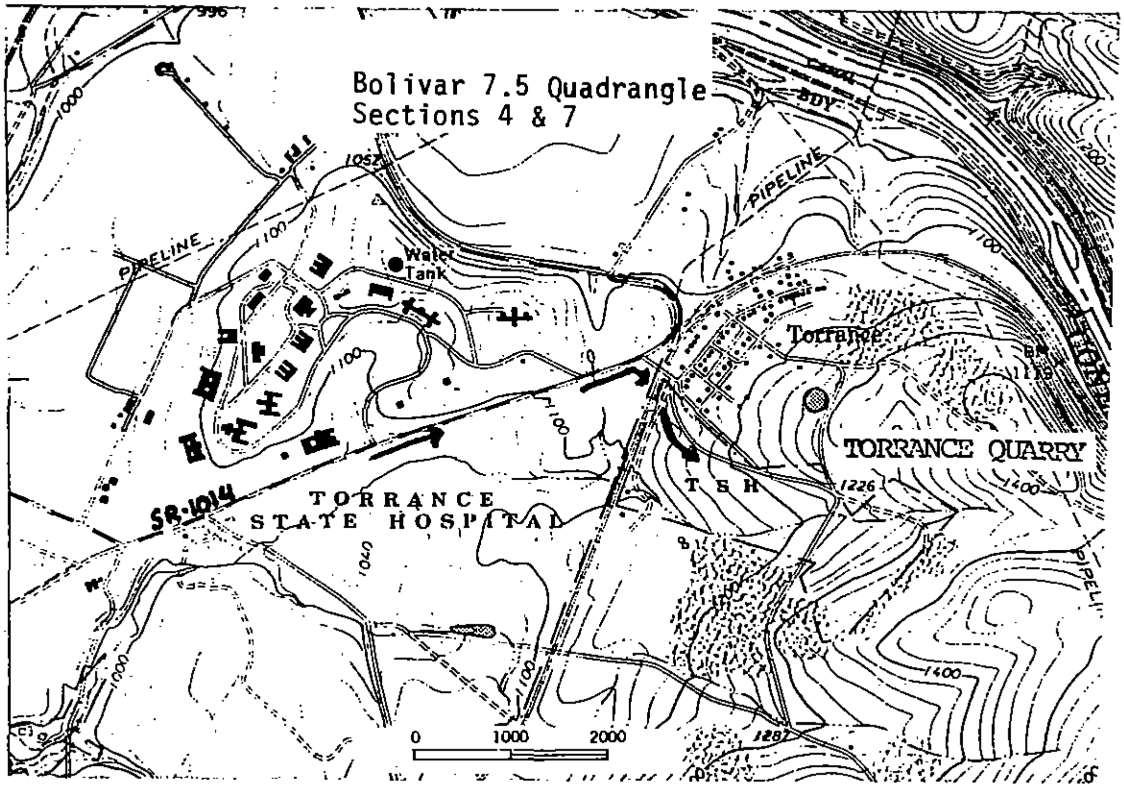


FIGURE 1-1

1.8	31.9	Left turn off Route 217 onto SR 1014 at sign for Torrance State Hospital. Pass hospital on left and bear right over railroad tracks (Figure 1-1).
2.2	34.1	Bear right immediately after railroad tracks onto quarry access road. Pass trailers on left side of the road.
1.0	35.1	Entrance of the Torrance Quarry owned and operated by the Davison Sand and Gravel Company.

STOP 1
Loyalhanna Limestone Exposure
Torrance Quarry
Davison Sand and Gravel Company

The Torrance Quarry mines the Loyalhanna for railroad ballast. The Torrance mine is one of the older Loyalhanna mines and produced 1,036,629 tons and sold 959,229 tons in 1993-1994. The mine employs approximately 30 people. The following discussion is quoted from Miller (1934).

Loyalhanna (Siliceous) Limestone

"The oldest limestone in Westmoreland County is the Loyalhanna, which has such a large siliceous content that it might more properly be termed a calcareous sandstone than a limestone. It has, however, been grouped with the limestones and is therefore described here. It consists os grains of silica cemented by calcium carbonate. It lies between the Mauch Chunk and Pocono series and is underlain by a big thickness of non-calcareous sandstone. At one time this bed was placed in the Mauch Chunk series. It is exposed only in Chestnut Ridge and Laurel Hill, both of which hills are pronounced upward folds anticlines). Were it not for these sharp folds it would not appear at the surface. The best exposures are in the gorges produced by Conemaugh River and Loyalhanna Creek cutting through Chestnut Ridge and Laurel Hill.

This limestone has in the past been burned for lime in several places. The calcareous portion produced a white lime which slaked readily while grains of quartz remained unchanged. The burned product containing the lime and sand made a fair mortar. In recent years the sole use made of this stone has been for railroad ballast, paving blocks and for highway construction.

One of the most characteristic features of the Loyalhanna is, the prominent cross bedding, which is especially pronounced on weathered surfaces. On weathering, the calcareous cement is removed by solution and the resulting mass is practically pure quartz sand. Where fresh, the rock breaks with a conchoidal fracture and is light blue to gray in color. In places it contains some pyrite which readily oxidizes near the surface and produces a rusty brown discoloration. The rock occurs is massive beds and, when blasted, comes out in large blocks, which, however, can readily be split because of its brittle character. In thickness it varies from 40 to almost 80 feet in Westmoreland County. Where Conemaugh River cuts through Laurel Ridge in the extreme northeast corner of the county, the Loyalhanna is about 50 feet thick. It is somewhat thicker in places where the same stream cuts through Chestnut Ridge. Here it has been worked on the Indiana County side...and on the Westmoreland County side by Booth and Flinn near Blairsville Intersection (Torrance Post Office). This is known as the Packsaddle quarry...The Torrance plant has an annual capacity of about 40,000 tons of crushed stone [Note production figures above, and 60 years later].

Loyalhanna Creek, cutting through Chestnut Ridge and into the west slope of Laurel Hill, has exposed the Loyalhanna limestone and made conditions favorable for quarrying, especially in the gap through Chestnut Ridge. For a number of years, Booth and Flinn have operated an extensive quarry along Loyalhanna Creek at Long Bridge, about I mile southwest of McCance Post Office. The calcareous portion worked is 50 to 55 feet thick and the quarry face is about half a mile long. Most of the stone is crushed for railroad ballast and for highway construction but some is made into paving blocks. The States Highway Department has accepted the finer stone for the State highways.

The base of the Loyalhanna lies about 200 feet above the creek bed. The strata are almost flat but actually form a low anticline with gentle dips toward the ends of the cut. The stone is bluish gray in color, greatly crossbedded and so massive that true bedding planes are not readily observed in the quarry face. Vertical joints break across the beds and a few solution cavities were seen. Fossils were not observed, but quarrymen report that they are occasionally noted.

Immediately overlying the Loyalhanna limestone is a non-calcareous sandstone about 18 feet thick and still higher up is red shale with some greenish bands and sandstones and limestones of the Mauch Chunk group. The material stripped as overburden averages about 30 feet is thickness.

At times most of the material is sold for railroad ballast but at other times it may be used for the highways or for Belgian blocks. The railroad ballast is from 1 and 1½ to 3 inches in size. The Belgian block for paving are of two sizes. The small ones are 8 to 14 inches long, 4 to 5 inches wide and 5 to 5½ inches thick. The larger ones are 8 to 16 inches long, 3½ to 5 inches wide, and 6 to 7 inches thick. All of the chips from dressing the stone and the fine sizes screened from the railroad ballast material are used on the roads. The stone is hauled from quarry face to the crusher by truck.

Analysis of composite sample of Loyalhanna limestone, Long Bridge
Pittsburgh Testing Laboratory, analyst after drying at 105° C

SiO	49.54
AL_2O_3	3.44
Fe_2O_3	1.72
TiO_2	0.30
CaO	24.80
MgO	0.58
Loss on ignition	19.30
SO_3	trace

South of Loyalhanna Creek, there are several places where the same limestone has been worked in both Chestnut Ridge and Laurel Hill. In most places the quarries were small and furnished only a small amount of stone for burning. These have long since been abandoned...An almost unlimited amount of Loyalhanna limestone is available in Westmoreland County but the operations must necessarily be confined to those localities where transportation facilities are favorable."

Road Log Continues from Stop 1.

1.0	36.1	Return to SR 1014. Turn left.
2.2	38.3	Return to Route 217 north. Turn right.
2.0	40.3	Return to Route 22 west (note that to reach ramp you must

make a left turn in Blairsville).

17.4	57.7	Follow Route 22 west to intersection with Route 66 south (pass Oakford Storage on right side of highway). This is the new section of Route 66 which is a toll road. Stop at Uni-Mart on right (next to Kings Restaurant) (FIGURE 1-2).

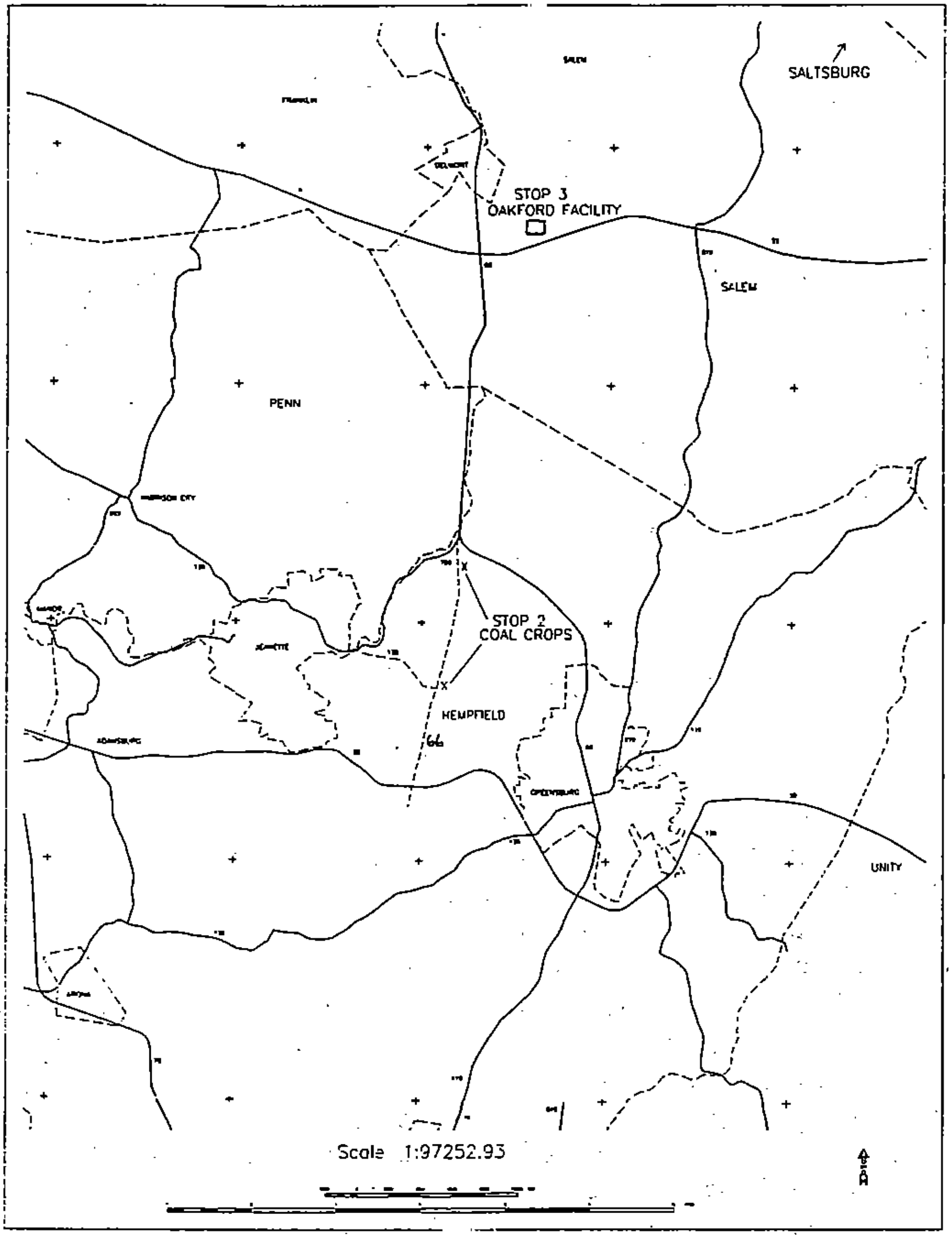


FIGURE 1-2

3.1	60.8	Pass slope with exposed coal/limestone on left side of road.
1.0	61.8	Exit Route 66 at Route 130 (Harrison City). Turn left at light and immediately re-enter toll booth–access road to reach exposed rock slope on right side of Route 66 north, Stop 2.

STOP 2
NEW EXPOSURES OF CONEMAUGH COALS, MARINE ZONES AND PALEOSOLS ALONG NEW TOLL ROAD 66 NEAR GREENSBURG.

Viktoras W. Skema
Pennsylvania Geological Survey

Cuts along the recently constructed toll road of the Pennsylvania Turnpike Commission, new Route 66, west of Greensburg, expose many large vertical sections through the Glenshaw Formation and provide new insight into the character of the marine portion of the Pennsylvanian Conemaugh Group (Figure 1-3). Two of these cuts are particularly outstanding. The first is a continuous compound section at Route 130 exposing rocks from below the Brush Creek coal up through the Duquesne coal horizon and into a portion of the overlying Birmingham shale. This section includes all of the major Conemaugh marine zones, a few of the lesser known ones, and an unusually thick occurrence of the Upper Bakerstown coal. The second interesting exposure is located at the beginning of the northbound exit ramp to old Route 66. The excavated slope here cuts perpendicularly through two fluvial channels situated between the Pine Creek Limestone and the Lower Bakerstown coal. Thick channel-bottom coals and other unusual features associated with these channels reveal interesting clues about possible climatic conditions and other aspects of depositional environment.

STOP 2a - Conemaugh Cut; Brush Creek through Skelly Limestone.

Section at Route 130 exit

The large road cut along the northbound lanes of the highway at the beginning of the Route 130 exit ramp combined with the contiguous cut of the descending ramp comprises 226 feet of continuous section. Above the main roadway, starting from the top, the cut contains the brackish to fresh water facies of the Skelley marine zone, the Ames Limestone, the Pittsburgh red beds, the brackish facies of the Noble marine zone, the Upper Bakerstown coal, and the top of the Saltsburg sandstone. Continuing down the ramp, the following units are exposed: the massive basal portion of the Saltsburg sandstone, the marine Woods Run Limestone and associated dark shale, and the marine Pine Creek Limestone. Across Route 130, the Brush Creek coal and Brush Creek limestone and associated dark shale are exposed along the northbound entrance ramp.

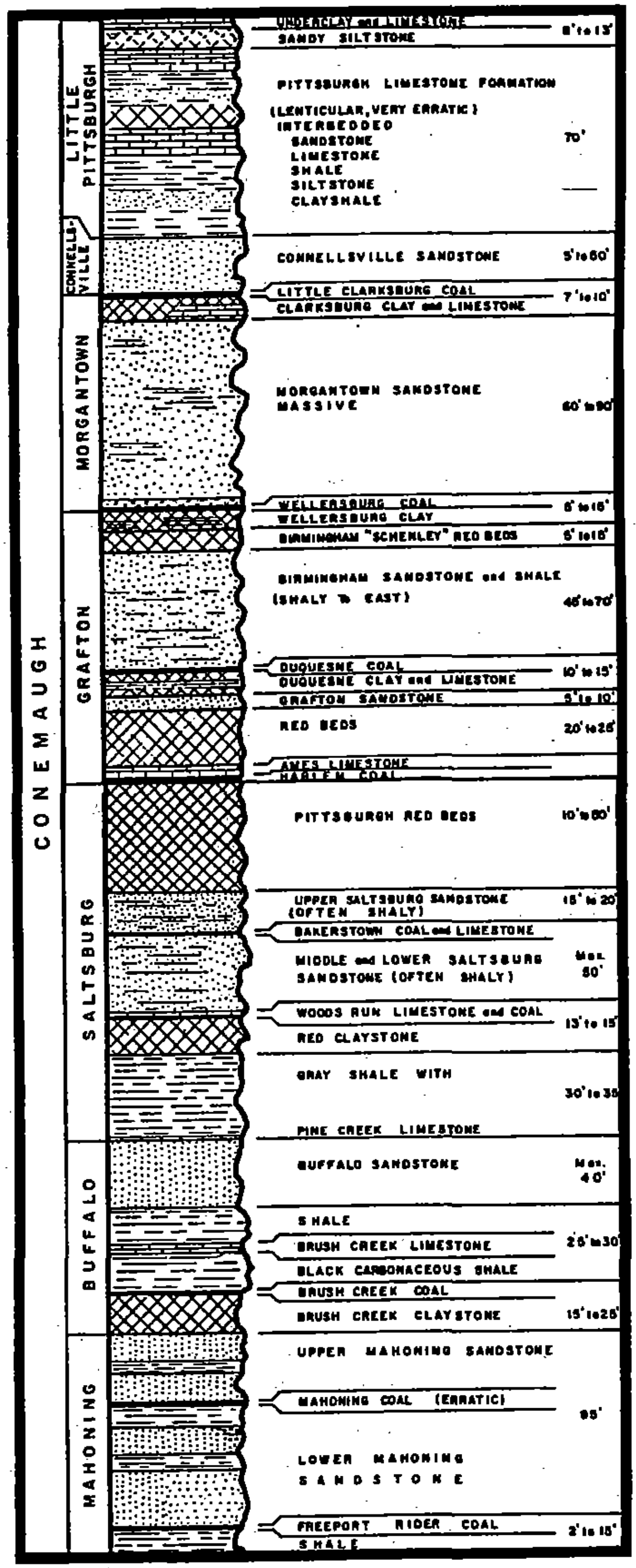


Figure 1-3 Generalized columnar section for the Greater Pittsburg.. Area.

Road Log Continues from Stop 2a

1.0	62.8	Continue north on Route 66 to exposed coal/limestone slope, Stop 2a.

STOP 2b
Brush Creek/Pine Creek channel coal deposit
Section at old Route 66 exit

Highway excavation through the hill south of old Route 66 uncovered two unusually shaped coal deposits. Both can be seen in the cut slope east of the highway 30 to 40 feet up from road level, situated directly above the Buffalo sandstone (Figure 1-4) They are relatively thick and distinctly lenticular shaped. The northernmost deposit is approximately 90 feet wide and, with partings included, measures 4.7 feet at its thickest point. The deposit on the southern end of the cut is about 30 feet wide with a maximum thickness of 2.9 feet. This southernmost coal can be seen also in the cut wall on the opposite side of the highway. The site construction superintendent reported that the thicker northernmost coal curved out into the highway and southward toward the thinner coal and ended abruptly before reaching it. The two coals are vertically offset with the southernmost, through-going coal, situated approximately 10 feet higher.

A close examination of the coals indicates that they were deposited at the bottom of two channels. The erosional surface at the base of the channel system containing the thicker, northernmost coal has the asymmetric profile characteristic of a down-cutting, laterally migrating, meandering stream. One side, the cut bank side, is steep, whereas the opposite side slopes gently up from the deepest part of the channel. The upper end of the erosional surface on the gently sloping side is covered by point bar sediments. These have a maximum thickness of 22 feet. Even though some details are obscured, it appears that these point bar deposits are composed of a laterally discontinuous, thin basal unit made up of sandstone that is generally coarser, relatively cleaner, and lighter colored than the thicker overlying unit, which is composed of interbedded silty sandstones, siltstones, and shales. The general upward reduction in grain size and especially the overall geometry of this particular deposit are characteristic of a typical point bar sequence formed by a meandering stream transporting a mix of mostly suspended sediment load with some coarser bed load. The coarser basal sandstones typify bed load deposits of the lower portions of the point bar and channel bottom. Whereas the slightly inclined, finer grained interbeds found in the upper unit are the result of suspension load sediments being deposited in the mid to upper portion of the point bar during floods. The backside of the point bar deposits thin gradually, become finer grained, and appear to grade laterally into overbank deposits.

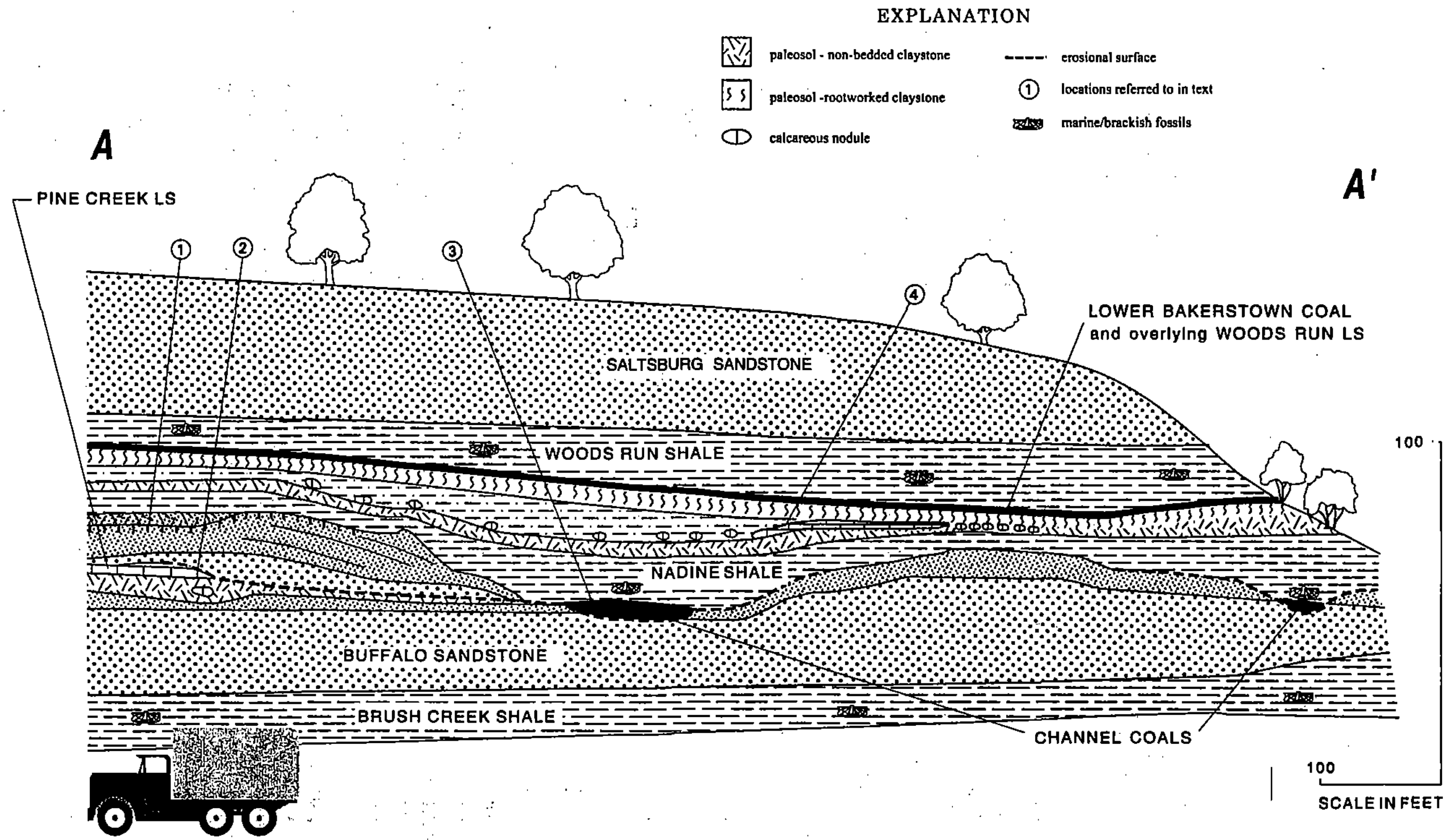


Figure 1-4 Road cut at old Route 66 exit shows meandering-stream paleochannels, which cut down through the Pine Creek Limestone and contain channel-bottom coals.

The top of the point bar at its highest point and along the sloping back side contains features suggestive of prolonged sub-aerial exposure (area 1: Figure 1-4). A thin, massive, sandy siltstone capping the top of the deposit contains vertical cracks filled with ferro-calcareous material. Directly below this bed, the top of the interbedded sandstone and sandy siltstone unit contains patchy deposits of arenaceous, limestone nodules. These features are not seen on the other, sloping, channel side of the point bar. The features are interpreted to be desiccation cracks and calcrete formed just above the water table in a paleosol that developed on the topographically higher portions of the point bar deposits after channel abandonment.

The erosional surface (heavy dashed line in Figure 1-4) of the channel containing the thicker coal is approximately 530 feet long. Proceeding from north to south, the surface initially has a relatively steep slope where it cuts down through the Pine Creek Limestone (area 2: Figure 1-4), dropping 6 feet vertically in 75 feet horizontally. The surface then flattens and slopes gently level for approximately 1 foot over the next 260 feet. In this distance, the erosional surface comes out from under the point bar deposits and onto the bed of the open channel. It then drops steeply into a narrow scour channel located in the center of the open channel bed.

The curved areal configuration of this stream segment and its spatial relationship with the other channel at the southern end of the highway cut (Figure 1-5) is the most persuasive indication that these deposits are associated with an abandoned meander loop. Stream flow appears to have been diverted when the meander loop was cut off at the neck by the other channel. No point bar or channel bottom deposits associated with this second channel were found. However, the non-bedded siltstone deposited on the Buffalo sandstone in the high ground area between channels may be partly levee deposits. The apparent scarcity of sediments and narrowness of the second channel suggests that it was abandoned quickly, possibly by major avulsion farther upstream.

The Conemaugh Group was originally referred to as the Lower Barren Coal Measures because of the pronounced economic inferiority of the coals found in that particular section. The coals are generally thinner, less persistent laterally, and of poorer quality than those of the overlying Allegheny and Monongahela Groups. They generally contain a large amount of the dull coal lithotypes (i.e., fusain, durain, and the duller of the thinly banded clarains) and consequently tend to have intermediate to dull luster (Karytsas, 1992). These characteristics have been attributed to the effects of climate (Cecil et al., 1985; Karytsas, 1992). Climate was thought to have changed from being uniformly wet to seasonally wet and dry soon after the beginning of Conemaugh deposition. The resulting periodic lowering of water table would have caused severe oxidation of accumulating plant debris substantially reducing the volume of peat, and increasing the percentage of the more carbon-rich, duller looking products of oxidation such as fusain.

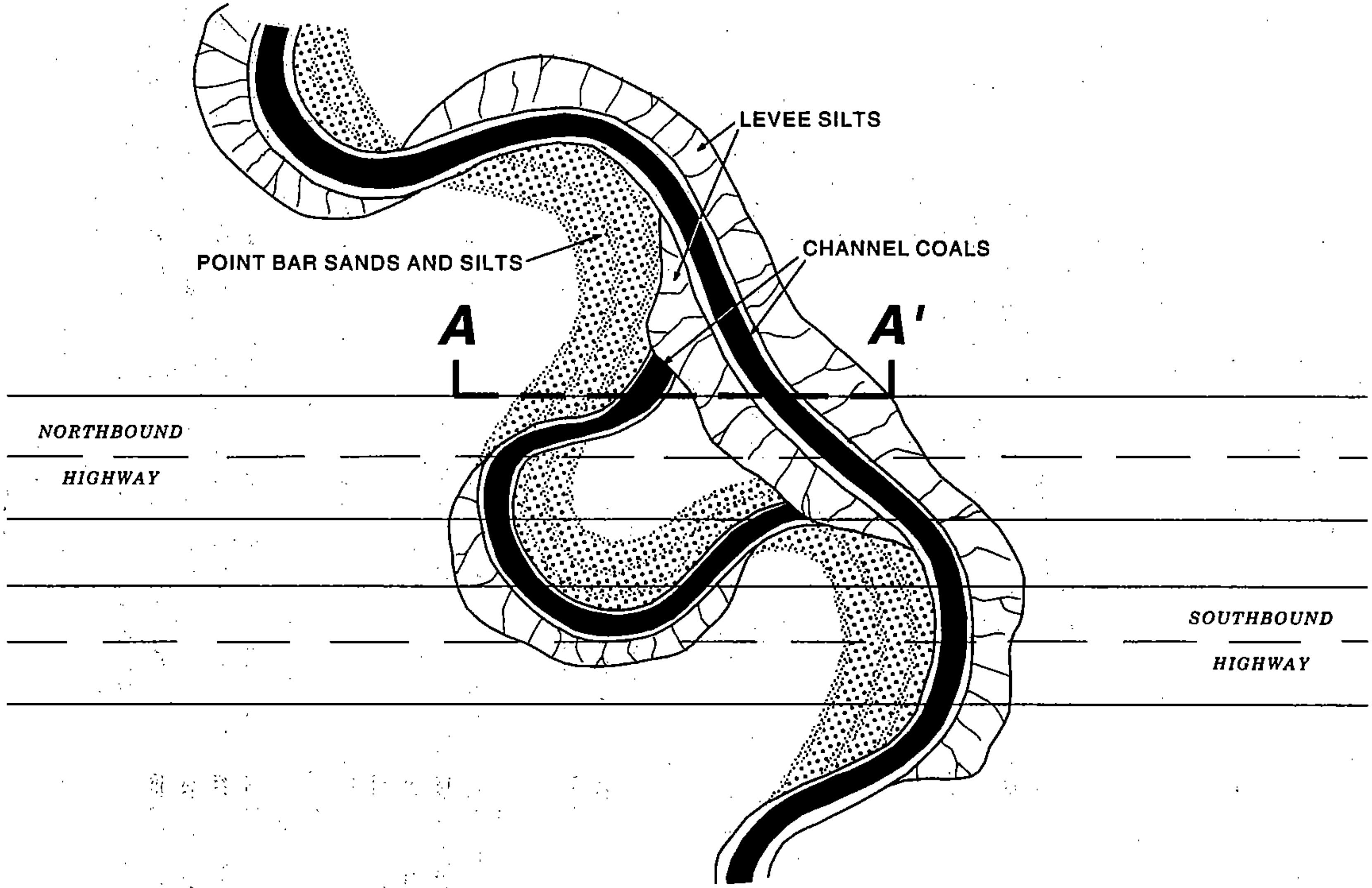


Figure 1-5 Aerial view of meandering-stream deposits and channel coals (diagrammatic and not to scale). Cross section A-A′ is shown in Figure 1.

The channel coals in the road cut compare fairly well with this general profile of Conemaugh coals. A megascopic examination indicates that both coals are banded and primarily composed of clarain with intermediate luster. The thicker of the two coals (area 3: Figure 1-4) contains several interbeds of dull coal, a few fusain lenses, and very thin pyrite laminae near the top. A few *Neuropteris* leaf and *Calamites* and *Sphenophylum* stem compressions were found on bedding planes of the dull coal interbeds.

An intriguing feature of the channel coals in this road cut is that they are restricted to the deepest portion of the stream bed. They do not cover the entire channel floor, nor do they conform to the shape of the abandoned channel as would be expected in oxbow deposits. A possible explanation for this unusual shape is that climatic conditions were generally dry, keeping the water table level low. In such climate, it is conceivable that only the deepest part of the channel would contain enough water to sustain luxuriant plant growth and to protect the accumulating peat from total destruction by oxidation during the cyclic dry periods. The desiccation cracks and calcrete on the top and back side of the levee deposits (area 2: Figure 1-4) provide additional evidence for this interpretation.

Additional indications of an alternating wet and dry climate can be seen in the section between the channel coal and the Lower Bakerstown coal. At least two other paleosol horizons appear to be present in this interval. The most distinct of these is situated directly beneath the Lower Bakerstown coal. It is considerably thicker and laterally more persistent than the paleosol that developed on the back side of the point bar. However, it is similar in that it has features suggestive of formation in a seasonally dry climate. Its profile from top to bottom consists of a thin, non-bedded, crumbly, olive gray claystone containing small carbonaceous root traces underlain by approximately 2.5 feet of non-bedded claystone having granular texture and containing small (typically pea size or smaller), irregular-shaped, ferro-calcareous nodules (glaebules). The glaebules are very calcareous at the bottom of the bed and become increasingly iron-rich upward. Some calcareous glaebules also occur in the upper part of the underlying bedded, silty shale. This profile corresponds well with the general description of other paleosols thought to have formed in semi-arid climate characterized by seasonally cyclic wet and dry conditions with an overall net deficiency in moisture (Smith, 1990).

Another possible paleosol horizon is situated about half way between the thick channel coal and the Lower Bakerstown coal. It is a 3- to 5-foot thick, non-bedded claystone containing small randomly oriented compaction slickensides. This claystone appears to have formed on the upper surface of a dark shale that blanketed the fluvial deposits and channel bottom coals. The orientation of this ancient soil horizon conforms with the underlying fluvial deposits forming a depression over the channel below. An unusual limestone conglomerate of limited extent was deposited on top of the paleosol along the sloping side of the depression (area 4: Figure 1-4). The rock is composed of mostly rounded, spherical to irregular-shaped, micritic, limestone clasts and a few sub angular, irregular-shaped, greenish gray, claystone clasts in a micritic limestone matrix. Small fractures containing crystalline calcite occur within the limestone clasts and also cutting through both limestone clasts and limestone matrix. The deposit thins upward as it rises out of the depression and at its uppermost end becomes nodular, very sideritic, weakly calcareous and has an extremely weathered appearance. It is interpreted to be an accumulation of calcareous glaebules eroded out of the underlying paleosol from the higher interchannel area and washing down into a fresh water pond filling the depression over the channel. The upper portion of the deposit is altered radically after burial because it is incorporated in the thick soil under the Lower Bakerstown coal.

The dark shale covering the accretionary deposits and filling the channels was deposited during a period of marine transgression. It is thin on the topographically higher point bar and inter-channel deposits and thicker in the channels. It contains a few brachiopod (*Lingula*), bivalve (*Dunbarrela*), and gastropod fossils, but these are found only at the base of the thicker channel fill deposits. Because of its stratigraphic position between the Pine Creek Limestone and the Woods Run marine zone, it is assumed that this unit is a distal deposit of the Nadine marine transgression. It has a very spotty occurrence in the Greensburg area, apparently being deposited only in stream valleys and other low areas.

The sedimentological features seen in this cut dramatically demonstrate that the rocks between the Pine Creek Limestone and the Lower Bakerstown coal are the product of a diverse and complicated set of depositional events. Deposition appears to have been strongly influenced by both widely fluctuating position of relative sea level and the effects of a semi-arid monsoonal climate. The Pine Creek marine transgression was apparently quickly succeeded by emergence and the development of an alluvial plain by accretionary, down cutting, meandering, stream systems. This was followed some time later by the weaker Nadine marine transgression. Depositional hiatuses of varying duration separated these events producing paleosols bearing the imprint of a semi-arid climate. Enigmatically, one of these paleosols, the one developed on top of the point bar and overbank deposits, appears to have formed at about the same time as the relatively thick channel coal deposits.

Road Log Continues from Stop 2.

3.1	65.9	Return to intersection of Route 22 and turn right (east).
0.7	66.6	Turn right to enter Stop 3, Oakford Storage Facility.

STOP 3

Oakford Gas Storage Facility
Murrysville and Fifth sandstone storage reservoirs.
Ray Follador, Angerman Associates, Inc.

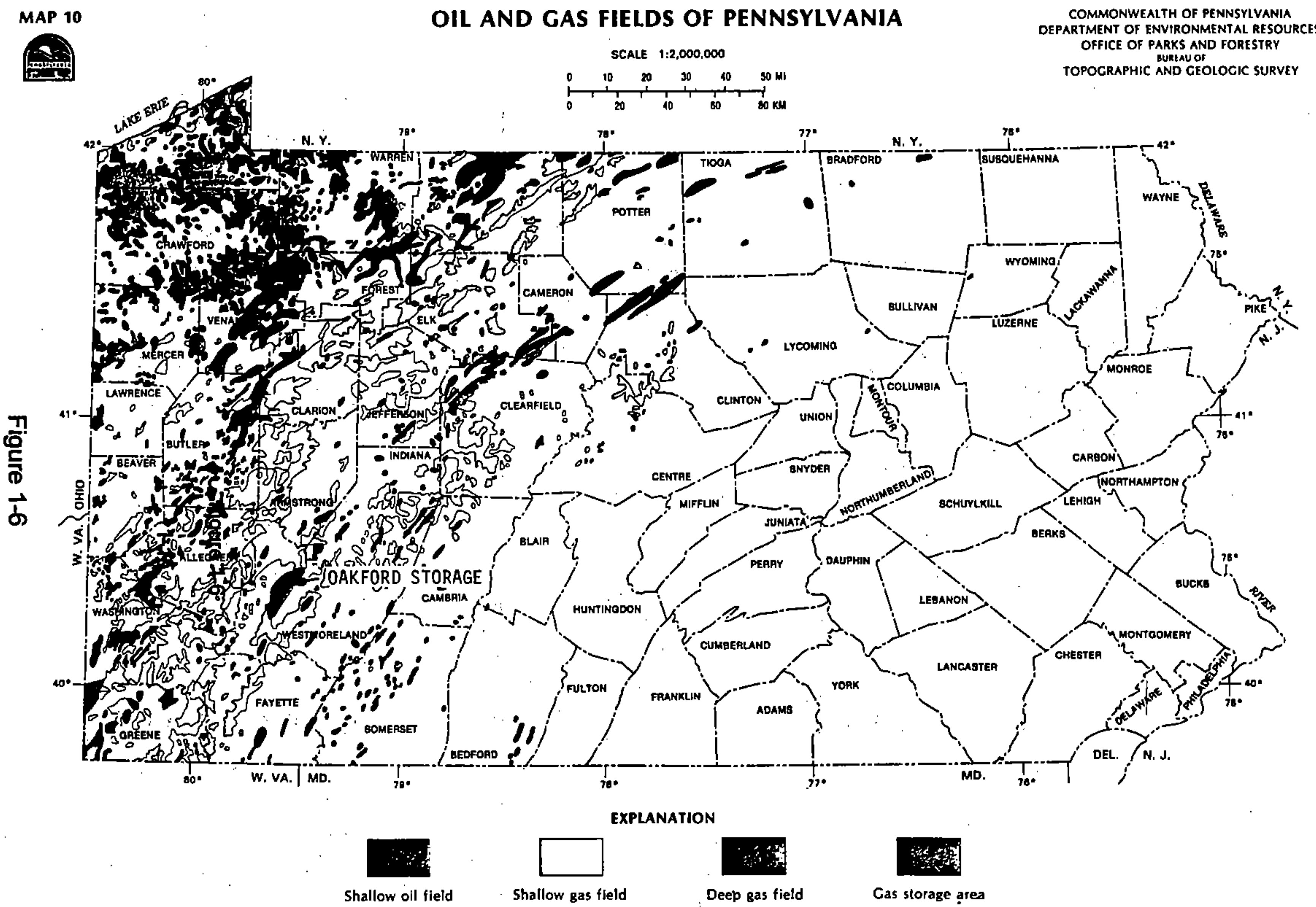
The Oakford Gas Storage facility near Delmont, Pennsylvania is owned and operated by the Consolidated Natural Gas Transmission Company (CNGT). This stop will begin with the viewing of a video describing the gas storage facility and compression stations and conclude with a walk through the main facility. CNGT facility employees who will act as our guides have not prepared any information concerning the geology, drilling, or historical development of the gas fields that were later converted to storage in 1951. The following is a condensed description of the geology of the storage reservoirs in this field as well as a brief history of the drilling and development of those gas fields.

Geography

The Oakford Storage Field encompasses greater than 13,000 acres located in Westmoreland County, Pennsylvania (Figure 1-6). This field has an northeast-southwest orientation with an estimated length of 13 miles. To the northeast the field ends in Salem Township two (2) miles southwest of the town of Saltsburg. The field extends to the southwest and traverses Route 30 just south of the town of Jeanette and reaches its southern limits south of the town of Arona in Hempfield Township (Figure 1-7). The width of the field varies along its strike. An estimated width of three (3) miles is common in the northern reaches of the field tapering to less than one mile at its northern and southern extremes.

Structure

The Oakford Storage Field is located structurally along the east flank and axis of the Grapeville anticline and mirrors this anticline along its entire length (Figure 1-8). The southern end of this anticline plunges abruptly south of Little Sewickly Creek east of the town of Herminie. From here, the crest of the anticline rises rapidly to the northeast to where two (2) domal areas are separated by a structural saddle (Johnson, 1925). Traveling to the northeast the first of these domal areas is located at the town of Grapeville in Hempfield Township and the second is near Jeanette. The anticline then rises to its highest point three (3) miles northeast of the town of Jeanette. The anticline then plunges to its northern termination near the town of Saltsburg.



MAP 10
OIL AND GAS FIELDS OF PENNSYLVANIA
COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
OFFICE OF PARKS AND FORESTRY
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
SCALE 1:2,000,000
0 10 20 30 40 50 MI
0 20 40 60 80 KM
LAKE ERIE
N. Y.
OHIO
W. VA.
MD.
DEL.
N. J.
DELAWARE
RIVER
ERIE
WARREN
MCKEAN
POTTER
TIOGA
BRADFORD
SUSQUEHANNA
WAYNE
CRAWFORD
FOREST
ELK
CAMERON
VENANGO
MERCER
LAWRENCE
CLARION
JEFFERSON
CLEARFIELD
BUTLER
BEAVER
INDIANA
ARMSTRONG
ALLEGHENY
OAKFORD STORAGE
CAMBRIA
WASHINGTON
WESTMORELAND
FAYETTE
GREENE
SOMERSET
BEDFORD
BLAIR
HUNTINGDON
FULTON
FRANKLIN
ADAMS
CUMBERLAND
PERRY
CENTRE
MIFFLIN
JUNIATA
CLINTON
LYCOMING
UNION
SNYDER
SULLIVAN
WYOMING
LACKAWANNA
LUZERNE
COLUMBIA
MONTOUR
NORTHUMBERLAND
DAUPHIN
LEBANON
LANCASTER
YORK
SCHUYLKILL
CARBON
MONROE
PIKE
NORTHAMPTON
LEHIGH
BERKS
BUCKS
MONTGOMERY
CHESTER
DELAWARE
PHILADELPHIA
EXPLANATION
Shallow oil field
Shallow gas field
Deep gas field
Gas storage area

Figure 1-6

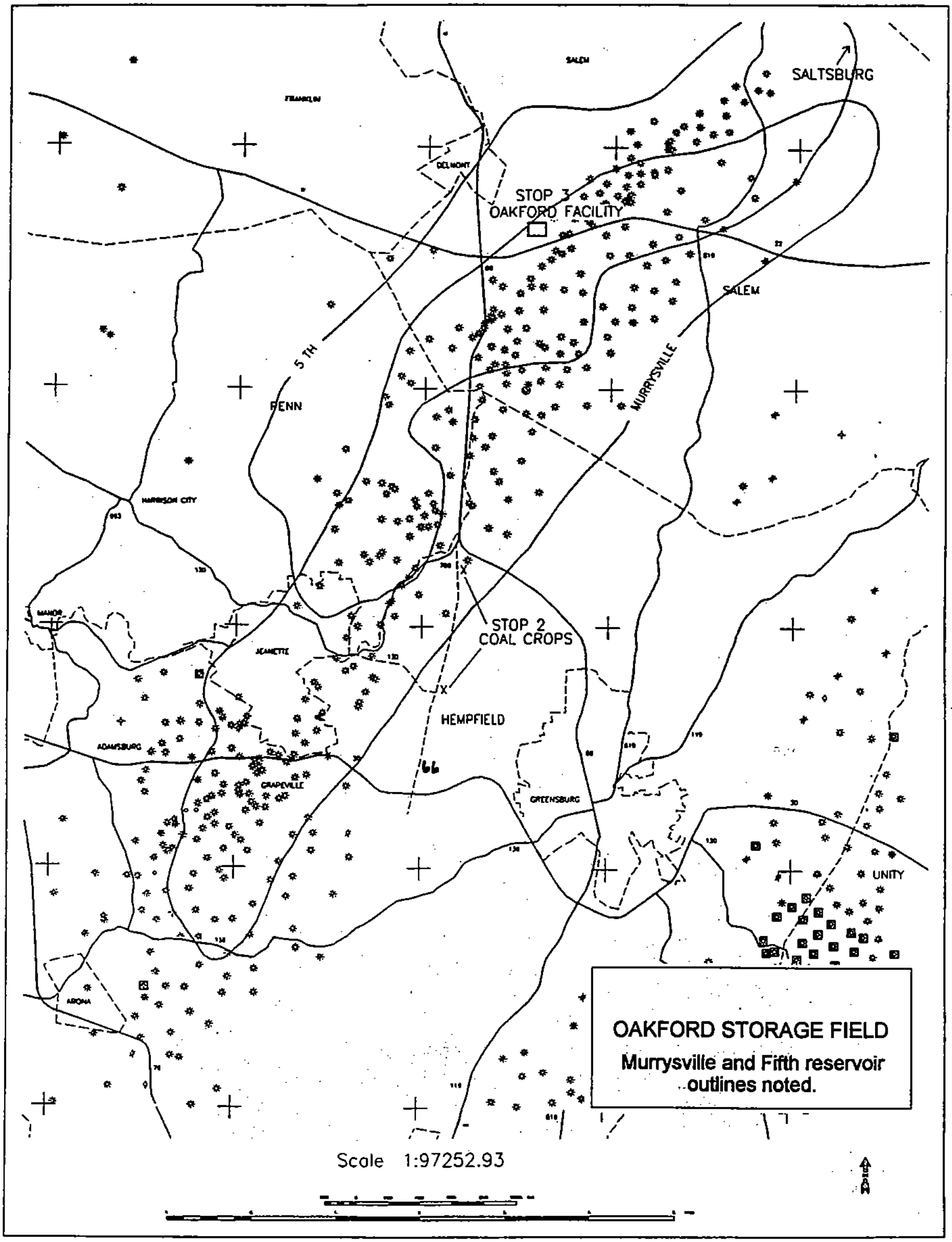

SALTSBURG
STOP 3
OAKFORD FACILITY
SALEM
5 TH
PENN
MURRYSVILLE
STOP 2
COAL CROPS
HEMPFIELD
UNITY
OAKFORD STORAGE FIELD
Murrysville and Fifth reservoir outlines noted.
Scale 1:97252.93

Figure 1-7

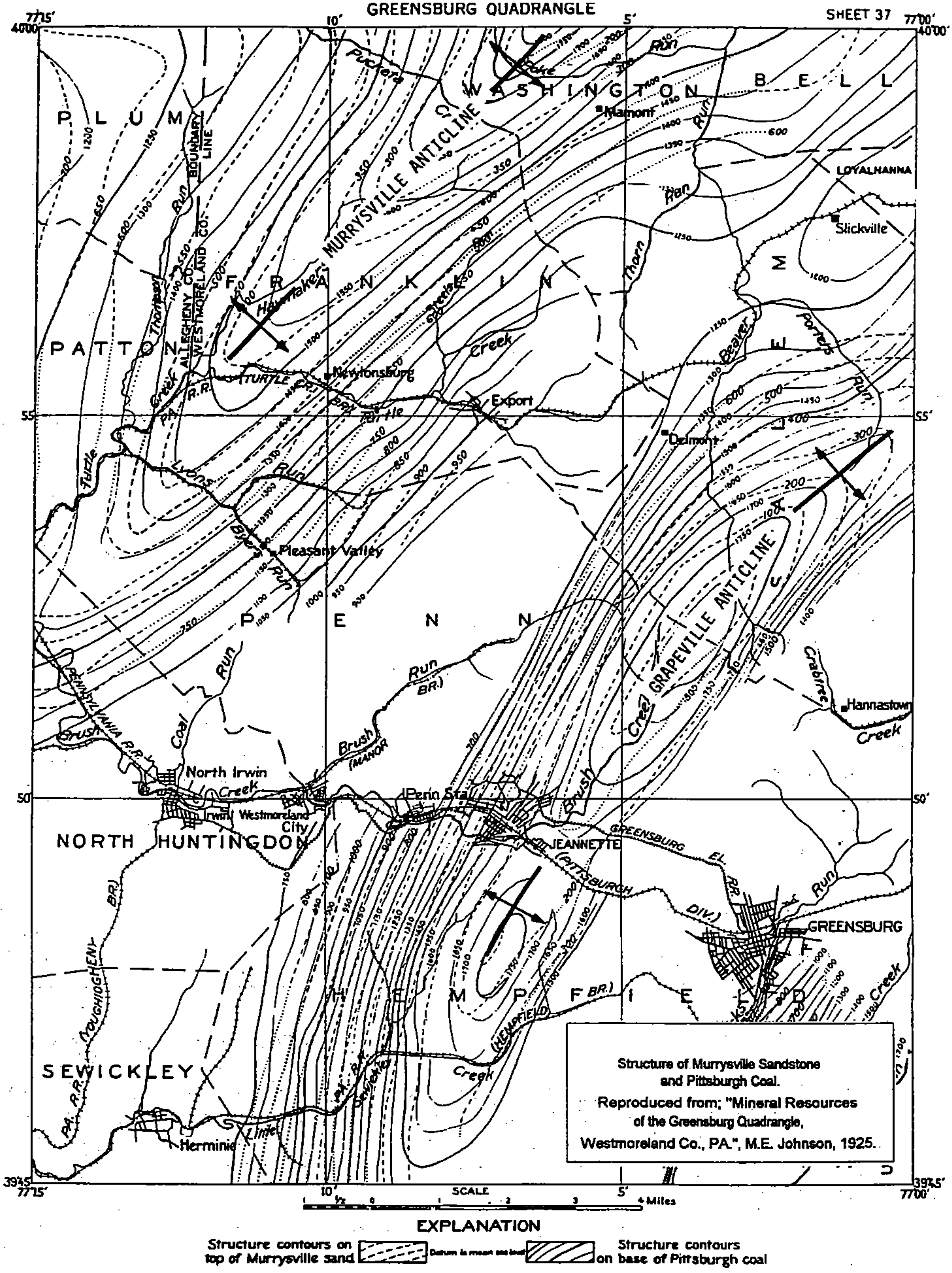


FIGURE 9. Structure contours on Murrysville sand and Pittsburgh coal.

Figure 1-8

Geology of the Storage Reservoirs

Several sandstone's have proven to be prolific gas reservoirs along the Grapeville anticline since 1887 when gas was first discovered along this structure. These gas fields were named the Delmont and Grapeville/Arona Fields at or near the turn of the century (Ashley and Robinson, 1922). Shows of gas and production have been reported in Pennsylvanian and Mississippian sandstones in this region but the greatest natural flows of gas were recorded in Upper Devonian Venango and Bradford Group sandstones (Figure 1-9). Of these reservoirs, the Murrysville and Fifth sandstones of the Venango Group serve as the gas storage reservoirs of the Oakford Field (Figure 1-7).

The shallower Murrysville sandstone caps the top of the Upper Devonian section and is an estimated 1400 feet beneath the surface. The gross sandstone thickness is 100 feet with an average pay thickness of 50 feet. The sandstone is very coarse and sometimes pebbly with a maximum estimated porosity of 20% in the pay section (Lytle, 1963). Structure plays a role in trapping gas in the Murrysville sandstone with gas accumulating in the crest of the anticline. The first productive gas wells drilled in the Murrysville sandstone in Oakford occurred in 1887 (Lytle, 1963). The original rock pressures of these wells were gauged at greater than 600 psi with initial flow rates ranging from 10 Mmcf to 40 Mmcf per day.

The Fifth sandstone is the lower of the two storage reservoirs and is an estimated 2200 feet beneath the surface. This sandstone has an estimated gross thickness of 60 feet. The net reservoir pay of the Fifth sandstone is an estimated 20 feet with an average porosity of 13% in the pay section (Lytle, 1963). The trapping mechanism for this reservoir is stratigraphic with nonporous sandstone and siltstones sealing the porous pay zones. The initial productive wells drilled to the Fifth sandstone occurred in 1907 (Lytle, 1963). These wells had original rock pressures of 1100 psi and initial flow rates of 20 Mmcf to 30 Mmcf per day.

Conversion to Storage

New York State Natural Gas, the predecessor to CNGT, began to convert the Murrysville and Fifth sandstone reservoirs to storage in 1951. Natural gas storage figures compiled for a 1960 report by the American Gas Association (AGA) reported the Murrysville and Fifth reservoirs to have total working capacities of 51,408 Mmcf and 8,952 Mmcf respectively for a total working capacity of over 60,000 Mmcf nine years after the conversion was initiated (Lytle, 1963). In the most recent survey of underground gas storage facilities by the AGA (1988), the Oakford Field is reported to have 277 total wells of which 231 serve as input/output wells and 46 serve as pressure control/observation wells. Four (4) compressor stations operate within the field with a total of 51,250 horsepower and field pipeline sizes ranging from 2 to 20 inches.

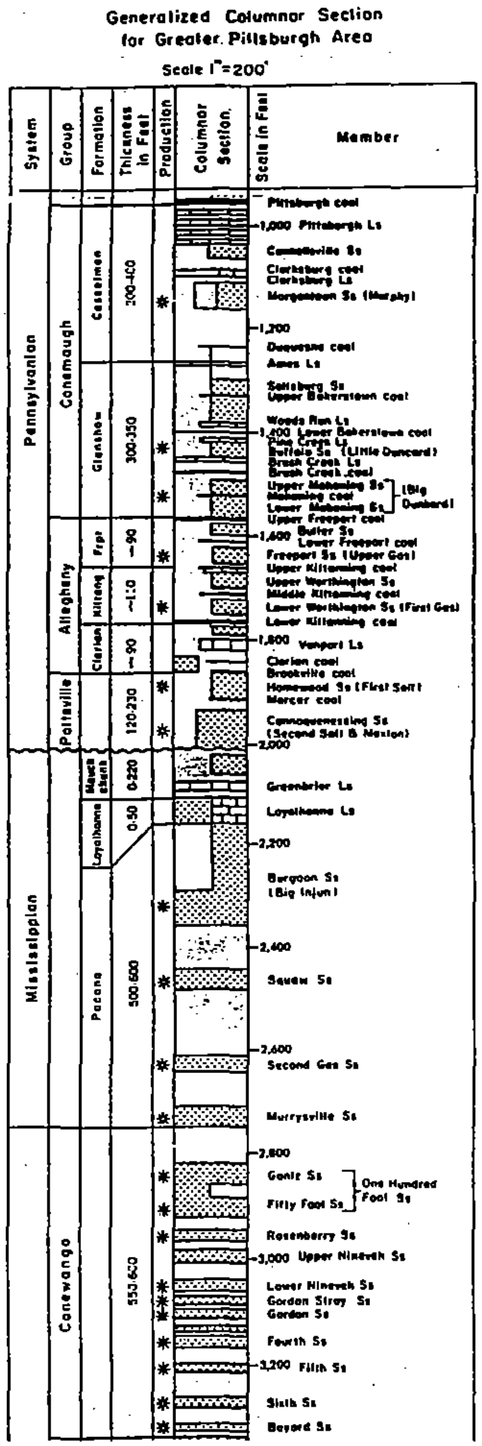


Figure 1-9 Generalized stratigraphic column showing productive.

The AGA reported the total base gas/working gas capacity of the Oakford Storage facility was 102,174 Mmcf in 1988. The future undeveloped (unused capacity) base gas at this time was estimated to equal 123,252 Mmcf bringing the ultimate storage capacity to equal 225,426 Mmcf.

Road Log Continues from Stop 3.

13.4	80.0	Follow Route 22 west to Monroeville Mall Park and Ride.

END OF ROAD LOG

Day Two
Saturday, May 20, 1995

ENGINEERING AND ENVIRONMENTAL GEOLOGY

Trip Leaders:
Christopher A. Ruppen, Michael Baker Jr., Inc.
Reginald P. Briggs, Geomega, Inc.

Welcome to the second day of the Pittsburgh Geological Society's 50th Anniversary Field Trip. Today's field trip will focus on aspects of the environmental and engineering geology of the rocks of the Pennsylvanian System of western Pennsylvania. As an introduction, the cut at the south end of the IKEA building is a large gunite face covering a Pittsburgh coal exposure. The Pittsburgh coal is located to the right of the grout and a down-to-the-right listric fault is exposed at this location. Whether this fault is the result of mining, earthwork or Mother Nature is not clear. To the left of the gunite, weathered coal is exposed. Note how erosion is occurring along the edges of the grout curtain. This area is the location of the McCurdy extension of the McDonald oil pool, first drilled in 1890.

Meeting Point: IKEA parking lot, Robinson Towne Centre.
Meeting Time: 8:00 AM to 8:30 AM. **DISEMBARK at 8:30 AM PROMPTLY.**

Mileage		
Interval	**Cumulative**	**Field Trip Itinerary**
0.0	0.0	At the south end of IKEA parking lot, Robinson Towne Centre (Figure 2-1).
0.2	0.2	Exit from IKEA, turn left.
0.2	0.4	Intersection from the left with the ramp off PA 60 north. Bear right.
0.6	1.0	Traffic light at intersection with Cliff Mine (and Beaver Grade) Road on Montour Run. Here we are in the upper Glenshaw Formation. The Ames Limestone Member at the top of the Glenshaw Formation of the Conemaugh Group crops out in the cuts on the entry road directly ahead. The sandstone at road level may be the Saltsburg sandstone. Turn left on to Cliff Mine Road.
0.9	1.9	Bear right on to PA 60 north.

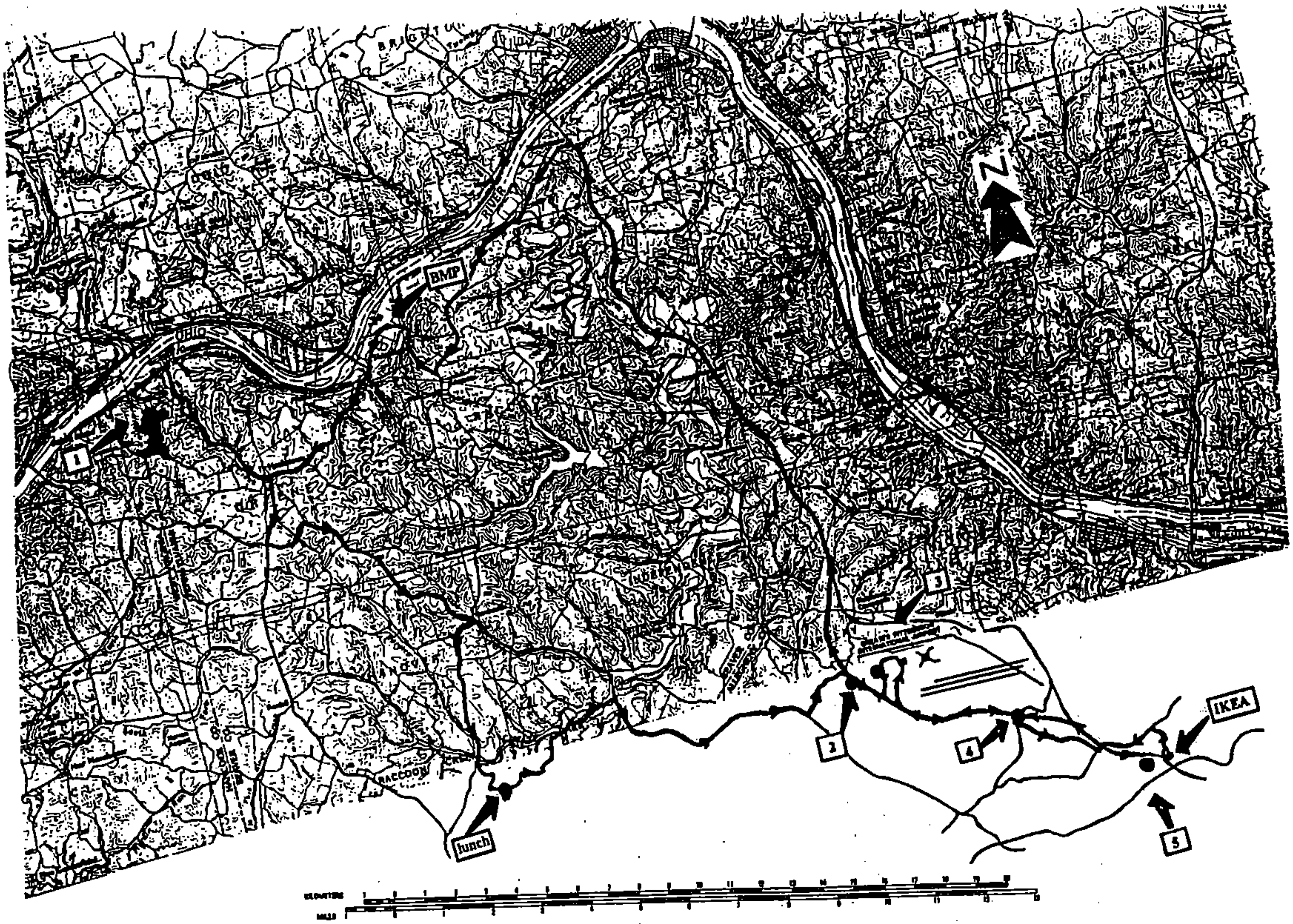
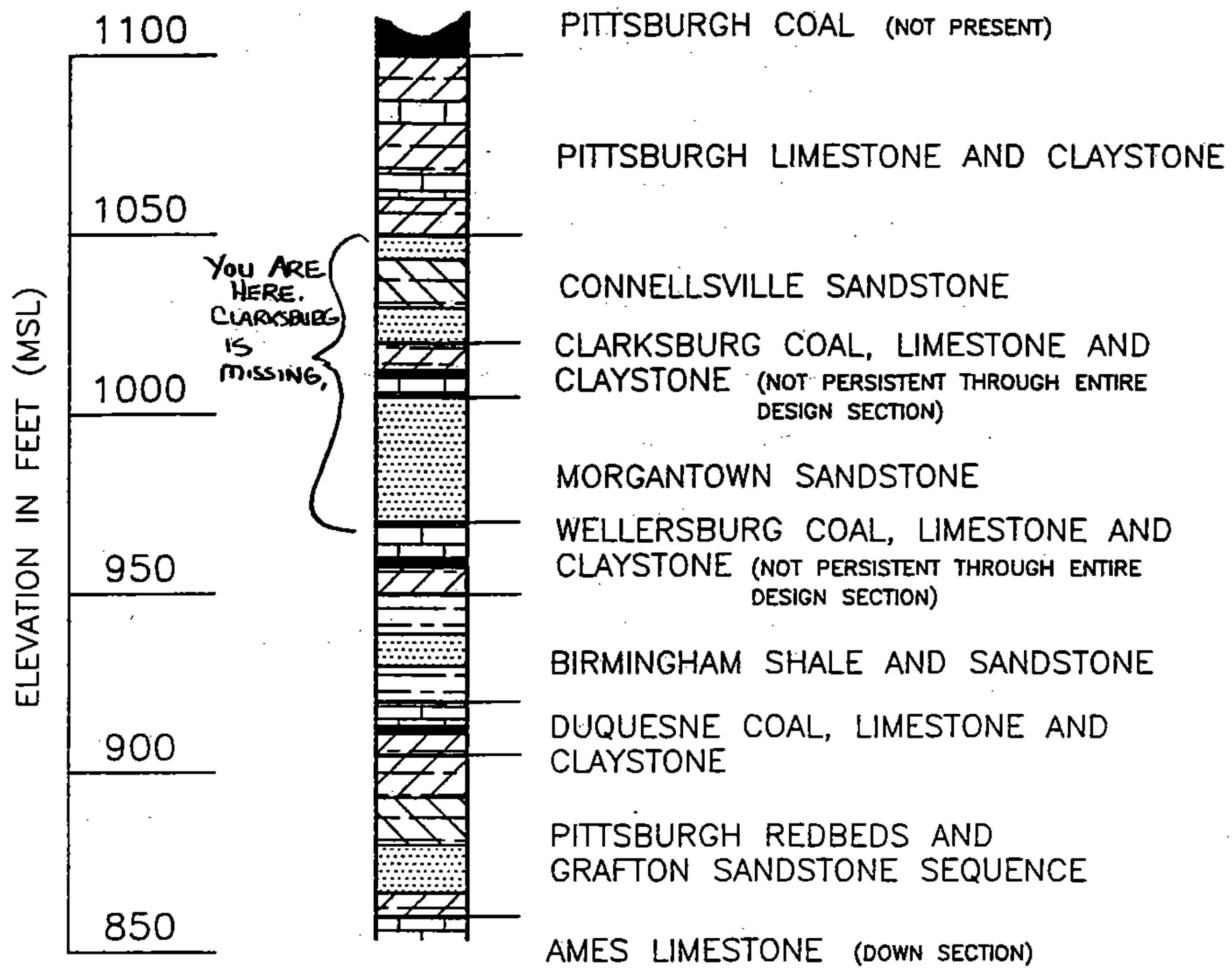


Figure 2-1 -- Map showing the route of Field Trip #2. Black dots are locations of field trip stops. Numbered squares and arrows show stop numbers. BMP - Bruce Mansfield power plant. IKEA - start and end of field trip log. Large arrow points north. Scale as shown.

0.5	2.4	Continue straight on PA 60.
0.7	3.1	Cuts on left expose the Morgantown sandstone in the Casselman Formation, Conemaugh Group. The Clarksburg claystone is missing at this locality (Figure 2-2). Basal conglomerate is present for first 50 feet at south end of cut at ramp grade. Highly fractured Morgantown sandstone is present at the south end of cut likely due to stress relief adjacent to small valley (notice benching added during construction to remediate this area).
1.5	4.6	Bench in the road cut on the right is the level of the Pittsburgh coal bed. Approximately 1.5 mile to the north is a mine fire in a isolated knoll of the Pittsburgh coal bed.
1.8	6.4	Landfill on the right.
0.6	7.0	Airport entrance. Continue straight on PA 60.
1.1	8.1	Mine seal in the Pittsburgh coal on the left. This is the drainage divide between the Raccoon Creek watershed and the Montour Run watershed.
1.4	9.5	Hookstown Grade Road overpass. Cut is in Pittsburgh limestone/claystone sequence through Clarksburg claystone(Figure 2-3). Note Clarksburg claystone is unusually thick in this area (up to 75 feet). This may be more of a depositional anomaly rather that structural.
0.6	10.1	Junction with business PA 60. Continue north on PA 60.
1.1	11.2	Beaver County line.
1.5	12.7	Crossing the north end of the Shannopin oil pool.
2.6	15.3	Saltsburg sandstone in the Glenshaw. Ames Limestone not far above.
0.6	15.9	Bridge over Raccoon Creek. USAir 427 crashed a mile west of here in September 1994 killing 132 people.
2.8	18.7	Center Township exit.



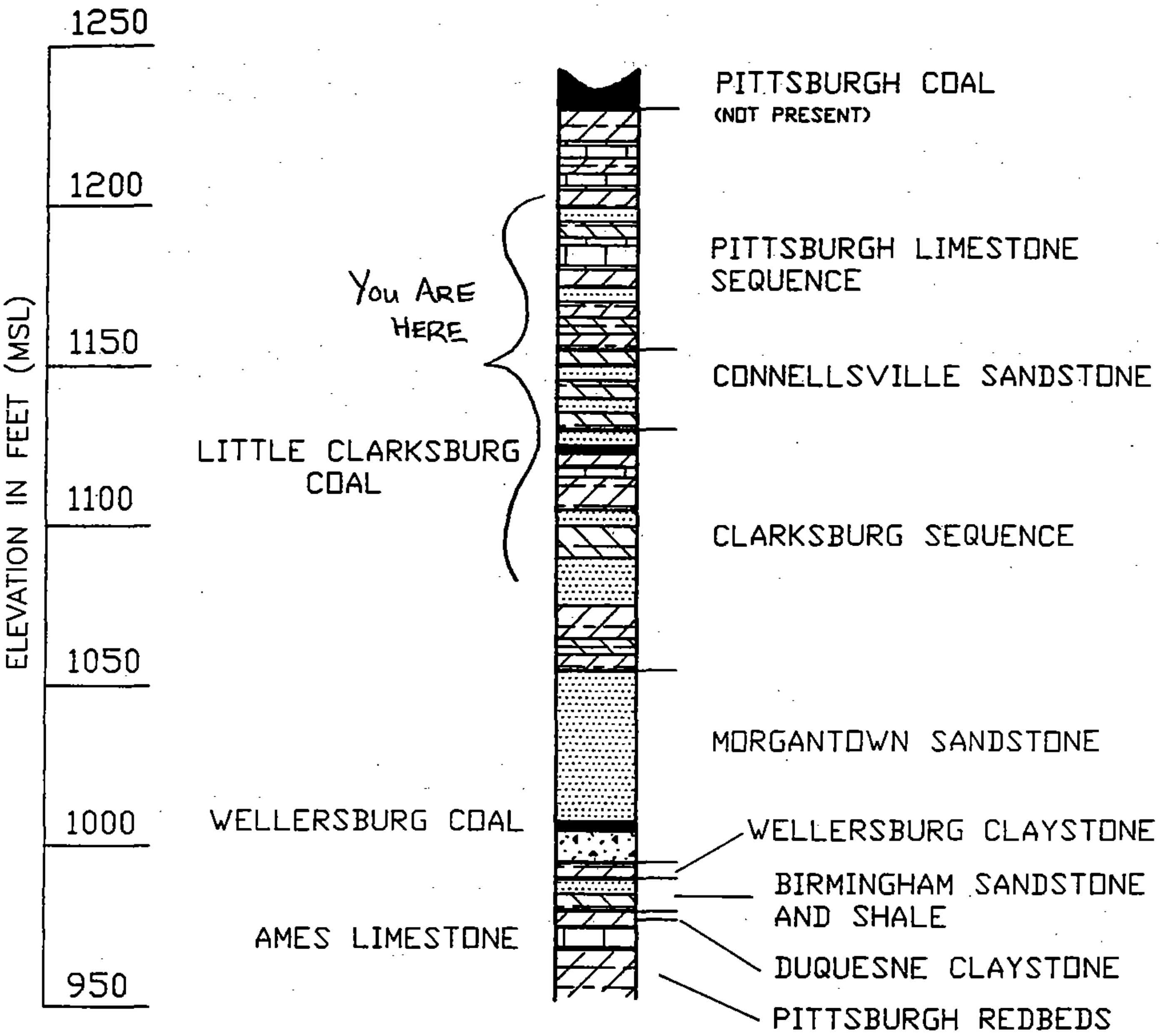
LOCAL STRATIGRAPHY

S.R. 60

SCALE: AS SHOWN S.O. No. 16539–ARA

DATE: DEC., 1989 FILE: CAR

Figure 2-2



LOCAL STRATIGRAPHY

S.R. 60

SCALE: AS SHOWN S.O. No. 16539–ARA
DATE: DEC., 1989 FILE: CAR

Figure 2-3

2.0	20.7	Bear off right on exit 12, Monaca/Shippingport. Bear left at end of ramp to stop sign.
0.3	21.0	At stop sign turn left on PA 18 South toward Shippingport. Note the stressed vegetation due to fumes from old mills.
0.7	21.7	On the right, Zinc Corp. of America on the flood plain of the Ohio River.
1.2	22.9	Raccoon Creek just upstream from its confluence with the Ohio River.
0.3	23.2	Road to the right leads to the corps of Engineers Montgomery Lock & Dam on the Ohio. Continue straight.
0.3	23.5	Now you can see the Ohio River.
3.6	27.1	Kennedy's Corners, turn right toward Shippingport. The upland surface in this area is relatively flat with a general elevation of 1,100 to 1,160 feet. It is interpreted as an ancient cut terrace of the Ohio River.
0.6	27.7	The 950-foot stack of the Bruce Mansfield Power Plant is visible straight ahead.
1.1	28.8	Turn right into entrance to the Bruce Mansfield Plant of Penn Power. After stop sign go right then left and follow signs to Main Entrance.
0.2	29.0	Plant visitors center. The Bruce Mansfield Plant is a coal-burning power plant with a demonstrated capacity of 2,360,000 kw. It receives an average of about 5,500,000 tons of coal per year by rail, river, and truck. It is mislabeled "Nuclear Power Plant" on topographic maps. After some months of tests and trials, the plant was opened officially on June 1, 1976, producing electricity to the power grid. It is expected to generate power through the year 2040. Flue gases from combustion of coal pass through scrubbers that remove sulfur oxides and particulates from the exiting boiler gases. The scrubbing process converts slaked lime to a sludge chiefly composed of gypsum, $CaSO_4 \cdot 2H_2O$. The sludge is pumped to an impoundment which will be this field trip's Stop 1. The scrubbers consume as much as 425,000 tons of

		lime each year. The limestone converted to lime comes from a huge underground mine in the Cabin Creek area near Maysville, Kentucky and is delivered to the plant by barges on the Ohio River. It is produced from a 50-foot section in the 300-to-350-foot-thick Middle Ordovician Camp Nelson Formation. The Camp Nelson is correlated approximately with the Bellefonte Formation in Pennsylvania. Return to highway.
0.2	29.2	Stop sign at highway. Turn right.
0.9	30.1	Intersection with PA 168 from the north. Continue straight on 168 South. On the right hand side just after the intersection is the Beaver Valley Nuclear Power Plant of Duquesne Light, with a demonstrated capacity of 1,643,000 kw.
1.6	31.7	Gabion wall stream stabilization for support of PA 168.
0.1	31.8	In the valley to the right was the former Peggs Run underground mine in the Upper Freeport bituminous coal bed, here about 42 inches thick. The Upper Freeport is the uppermost unit of the Freeport Formation of the Allegheny Group. Ahead on the left the coal bed has been strip mined.
1.6	33.4	Stop sign in Hookstown. Continue straight on Georgetown Road.
0.5	34.9	Sandstone in the Kittanning Formation of the Allegheny Group exposed in the Mill Creek valley.
1.8	36.7	Turn left, with caution, onto a gravel road where the paved road curves to the right. Go about 50 yards to a T-intersection and turn left on an abandoned right of way of the former Penn Central Rail Road. On the right are extensive inactive sand and gravel pits in the Ohio River flood plain and on the left, the lower Mill Creek Valley.
0.3	37.0	Gate to the Penn Power gypsum impoundment reservation.
0.5	37.5	On the right, intersection with a gravel road heading uphill. Continue straight across former railroad embankment crossing Little Blue Run. Below us on the right is the intersection of Mill Creek and Little Blue Run, and beyond is the Ohio River. At the end of the embankment turn left.

0.5	38.0	Base of Little Blue Run dam, STOP 1.

STOP 1A
Little Blue Run Dam

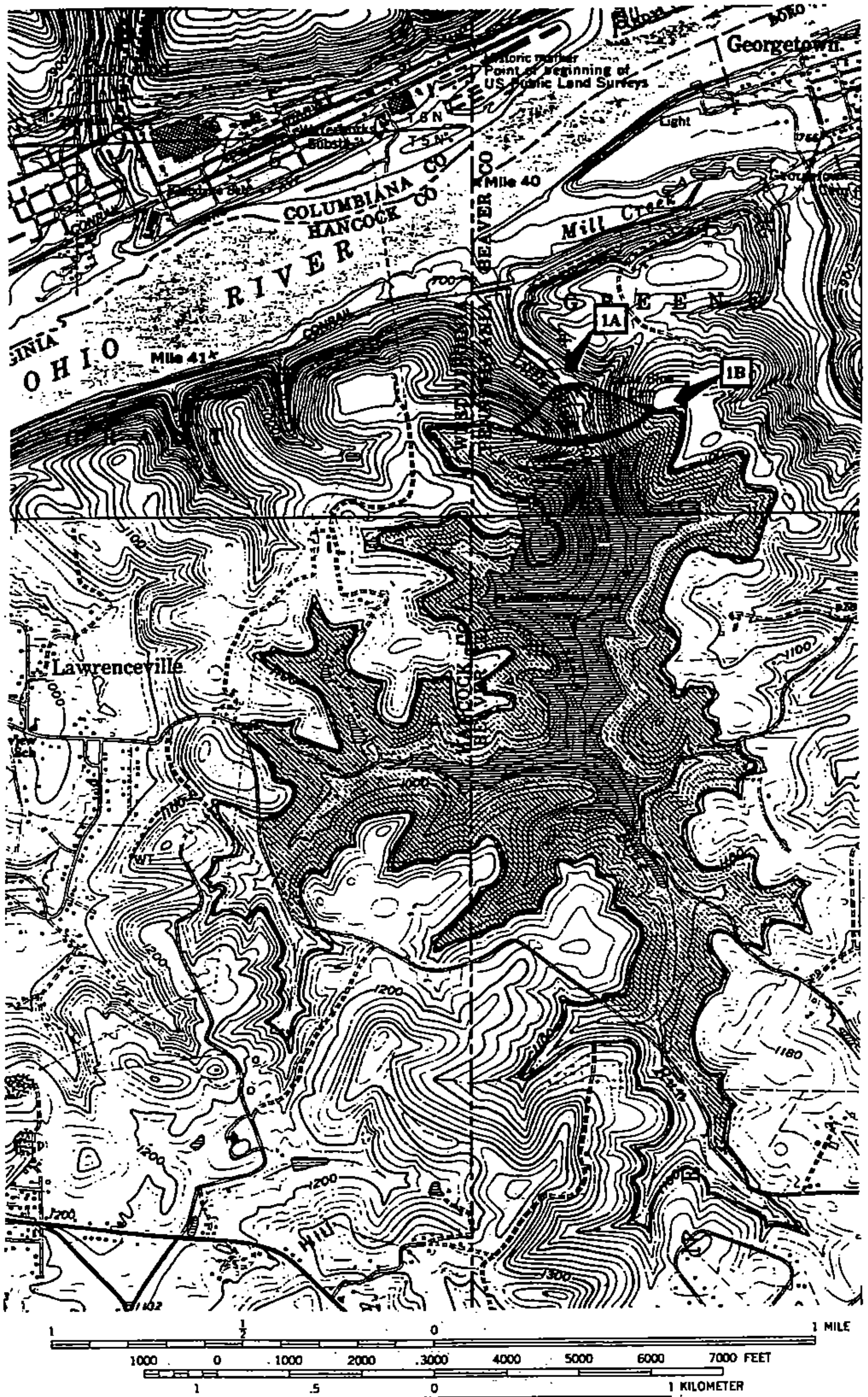
The Little Blue Run Dam was constructed to contain the scrubber sludge from the Bruce Mansfield power station on the Ohio River at Shippingport, PA. The Bruce Mansfield power plant clean air disposal system includes four positive displacement pumps each with a capacity to pump 1,200 gpm of waste slurry from the mixing tank through four 7-mile-long pipelines into Little Blue Run Dam.

The Little Blue Run Dam was constructed between July 1, 1974 to July 1, 1977 (Figures 2-4 and 2-5). The dam is 420 feet high, 1,700 feet thick at the base and 2,200 feet along its crest. It contains 9,000,000 cubic yards of earth and rock and is reputed to be the largest earth and rock fill dam in the East. All materials used in dam construction were mined locally in the Little Blue Run drainage area (Appendix A).

The dam and its reservoir cover ground on the west edge of the Hookstown oil pool. Oil and gas wells in the area were plugged. Sixteen monitoring wells surround the site. The dam is designed to contain the heaviest 24-hour rainstorm expectable in a 100-year period. Note targets painted on some of the riprap boulders. Presumably these are used for periodic monitoring of possible movement in the face of the dam. On the east side of the face of the dam is a weir for measuring flow of seepage. The gypsum sludge has a high pH, and if the pH exceeds a certain limit, acid is added to the runoff in the small impoundment below.

Road Log Continues from Stop 1A

0.5	38.5	Turn right uphill, climbing the east side of the valley of Little Blue Run.
0.8	39.3	Blue Run Dam pump and maintenance station near the east abutment of the dam, STOP 1B.



CONTOUR INTERVAL 20 FEET

Figure 2-4 – Map of the Little Blue Run sludge impoundment. 1A and 1B are stops at base and top of dam. Top is north. Scale as shown. Base from East Liverpool North and East Liverpool South 7.5-minute quadrangles.

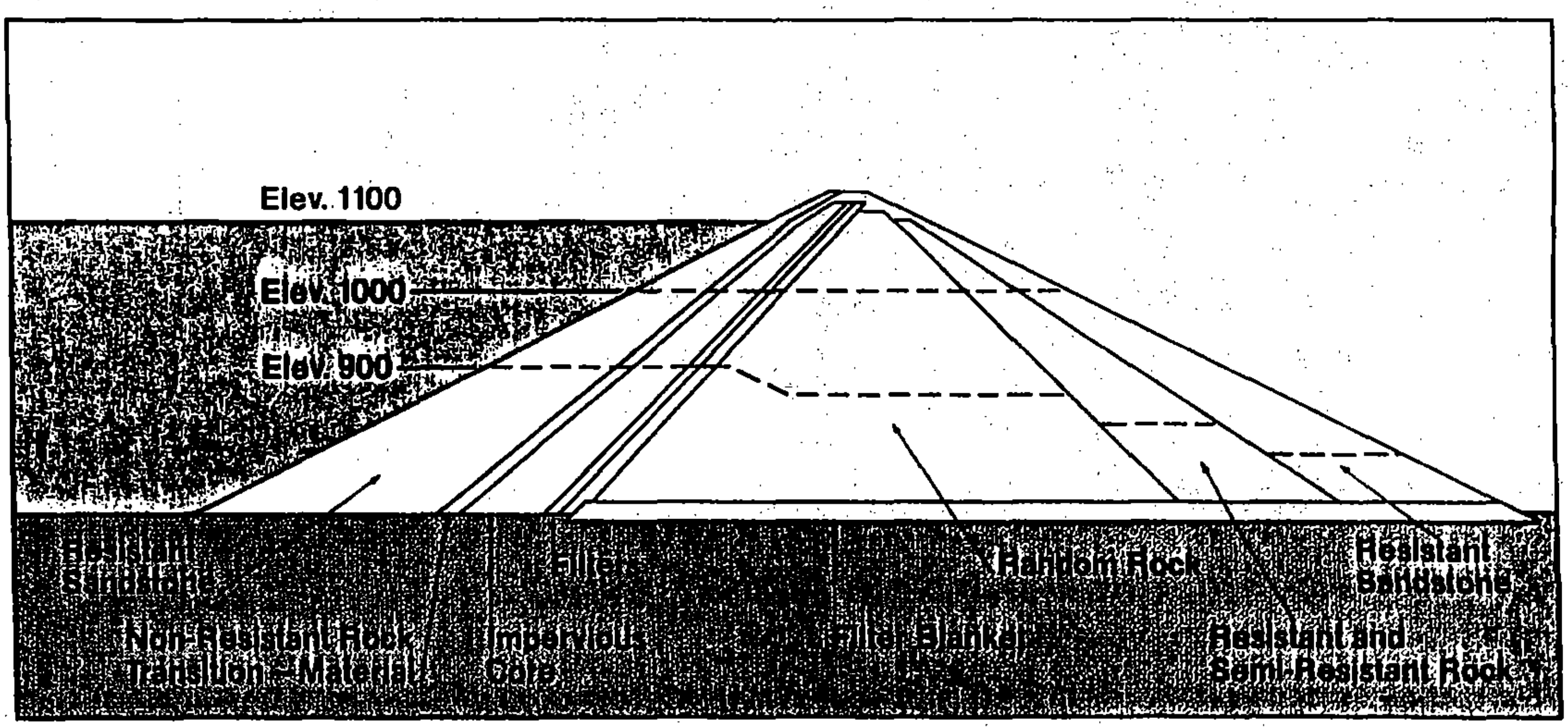


Figure 2-5 -- Sketch from south (left) to north (right) through the Little Blue Run dam.

STOP 1B
Blue Run Dam Pump and Maintenance Station

Park here and walk a short distance to the north then turn left and walk 100 yards out onto the crest of the dam (Figure 2-4). The total site includes 1,300 acres, just over two square miles, and eventually the 860-acre lake will cover 92,000,000 cubic yards of scrubber waste. When the power plant is in full operation, the impoundment receives about 3,000,000 gallons of sludge per day. The first sludge was pumped to the impoundment on December 5, 1975, during the power plant run-up trials and before the dam had been topped off. The floats you see carry the sludge piping out into the lake. The pipes can be moved to allow even deposition of the sludge. Particularly when viewed from the air, the impoundment has a striking blue color, much like the blue seen over sandbars and near beaches in tropical seas.

Depending on operational variables, the sludge capacity of the impoundment will be reached between the years 2007 and 2015. To handle sludge once the impoundment is full, Penn Power is considering conversion to a dry system, with the sludge still piped to here, where it will be dewatered with the water returned to the power plant. The damp sludge will be stacked on the full impoundment, below the level of the rim of the drainage basin. Tests have shown that the sludge can be compacted to a bearing capacity of 4½ tons per square foot.

The crest of the dam is at the approximate elevation 1,100 feet. Here the Upper Freeport coal bed horizon is at approximately 940 feet elevation, so the base of the dam rests on Allegheny Group strata while the crest is at a level about half way up in the Glenshaw Formation. Below us the normal pool elevation of the Ohio River is 665 feet, so the crest of the dam is about 435 feet above the river. Return to the paved road along Mill Creek.

Road Log Continues from Stop 1B

1.6	40.9	Intersection of gravel road with Georgetown (Mill Creek) Road. Turn right.
3.4	44.3	Stop sign at intersection with PA 168 in Hookstown. Turn right, south, on PA 168.
1.5	45.8	Intersection of PA 168 and US-30. Turn left onto US-30.
5.3	51.1	Intersection of US-30 and PA 18. Turn right, south, on PA 18. A short distance up the hill we pass the horizon of the Ames Limestone.

ALTERNATE ROUTE

If running early, instead of turning right onto PA 18 at mile 51.1, continue straight on US-30 to cumulative mile 51.9, to a yellow brick house on the right. This house was built on fill over the very marshy ground along Little Traverse Creek. The front yard of the house has collapsed into the creek, and stress cracks can be seen in the brick of the front wall of the house. Continue on east along US-30, noting on the right near cumulative mile 52.8 very wet ground and dams built by those superlative engineers, the beaver, who lent their name to the county. Continue east on US-30 to Raccoon Park entrance at cumulative mile 54.6. Turn right into the park and take the reverse route to the lunch stops given below.

Road Log Continues

2.8	53.9	Recurring embankment failure on the west side of the road, perhaps associated with the unstable Clarksburg red beds in the Casselman Formation.
0.4	54.3	Cross Traverse Creek to intersection on left of PA 18 and the main road through Raccoon Creek State Park (which actually is on Traverse Creek). If you were to continue 0.4 miles farther on PA 18, on your right you will find the trail to Frankfort Springs, a spa famous during the 19th century and early 20th century. Turn left into the Raccoon Park Road.
1.1	55.4	LUNCH STOP – Picnic area with rest facilities. Lunch today is sponsored and provided by Michael Baker Jr., Inc.
0.6	56.0	ALTERNATIVE LUNCH STOP.
1.3	57.3	Main park picnic area on the left.
2.2	59.5	Intersection of Raccoon Park Road and US-30. Turn right on US-30.
0.8	60.3	Crossing Raccoon Creek.
4.1	64.4	Intersection of US-30 with Moon Clinton Road in Clinton. Turn left on Moon Clinton Road.
0.8	65.2	The water tank on the knob on the right side of the road is 100 feet above mined-out Pittsburgh coal bed. Reportedly, this

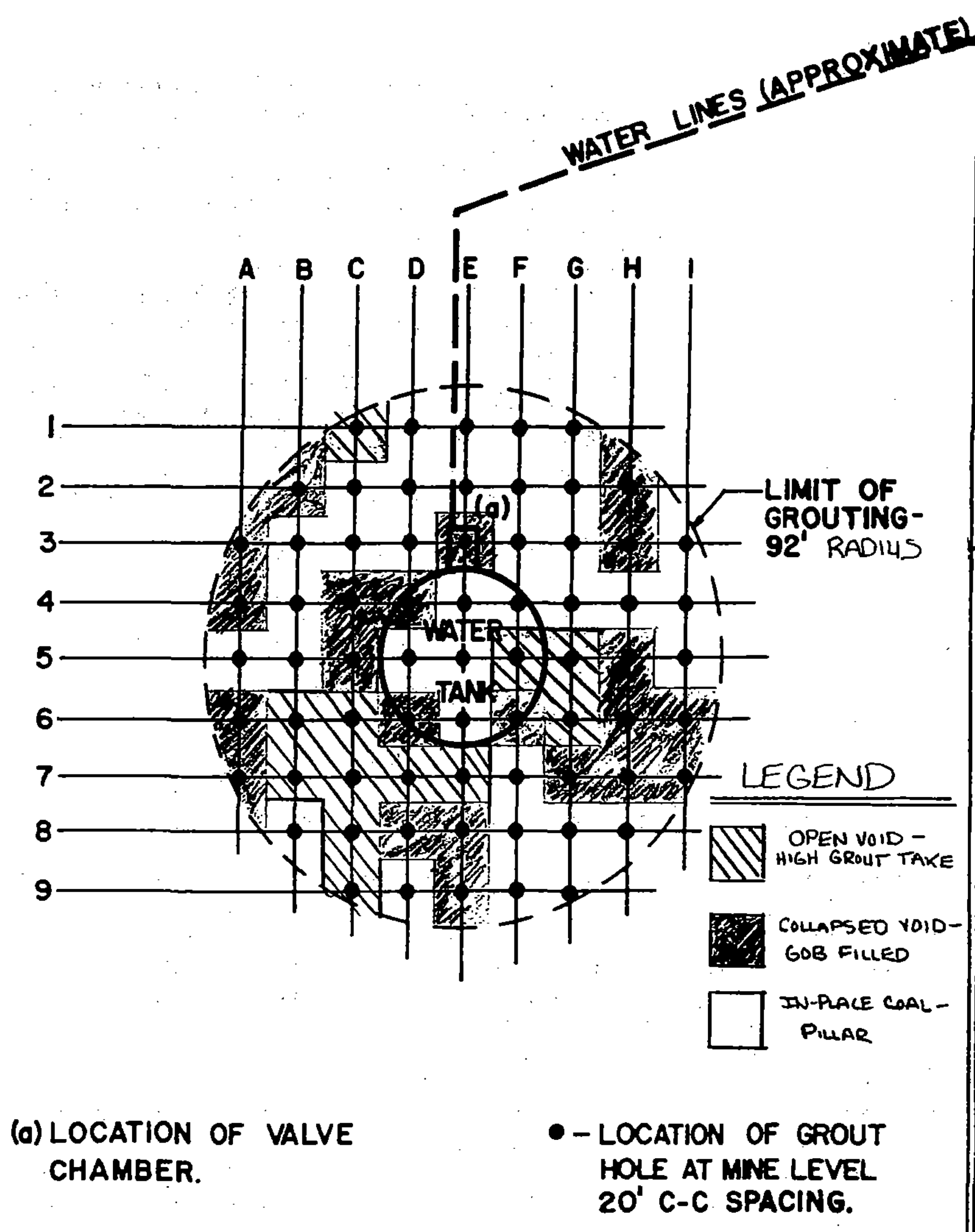
water tank is the highest point in Allegheny County. During the construction of new S.R. 60, Moon Clinton Road was relocated and lowered. Due to the close proximity of the mined Pittsburgh coal under old Moon Clinton Road, the coal was undercut, removed and backfilled with replacement embankment to eliminate any chance of future subsidence under Moon Clinton Road. Because of this under cut and the adjacent cut on mainline, a grout program occurred to back fill the mine and stabilize the area under the water tank prior to excavation. Approximately 80 100-foot grout holes were drilled to inject the grout. Approximately 2,000 cubic yards of grout were needed to accomplish this program (Figure 2-6). Figure 2-6 depicts the findings of this program which determined areas of in-place coal (remaining pillars), gob filled areas and zones of open voids which experienced high grout takes.

0.1	65.3	Turn right onto ramp to PA 60 south.
0.3	65.6	Proceed to Stop 2. Landslide on the right at the end of the ramp poses a threat to a pipeline parallel to the highway.

STOP 3
Stabilized Landslide

A geotechnical investigation was conducted for a landslide within Detention Basin No. 5 located along the Southern Expressway, S.R. 6060, between the Moon Clinton Road and Midfield Terminal interchanges, during the Summer of 1994. The landslide is located approximately 150 feet to 200 feet right of the southbound lane on the southwest side of Detention Basin No. 5. The most significant concern of the landslide was its impact on a 24" natural gas pipeline located approximately 35 feet upslope of the main scarp of the landslide. Additionally, the landslide resulted in a partial blockage of the riser outlet pipe for the detention basin and decreased the capacity of the reservoir.

To monitor movement of the slide, standard inclinometer casings were installed in Borings D1 and D2 during the subsurface investigation of the landslide in August, 1994. The inclinometer casing was installed to an approximate depth of 32 feet in Boring D1, located upslope of the Columbia Gas transmission line, and to a depth of 36 feet in Boring D2, downslope of the gas pipeline. Upon completion of the inclinometer installation on August 23, 1994, baseline readings were obtained for both inclinometer on August 30, 1994. The inclinometer readings were obtained using Slope Indicator Company equipment that includes the Digitilt Inclinometer Probe and the Digitilt Datamate data capture device. After the baseline readings were obtained, readings were taken approximately every two weeks.



ATTACHMENT TO FOUNDATION GROUTING SPECIAL PROVISION

WATER TANK GROUTING PLAN

SCALE 1" = 50' S.O. No 16539-ARA

DATE 6-1-90 FILE

Figure 2-6

A total of 6 rounds of readings were obtained for Inclinometer D1, and 7 rounds of readings for Inclinometer D2, from September 20 to November 30, 1994.

The results of the monitoring indicate Inclinometer D1 has experienced virtually no movement and an extremely small amount of cumulative movement of approximately 0.10 of an inch or less was detected in Inclinometer D2. Figure 2-7 illustrates inclinometer output from a different project where significant movement was detected over a period of time. This figure is included to demonstrate the value of this type of instrumentation in monitoring of slope movements. Notice, in the first of the two graphs, a sharp change in the graph has occurred at approximately 32 feet in depth. This indicates significant movement was occurring at that depth along a failure plane. The second graph illustrates the rate of movement or amount of movement that has occurred over time. Both graphs provide important data on slight or significant subsurface movements in failing soils.

Road Log Continues from Stop 3.

9.5	66.1	Bear off right onto ramp to airport.
1.3	67.4	Passing departure gates at the landside terminal.
0.7	68.1	The "Governor's Overlook" overview of construction of the New Midfield Terminals, Optional Stop 3.

OPTIONAL STOP
Governor's Overlook

The "Governor's Overlook" provides an excellent overview of construction of the New Midfield Terminals. Figure 2-8 presents an overview of the Midfield Terminal Site Complex. The scope and magnitude of this project made it a geotechnical engineer's dream. Picture now typical airline passengers parking their car in the long-term parking lot and walking through the terminal of the future to their planes; they get a chance to pass over several different types of foundations, each working together to provide a firmly supported complex (Figure 2-9).

As patrons leave their cars, the passengers stand on areas that are either in a rock cut, that is up to 75 feet deep, or on top of a 65-foot high embankment section depending on which area of the parking lot they are located. Passengers enter the enclosed walkway supported on spread footings in either soil or rock. The walkway continues onto a bridge structure supported by caissons and then crosses over the Parking Garage supported by caissons. They then cross into the Landside Building that is supported on three types of foundations due mainly to its large size: the northern end of the building is supported on

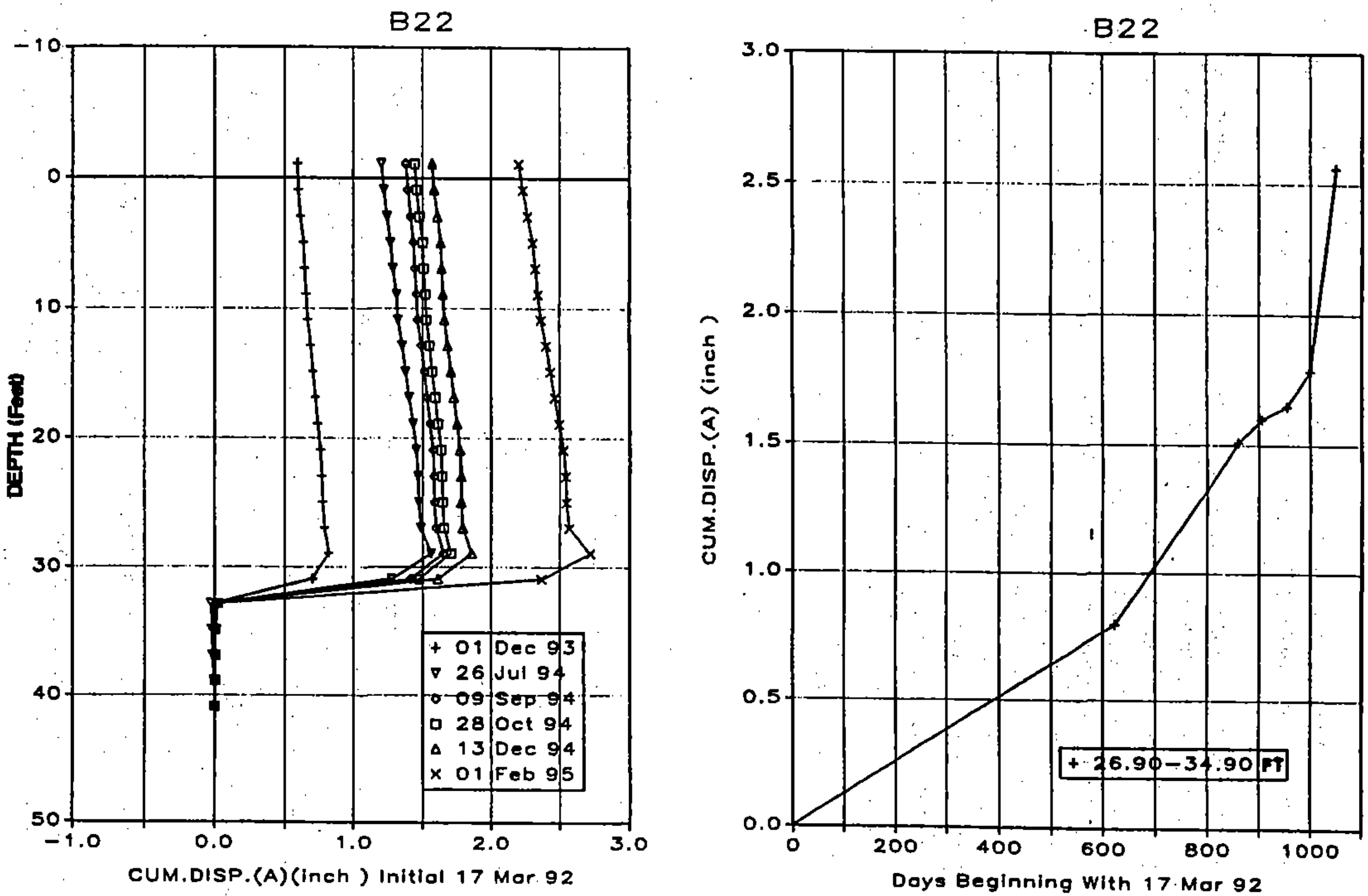

B22
DEPTH (Feet)
CUM.DISP.(A)(inch) Initial 17 Mar 92
+ 01 Dec 93
▽ 26 Jul 94
◇ 09 Sep 94
□ 28 Oct 94
△ 13 Dec 94
× 01 Feb 95
B22
CUM.DISP.(A) (inch)
Days Beginning With 17 Mar 92
+ 26.90–34.90 FT

Figure 2-7

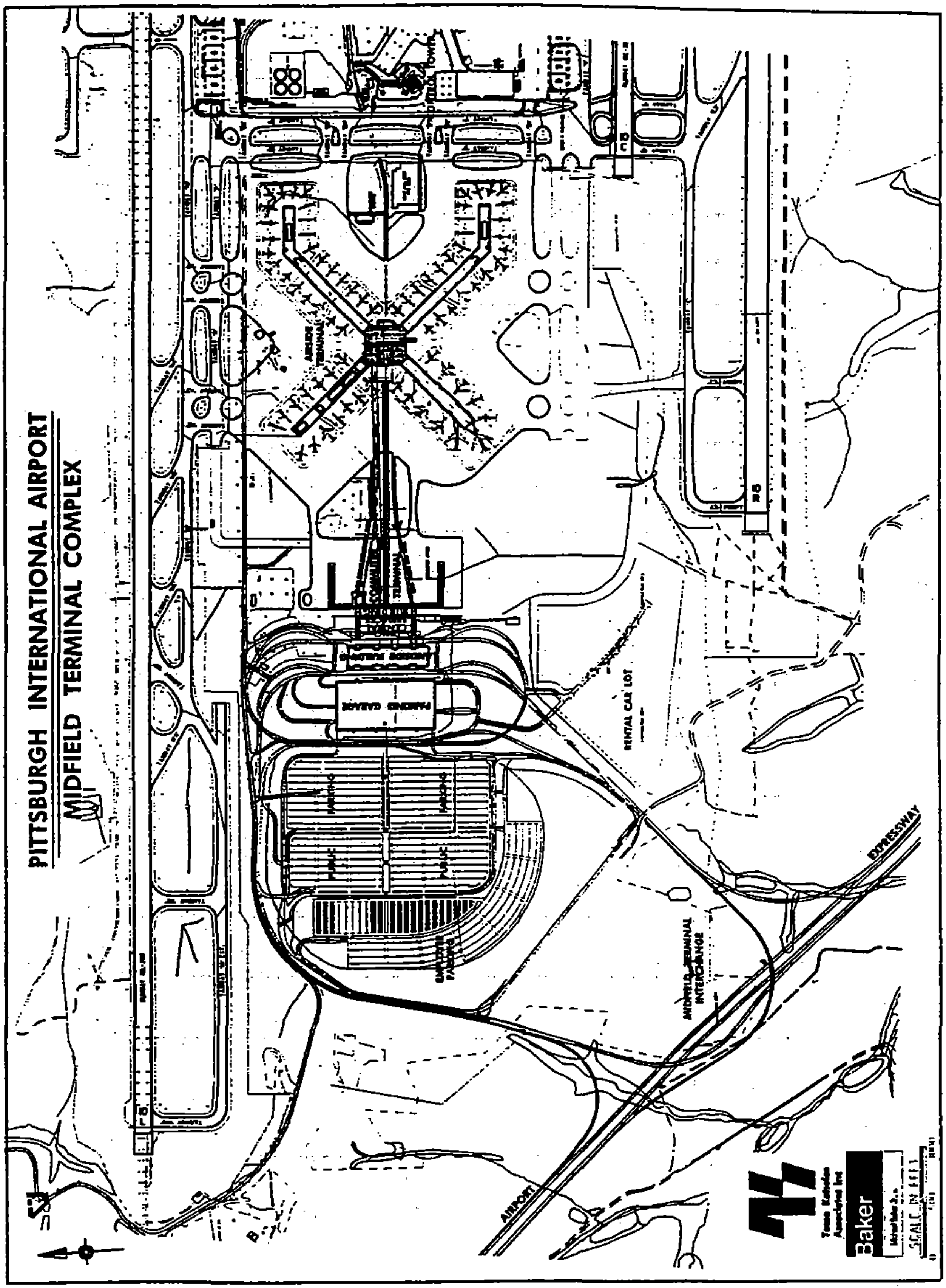


Figure 2-8 Pittsburgh International Airport Midfield Terminal Complex.

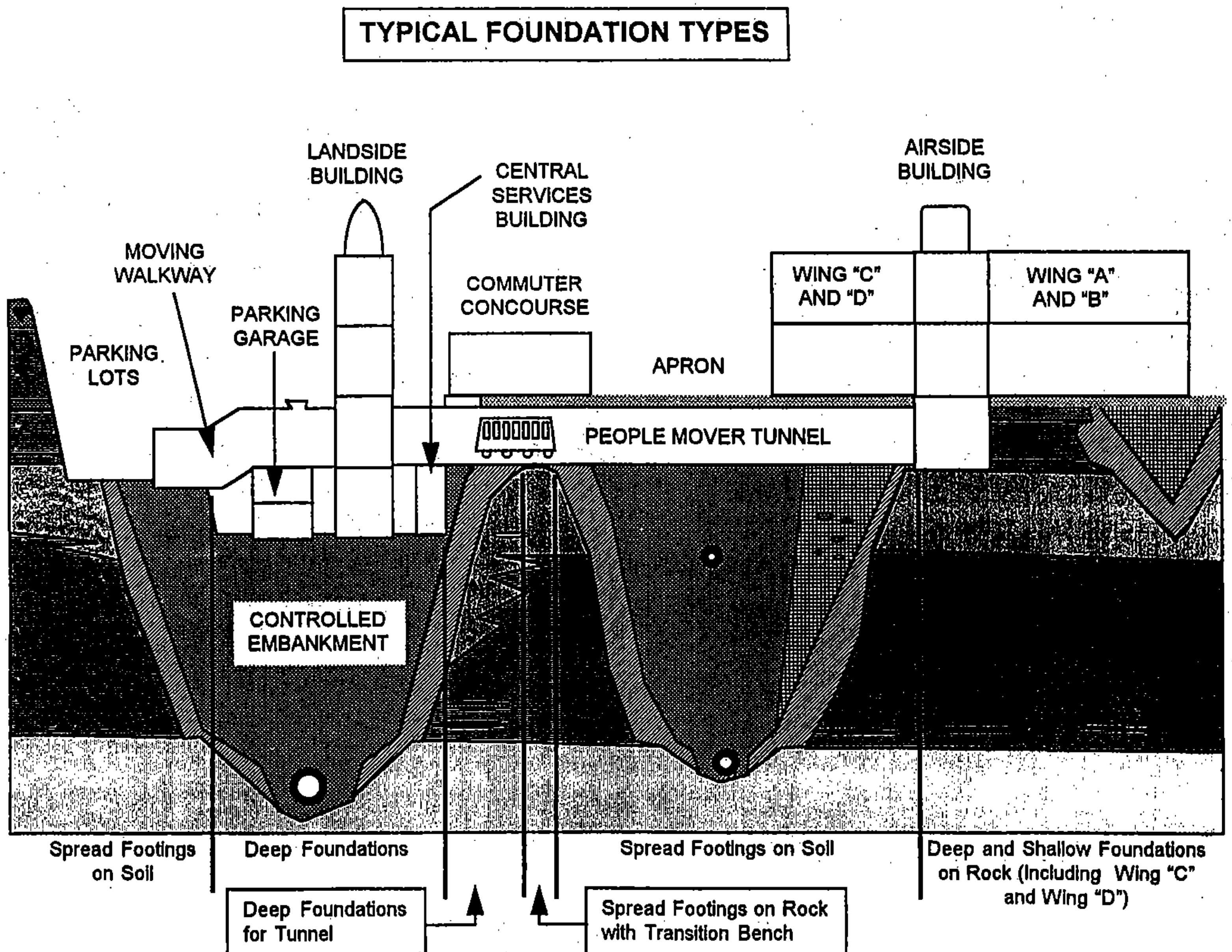


Figure 2-9 Typical foundations at the Pittsburgh International Airport Midfield Terminal Complex.

spread footings on rock and the southern portion of the building is supported on pedestals on rock, then on auger cast piles.

The passengers proceed to the people mover system. At the western end, this system passes over a bridge supported by auger cut piles and through a tunnel supported by auger cast piles. Still moving forward in the tunnel, it passes over spread footings on rock, followed by spread footings on soil as it crosses an embankment area that was preloaded with a 17-foot high surcharge embankment to reduce long-term settlement.

At the eastern end of the people mover system passengers enter the lower floor of an Airside Building that is supported on four different types of foundations, depending on the location within the building Spread footings on rock are used where rock is at footing elevation, while in transition areas pedestals are used. Auger cast piles were used in areas where the depth to rock exceeded 50 feet. When the depth to adequate bearing exceeded 50 feet, steel H-pile section were used. A small area of the Airside Building core also is supported on short steel H-piles that were installed to maintain the construction schedule prior to approval of the auger cast pile alternative. Finally, as our passengers cross from the Airside Building to their airplanes they pass through an enplaning bridge (jetway) supported on a concrete caisson.

Table 2-1 provides a breakdown of the pile and caisson quantities installed on this project.

Structure	Steel H-Pile (lineal foot)	Auger Cast Pile (lineal foot)	Caissons (lineal foot)
Landside*	—	170,384	—
Airside	29,507	172,182	3,225
Tunnels	7,070	51,568	161**
Parking Garage	—	—	19,610
Bridges	22,642	***	****
Totals	59,219	394,134	22,996

* Landside Building includes Central Services Building

** Installed for Baggage Building

*** Length of auger cast pile used to support bridge structures adjacent to Landside Building is included with Landside Building.

**** Moving sidewalk bridge quantities included with Parking Garage.

A total of 476,349 lineal feet or about 90 miles of deep foundation systems, not including pedestals, were installed for this massive project. To put this in perspective, this is as far as from here to Erie or a greater length than we will travel today on this trip. (For those who may wonder, the total volume of soil and rock removed from the deep foundation holes was about 23,750 cubic yards). An additional 17,416 lineal feet (three miles) of pile pre-drilling holes were drilled and abandoned due to construction errors, hole cave-in, or re-design that occurred after initial piles had been installed. Based upon project performance to date, these various foundation systems are performing as expected.

Road Log Continues from Optional Stop

0.5	68.6	Ramp to PA 60 south.
0.6	69.2	Rejoin PA 60 south.
0.8	71.0	In the distance on the forward left is a landslide adjacent to the same gas line as at Stop 2.
0.6	71.6	Bear right on off ramp to McClaren Road.
0.4	72.0	Upper and lower Pittsburgh limestone, in the Casselman Formation below the Pittsburgh coal bed, is exposed in the cut on the right.
0.2	72.2	End of ramp. Turn left onto McClaren Road.
0.1	72.3	Bridge over PA 60.
0.7	73.0	Downhill past Pennsylvania Air National Guard entrance. The Morgantown sandstone is well exposed on left and right.
0.2	73.2	Old road blocked on the right. Use this to turn around and head back.
0.5	73.7	New Pennsylvania Air National Guard entrance on the right. Amusing problem with gates.
0.4	74.1	Pull off to side of road, Stop 4.

STOP 4
Pittsburgh Coal Mine Seals

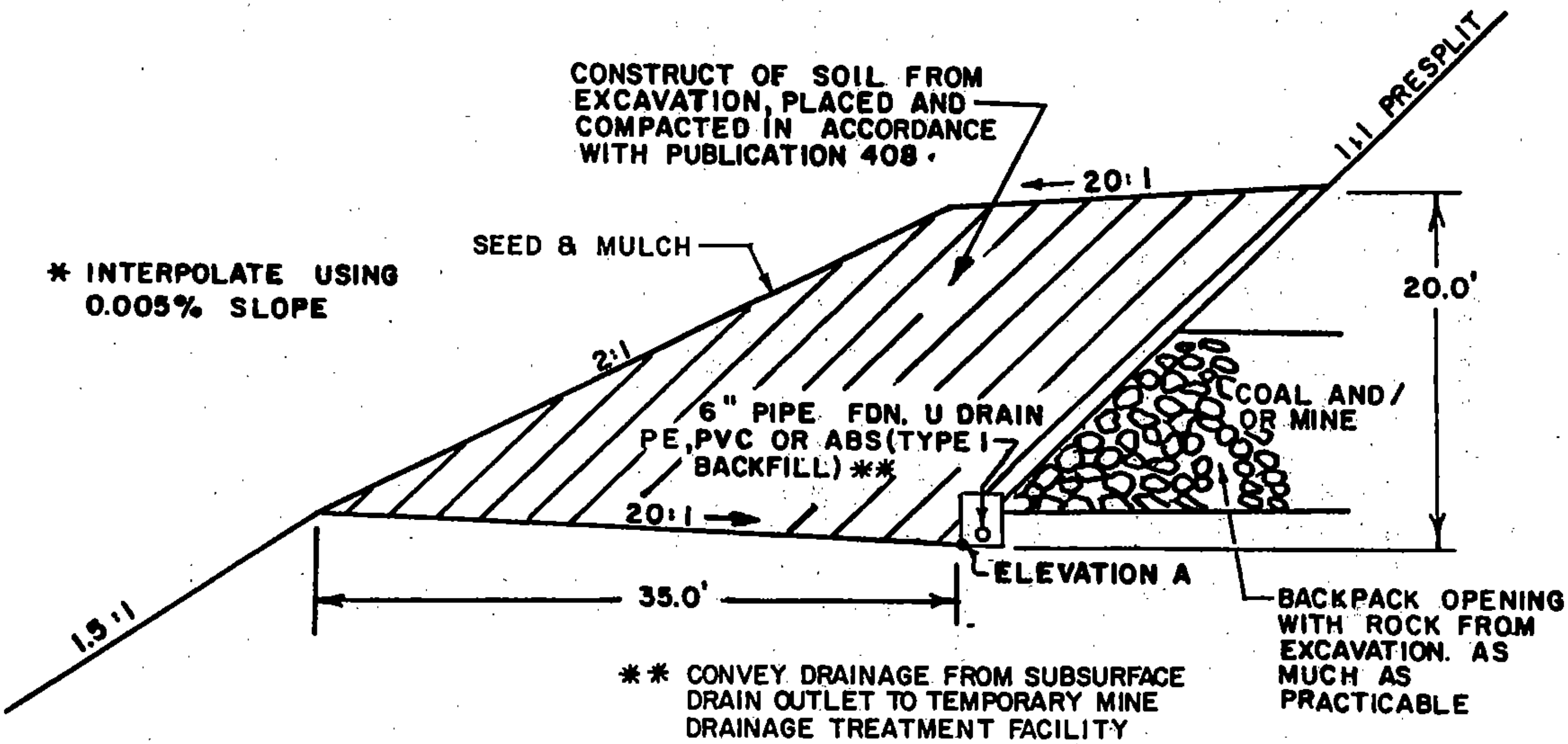
Leave bus and walk uphill about 50 yards to view a number of coal-mine seals in the Pittsburgh coal bed. This interchange is constructed in the lower Monongahela and upper Conemaugh Groups, specifically the Pittsburgh and Casselman Formations. The Pittsburgh coal is present approximately 50 feet above S.R. 60 grade elevation. The coal was deep mined by room-and-pillar mining methods in the early 1900's and subsequently surface-mined along the crop line. The coal has a localized synclinal structure within the interchange with the low area located in the northwest corner of the interchange (off to your right looking towards the Airport). The coal was as low as elevation 1,132 feet amsl in this area and as high as elevation 1,144 feet amsl in the southwestern corner of this same interchange (looking towards the town of Imperial). Because of this localized fold, the old Pittsburgh coal mine was subsequently flooded.

Since this entire interchange is below the elevation of the coal (therefore in cut), the mine had to first be dewatered prior to any excavation into or below the mine. A 12-inch diameter boring was drilled into the low portion of the mine (approximate elevation 1,132 amsl), to establish a pumping location to dewater the mine. Water pumped from the mine was piped to a temporary mine drainage treatment facility located in the valley to the northwest. Here, mine drainage was treated with either soda ash or potassium permanganate briquettes to bring the water to regulatory standards for pH, iron, manganese, alkalinity, acidity and suspended solids. Monitoring wells were measured to record the mine pool drawn down to establish when the mine was actually dewatered and when excavation could actually commence. Millions of gallons of water were pumped and treated from this mine prior to development of the cuts. The coal face was ultimately covered with an embankment seal and underdrain (Figure 2-10). From this location, six coal or mine seals can be observed.

Another issue related to stratigraphy playing a major role in the construction sequencing was the availability of quality durable rock. Typically, bases of embankments, old stream valleys and undercut areas are filled with rock prior to construction of the soil embankments. This particular project attempted to tighten the specification of this rock to ensure that on-site, durable, competent rock be placed in these areas. This rock was available on site from the Pittsburgh limestones and the Connellsville sandstone (in areas) but it required very careful sequencing of the construction work to best utilize the available natural materials.

Road Log Continues from Stop 4.

0.2	74.3	Turn left onto Aten Road.



TYPICAL SECTION
MINE SEAL

Figure 2-10

0.6	74.9	Stop sign at Old Ridge Road. Continue straight.
0.2	75.1	Stop sign at Cranbrooke Road. Continue straight.
1.1	76.2	Traffic light at T intersection with Cliff Mine Road. Turn left.
0.2	76.4	Follow Cliff Mine Road under PA 60 overpass.
2.1	78.5	Traffic light at entrance to Robinson Towne Center. Turn right uphill.
0.6	79.1	Pull off to view North Fayette Township Interchange, Stop 5.

STOP 5
North Fayette Township Interchange

This stop is an overview of the construction of the future North Fayette Township Interchange from old Steubenville Pike (Figure 2-11). This project is a Public-Private Partnership between the Federal Highway Administration, the Pennsylvania Department of Transportation, the Township of North Fayette and Metro Property Developers. The prime contractor performing the work is Atlas Services. Observations at this site will be dependent on the contractor's work operations around the time of our field trip. Possible activities or operations to review include toe bench and undercut development, cut excavation, high embankment culvert installation, induced trench development, rock embankment placement (408, 408 modified and 510 modified) and culvert relining under the existing Parkway.

Road Log Continues from Stop 5

79.3 Entrance to IKEA.

79.5 South end of IKEA parking lot.

END OF Road Log, Day 2.

Stop 5

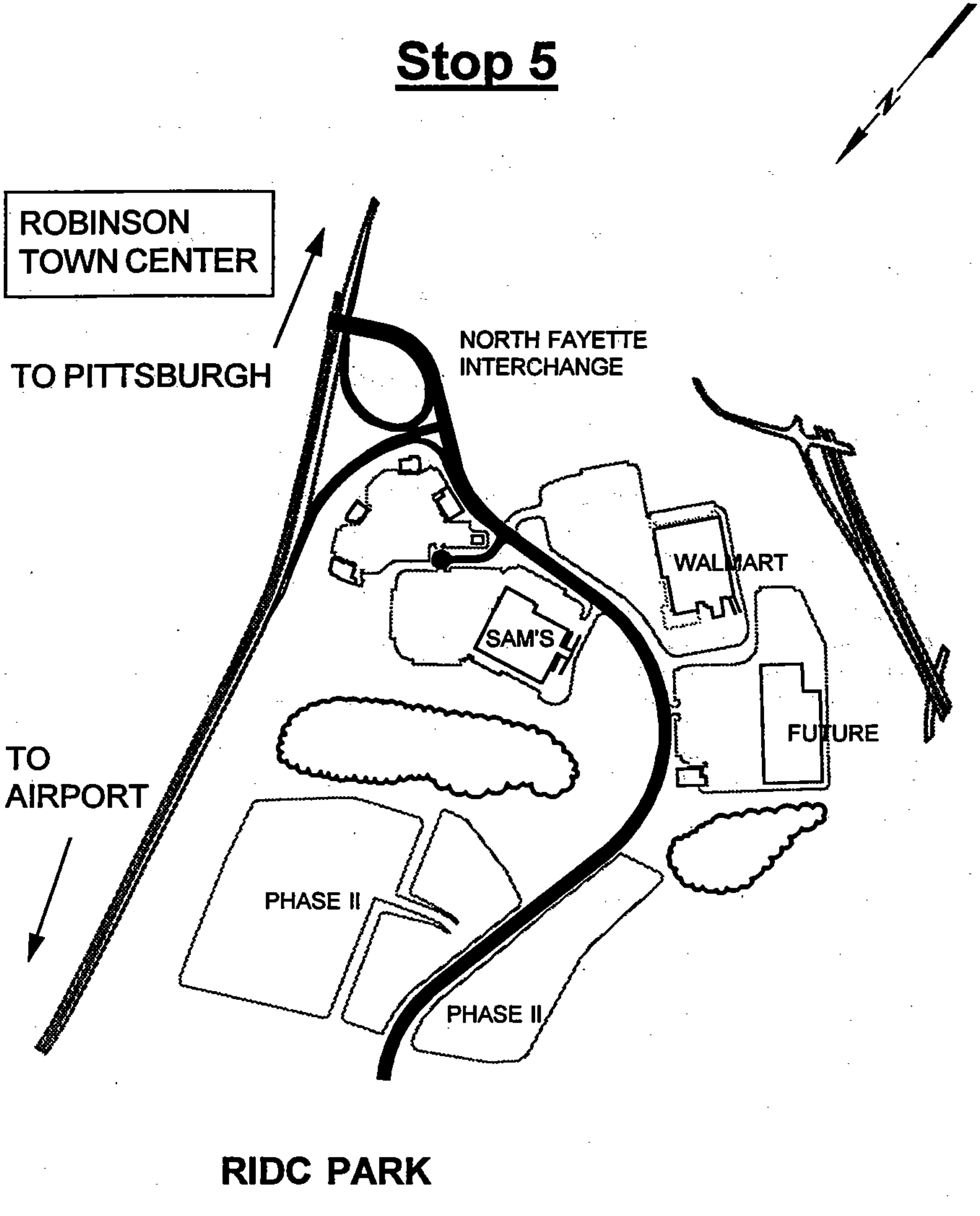


Figure 2-11

Day Three
Sunday, May 21, 1995

BEDROCK GEOLOGY AND URBAN GEOLOGIC PROBLEMS OF NORTHERN ALLEGHENY COUNTY, PENNSYLVANIA

Trip Leaders:
Charles H. Shultz, Slippery Rock University of Pennsylvania
John A. Harper, Pennsylvania Geological Survey
Judith E. Neelan, Pennsylvania Department of Environmental Resources

Introduction

Welcome to the third day of the Pittsburgh Geological Society's 50th Anniversary Field Trip. This day has been designated the "Fossils and Stratigraphy" day, but in reality you will be seeing a lot more than just fossils and strata. There's a little bit for everyone, from geologic structure to soft-sediment deformation, from landslides long past to landslides active now, from ancient stream channels to even more ancient animals.

On this trip we will be visiting five sites in the northern half of Allegheny County. The first site is a roadcut along I-279 near the Camp Horne Road interchange that exposes one of western Pennsylvania's more important, more interesting, and **most destructive** portions of the local stratigraphic section. The second site, Fall Run Park in Shaler Township, is a beautifully preserved (mostly) little segment of western Pennsylvania as it might have looked 200 years ago. But look closely – thanks to the environmental problems inherent in developing Pittsburgh's suburbs, it might not be around much longer. The third site is the famous Bakerstown Station railroad cut which exposes some of the most complex geologic structure in southwestern Pennsylvania. Stop 4 is the Witco Corporation plant near Bakerstown Station where movement in the unstable claystones of the Pittsburgh red beds is having a destructive impact on a parking lot and to one of the company's buildings. The fifth site, on I-79 at the Wexford exit, is a view of an ancient meandering stream in cross section showing both lateral and vertical aggradation.

Meeting Point: Carmody's Tavern and Banquet Hall
Meeting Time: 8:00 AM to 8:30 AM. **DISEMBARK AT 8:30 AM PROMPTLY.**

Mileage Interval	Mileage Cumulative	Field Trip Itinerary
0.00	0.00	Parking lot of Carmody's tavern and banquet hall on Route 910 just west of the Wexford exit of I-79 (Figure 3-1). Turn left onto Nicholson Road.

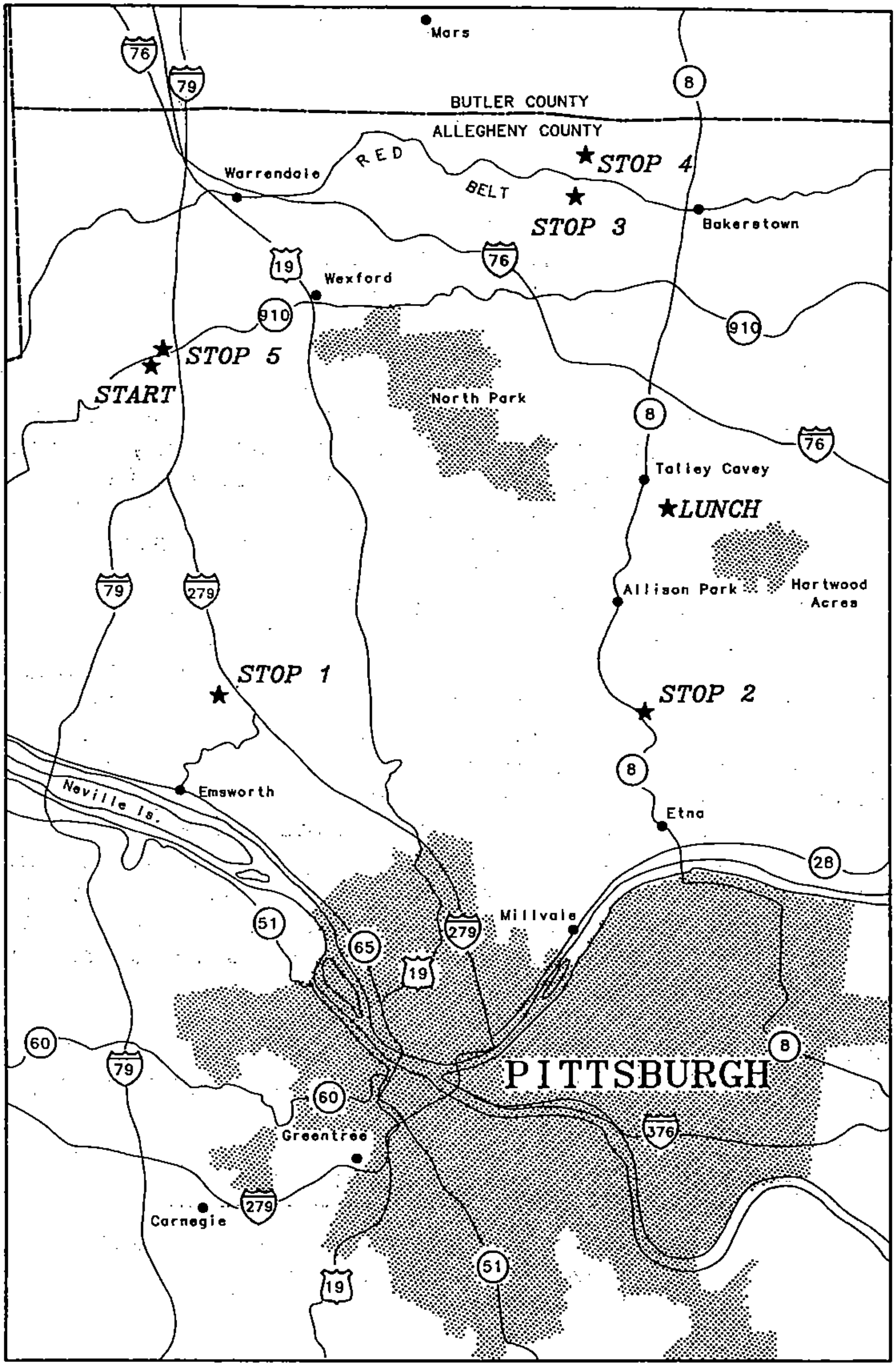


Figure 3-1. Map showing the locations of field stops for Day Three.

0.10	0.10	Turn right onto Route 910 (the Orange Belt) and head east toward Wexford.
0.20	0.30	Turn right onto the entrance ramp to I-79 southbound.
0.40	0.70	Merge left into traffic on I-79.
1.00	1.70	Connellsville sandstone (upper Casselman Formation) outcrop on right.
0.85	2.55	Roadcut on right side of highway exposes a small, gentle anticline and syncline in the Clarksburg limestone and overlying Connellsville sandstone. The Clarksburg limestone here contains numerous nonmarine fossils, mostly ostracodes and worm tubes (*Spirorbis*). The folds seen here are not tectonic in origin. They represent draping caused by differential compaction of mudrocks and sandstone.
0.15	2.70	Bear left onto southbound entrance to I-279.
1.00	3.70	Roadcuts on the left over the next 0.45 mi. expose thick sequences of lower and middle Casselman Formation sandstones that probably consist of Combined Morgantown and Birmingham units.
0.70	4.40	Roadcut on the left extends approximately 0.3 mi. to the south, exposing a thick sequence of sandstone. A cursory look at this outcrop as you drive by appears to reveal a single sandstone unit. However, there are some distinct differences within the sandstone. The lower portion of the outcrop consists of thick-bedded, massive, gray sandstone, highly fractured in a nearly circular pattern, with mineralization stains along the fractures. The upper part of the outcrop consists of massive yellowish sandstone, very different from the lower part. Around the bend from where the outcrop begins, a thin coal seam with underlying dark-colored shale splits the seemingly single sandstone unit into two discrete units. In stratigraphic terms, what you see is the Wellersburg coal and shale interval separating the underlying Birmingham sandstone from the overlying Morgantown sandstone. The coal and shale disappear abruptly to the north beneath a Morgantown stream channel that has scoured into the top of the Birmingham.

0.75	5.15	Roadcut on the left is a good illustration of the state highway department's approach to reducing erosion of roadcuts by cutting numerous small terraces into sloping surfaces. We will see more of this technique at Stop 1.
0.75	5.90	Small landslides (earth-flow lobes) in the unstable mudrocks of the upper Glenshaw Formation (Pittsburgh red beds) occur on the right. These rocks are very unstable and have caused numerous problems for homeowners and highway engineers for as long as people have lived in southwestern Pennsylvania.
0.65	6.55	Turn right onto dirt access road leading to large roadcut on the right and park on the flat area below the terraces.

STOP 1
LARGE ROAD CUT ON I-279 NEAR CAMP HORNE ROAD

Passengers will disembark from the bus and gather around for a brief lecture before climbing the slope. As you ascend the cut, try to take some time looking at the various lithologies at each terrace or bench. You might be surprised at what you find.

Stratigraphy

This large roadcut exposes the strata of the middle Conemaugh Group, from the Upper Saltsburg sandstone at the base to the Morgantown sandstone at the top. From the base of the cut upwards, you will encounter the following section (Figure 3-2): 1) gray sandstone at the level of the parking area; 2) seven terraces of red and gray claystones (red beds) containing caliche nodules; 3) five terraces of red and gray claystones, very weathered, with some spheroidal weathering, greenish reduction zones, root casts, manganese dendrites, and questionably, some trace fossils; 4) the Ames Limestone Member; 5) two terraces of red and gray claystones; 6) the top terrace, containing a small lens of gray sandstone and a barrier of large sandstone blocks used to prevent rockfalls from reaching the highway; and 7) the steep flat face of sandstone at the top which contains a basal layer of mud chips and slabs that exhibit soft-sediment deformation, indicating an origin in stream-bank failure. The sandstone originated as a channel deposit, but the exact nomenclature is in question. As with the roadcuts to the north, this might be a combination of Birmingham and Morgantown sandstones, or it might represent only one of them. Notice the irregular base of this rock unit, typical of stream channels that cut into the surrounding strata and then fill the gaps with sand.

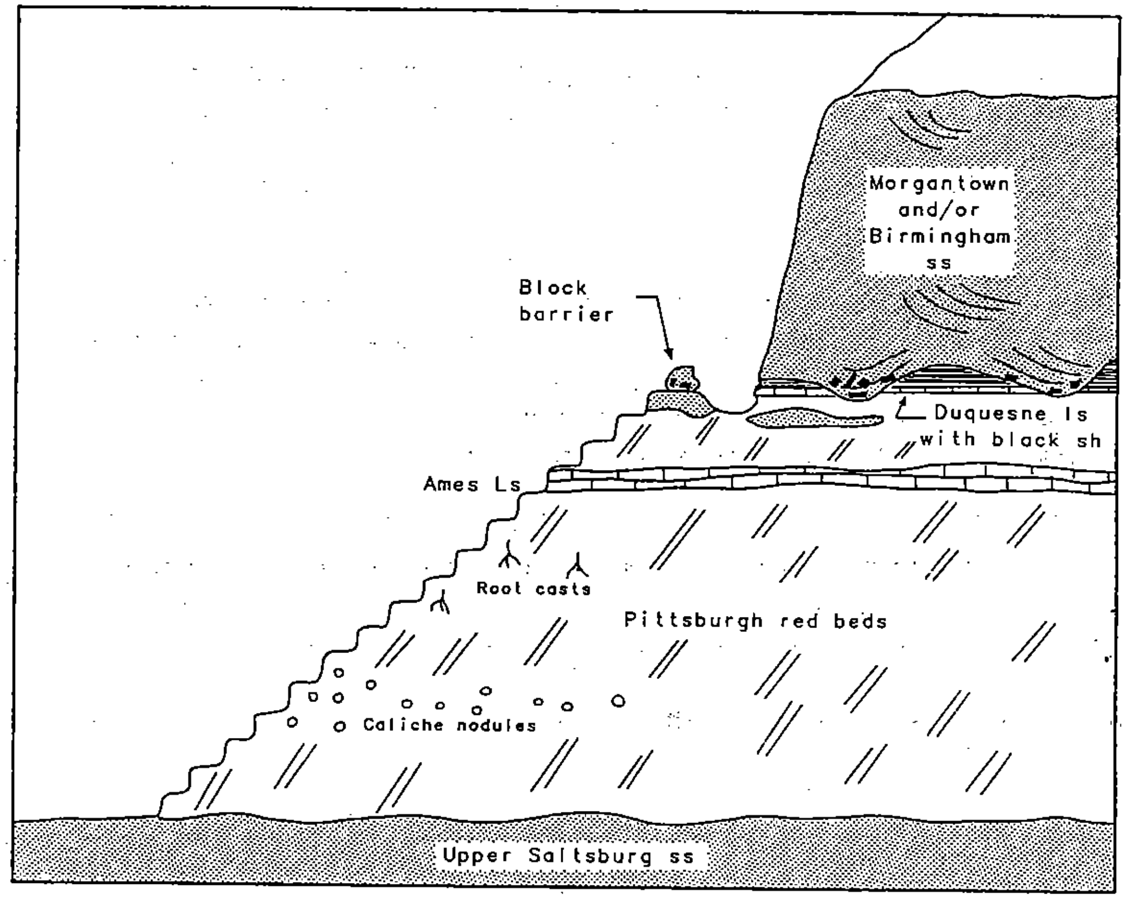


Figure 3-2 **Generalized cross section of the roadcut on I-279 just north of the Camp Horne Road exit (Stop 1).**

Geotechnical Aspects

The cyclic nature of the rocks of western Pennsylvania creates a plethora of construction problems because of their diverse and heterogeneous nature. Although thick, massive sandstones such as that at the top of this roadcut might be relatively stable, the associated rocks typically consist of thin coals and limestones and thick sequences of mudrocks that have a tendency to fail under the seemingly minor stress situations, like gravity. Each of these rock types possess different physical properties that, in conjunction with climate, slope, and other factors, affect their stability. For example, the Pittsburgh red beds, which are notorious as the cause of most landslides in the Pittsburgh area, slake rapidly in water. Kapur (1960) found that these typically red claystones tend to lose strength with each seasonal cycle (freeze-thaw, wetting-drying). Porosity is relatively high, up to 40% according to Pomeroy (1980), but permeability is very low; therefore, the water that collects in the rock has little chance of draining and ends up helping to destablize the claystone from the inside out. In comparison with an "average" Conemaugh sandstone, the Pittsburgh red beds have little strength (Table 1). Since the red beds constitute only one of numerous unstable rock units, most of the local geologic section has caused headaches among western Pennsylvania's engineering firms.

Table 1. Rock test data for the Pittsburgh red beds and Saltsburg sandstone (McGlade et al., 1972).

CHARACTERISTIC	PITTSBURGH RED BEDS	SALTSBURG SANDSTONE
Shear normal to bedding	320 psi	974 psi
Shear cross-angle to bedding	466 psi	1,255 psi
Unconfined compressive strength	1,661 psi	9,991 psi
Tensile strength	576 psi	4,330 psi
Bearing capacity	4-8 tons/ft^2	25 tons/ft^2

The terracing of roadcuts, called serrated slopes, can be seen along I-279 between this locality and East Ohio Street on the North Side. The original intent of this type of terracing was in helping to develop a soil profile and vegetation growth, and therefore to prevent erosion, on slopes underlain by medium hard rock. However, the project engineer decided to use it everywhere except on the sandstone cliffs, regardless of rock strength (W. Adams, personal communication, 1995). There are two main reasons this technique does not work very well on these slopes: 1) the red beds tend to collect water and saturate the slope, rather than sheeting off as originally intended; and 2) seeding, which was supposed to begin within days of completion of the terraces, never occurred. No seeds - no plants - no erosion control.

Fossils

A large variety of fossils can be found in several strata at this locality (Figure 3-3). The claystones within the interval of the Pittsburgh red beds contain vertical stains that probably represent casts of land plants growing in a paleosoil. It also might be possible to find a few trace fossils of "worms" that crawled over stream bottoms in the thin sandstones in this interval.

The Ames Limestone is, arguably, the most fossiliferous stratum in western Pennsylvania. It contains a wholly marine fauna dominated by brachiopods and horn corals, but also has a rich molluscan assemblage of snails, clams, and cephalopods. Less obvious elements include "algae," foraminiferans, bryozoans, chiton plates, trilobites, crinoids (both intact and disaggregated), isolated starfish plates, and shark teeth. It also contains a wealth of trace fossils.

The Duquesne interval, which occurs just below the nearly vertical sandstone cliff at the top of the cut, is well known for its nonmarine fish fossils. Outcrops of the Duquesne limestone around the Pittsburgh area are particularly fossiliferous, containing large quantities of the worm tube *Spirorbis*, ostracodes, and conchostracans, in addition to the remains of bony fish and lungfish. The jet black shale lying above the Duquesne limestone also contains the remains of many fish. By carefully splitting the shale a collector may find hundreds of small, rhomboidal scales of the bony fish *Elonichthys*, as well as the spines and bones of this and other fish. It is possible at times to find patches of scales, indicating that the remainder of the fish may be present within the rock (Figure 3-3). Finally, the sandstone at the top of the cut contains a basal lag deposit of logs and other plant debris in association with abundant mud chips and slabs. These can be seen in many of the blocks laid out at the top of the terraced portion of the cut.

Fossils of the Ames Limestone

The Ames Limestone typically occurs in several easily identifiable layers, including a 0.5-3 in (1.25-7.5 cm) basal layer of hard calcareous shale, 18-36 in (45-90 cm) of very hard, very fossiliferous, argillaceous limestone, an upper layer about 10 in (25 cm) thick of brittle calcareous shale and all of these layers contain fossils (Figure 3-3).

The basal layer, which Brezinski (1983) called the calcareous shale lithofacies and Saltsman (1986) referred to as *Neochonetes*-mollusc shale lithofacies, commonly contains a hash of phosphatized shell debris and organic-matter stains. This is the molluscan layer of the Ames representing the initial transgressive phase of the Ames seaway into Pennsylvania. It is dominated by snails and clams, with some nautiloids (probably floated in after death), brachiopods, particularly *Neochonetes granulifer*, and other faunal elements. Most molluscs have shell structures of aragonite, the metastable form of calcium carbonate; after death and burial the aragonite tends to dissolve or recrystallize

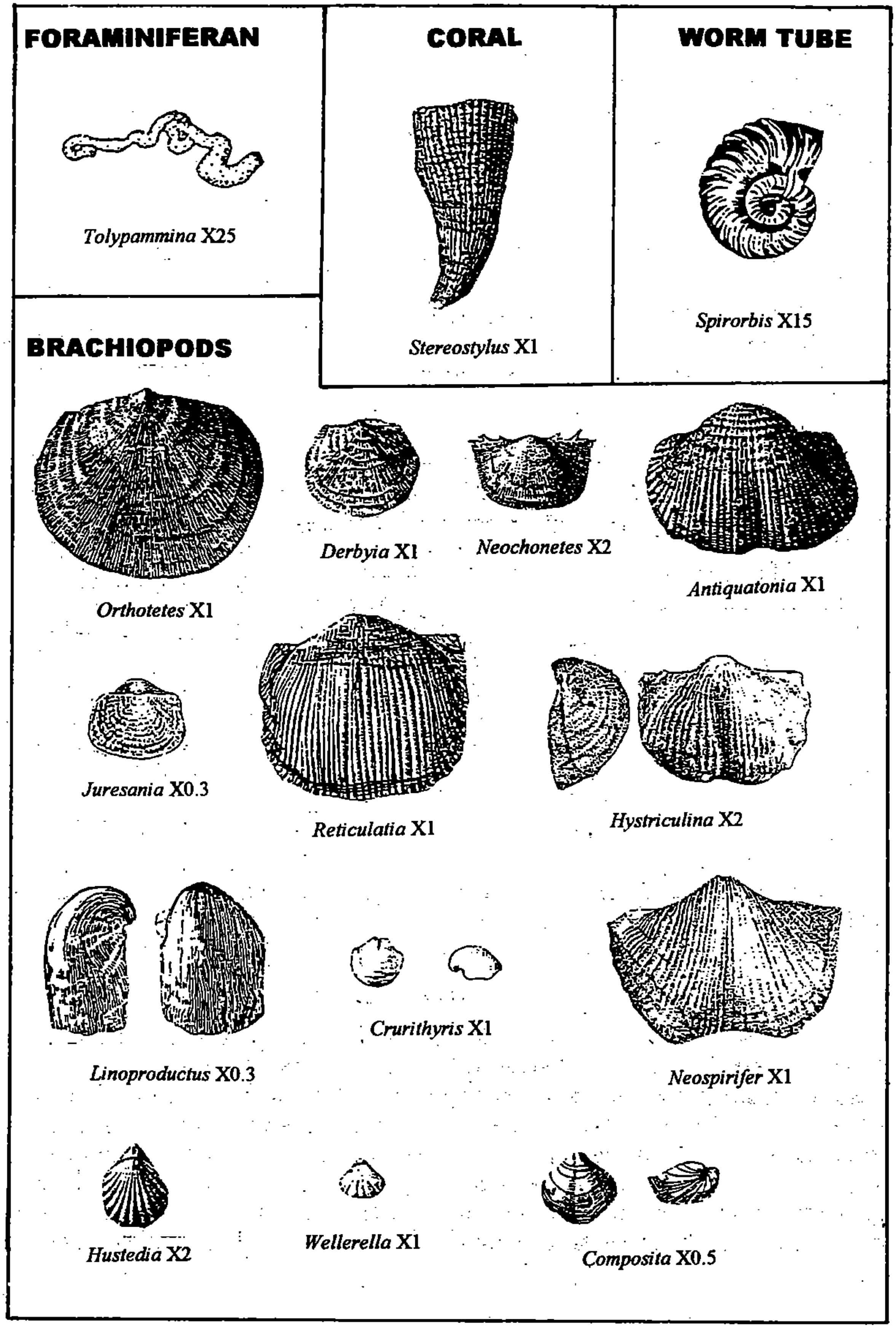
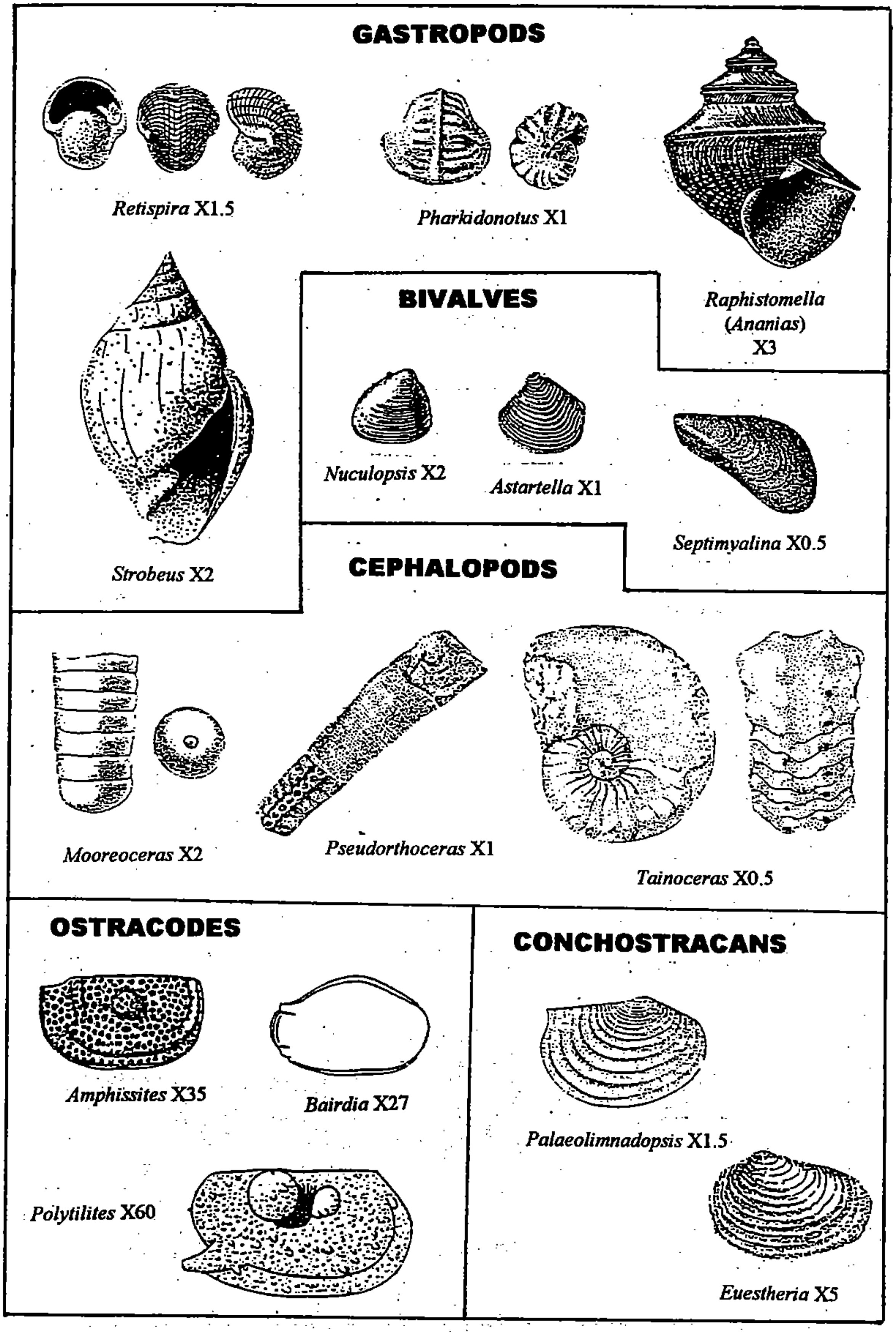
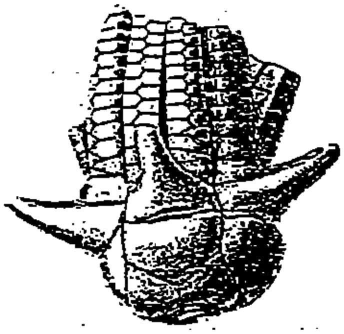


Figure 3-3 Common fossils that can be found in the Ames Limestone and Duquesne shale.

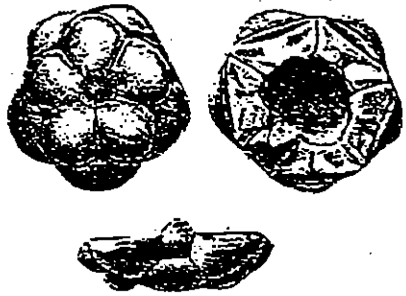

GASTROPODS
Retispira X1.5
Pharkidonotus X1
Raphistomella (Ananias) X3
Strobeus X2
BIVALVES
Nuculopsis X2
Astartella X1
Septimyalina X0.5
CEPHALOPODS
Mooreoceras X2
Pseudorthoceras X1
Tainoceras X0.5
OSTRACODES
Amphissites X35
Bairdia X27
Polytilites X60
CONCHOSTRACANS
Palaeolimnadopsis X1.5
Euestheria X5

CRINOIDS

Crinoid columnals

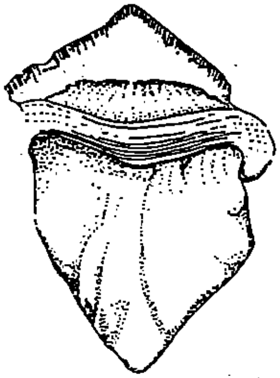


Delocrinus X1

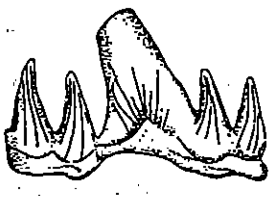


Endelocrinus X2

FISH

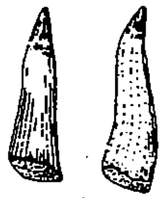


Petalodus X2

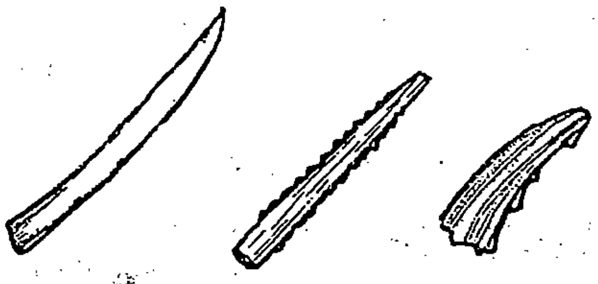


Cladodus X1.3

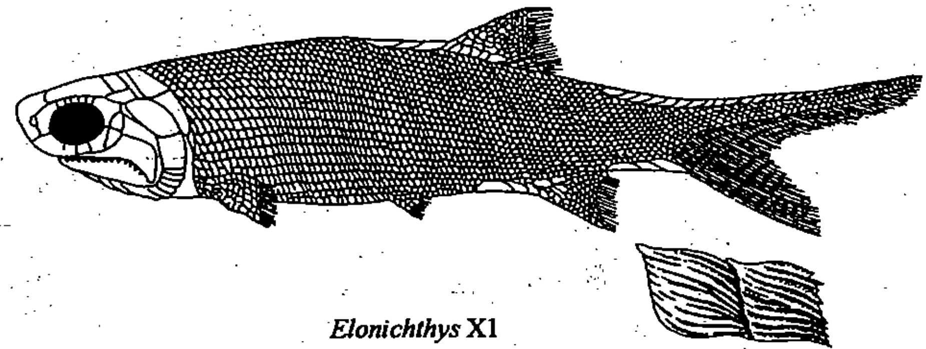
Diplodus X14



Paleoniscus X7

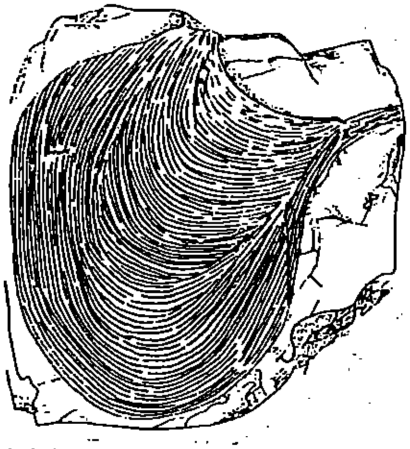


Miscellaneous fish spines X5

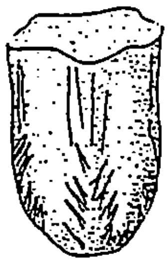


Elonichthys X1 with greatly enlarged scales

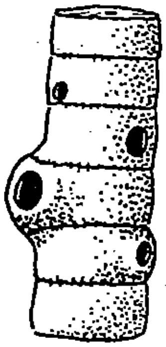
TRACE FOSSILS



Zoophycos X0.5

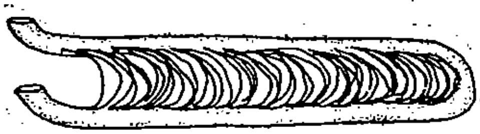


Conostichus X0.3



Tremichnus X1

Clionolithes X6



Rhizocorallium X0.6

Clionolithes X0.5

Zapfella X1

Zapfella X4.5

Conchotrema X2

into calcite. In this lower molluscan layer, however, many of the molluscan shells have been either preserved as aragonitic shells (probably due to the organic matter in the sediment) or replaced by phosphatic minerals that preserve them in exquisite detail. The enterprising collector might even be able to spot a fossil or two with preserved color banding highlighting the shells. Look for pieces of limestone that appear to be coated with tar or asphalt. The whitish blotches in this dark tar-like organic material are fragments of shell material.

The middle layer of limestone, seemingly representing a single depositional event, constitutes the Ames Limestone proper or what is regarded as the typical Ames. This "single" open-marine depositional event actually represents a sequence of deposits that have more or less coalesced. Layer boundaries are extremely difficult to detect, but can be seen in terms of accumulations of black phosphate pebbles and the horn coral *Stereostylus*. Saltsman (1986) recognized a variety of lithofacies in this layer, representing separate depositional environments.

The upper shale section of the Ames, which is highly weathered and not well exposed at this locality, typically contains abundant brachiopods (especially *Crurithyris* and *Composita*). *Crurithyris* commonly occurs in such abundance that it makes the rock look like a conglomerate. For this reason Saltsman (1986) called it the *Crurithyris* shale lithofacies. The rock itself consists of easily broken, buff-colored, slightly calcareous shales and other mudrocks, often containing a profusion of calcareous nodules, that represent the regressive phase of the Ames incursion. Fossil content decreases upward rapidly within this layer.

In most places where the Ames crops out, the collecting is almost unparalleled in western Pennsylvania. The easiest collecting occurs in the calcareous shales above and below the main limestone bed. These shales generally weather readily and the calcite shells, which are more resistant than the clay-rich matrix, readily erode out of the outcrop. In the limestone the rock and shells are equally resistant; therefore, the shells commonly break during attempts to remove them. Invertebrate shell fragments are commonly easy to find. More diligent searching is required to locate whole or almost complete specimens.

The most abundant marine invertebrate fossils in the limestones are species of the horn coral, *Stereostylus*, numerous kinds of brachiopods (especially *Crurithyris*), and the plates and columnals of crinoids. Many fossil forms, particularly molluscs, are more common, and easier to collect, in the lower unit. The Ames Limestone also contains many ichnofossils (trace fossils). *Conostichus*, interpreted as the resting trace of a jellyfish or sea anemone, occurs all through the Ames and can be collected near the upper surface. *Tremichnus* fossils, swollen pits in the surface of crinoid stems and plates, can be found almost anywhere crinoid debris is common. *Clionolithes*, *Conchotrema*, and *Zapfella* are tiny borings made by sponges, worms, or barnacles in fossil sea shells.

Road Log continues from stop 1

0.15	6.70	Exit STOP 1. Return to I-279 and turn right onto southbound lane.
0.75	7.45	Bear right onto exit ramp at Exit 21 to Camp Horne Road.
0.40	7.85	Turn right onto Camp Horne Road.
0.30	8.15	Buffalo sandstone exposed in roadcut on right and in numerous roadcuts from here down to the intersection with Route 65 in Emsworth.
0.60	8.75	Turn left into Avonworth Community Park.
0.10	8.85	Park in lot and disembark.
0.10	8.95	Return to Camp Horne Road and turn right.
0.60	9.55	Turn right onto entrance ramp to I-279.
0.60	10.15	Merge with traffic on I-279.
1.60	11.75	Exit 20 to Bellevue. Stay on I-279. From this point south to Pittsburgh most of the highway roadcuts exhibit the terraced aspect seen at Stop 1. The bedrock ranges from lower Casselman Formation to upper Glenshaw Formation (i.e., Birmingham shales and siltstones at the Bellevue exit down to the Upper Saltsburg sandstone at Suffolk Street across the highway from St. Boniface Church) and the entire section is prone to instability.
5.40	17.15	Bear right on exit ramp at Exit 15 to Route 28.
0.50	17.65	Turn left onto East Ohio Street.
0.35	18.00	Merge with traffic on northbound lanes of Route 28 at the H. J. Heinz plant.

0.40	18.40	Troy Hill, on the left, is flat-topped and lower in elevation than the surrounding hills. Troy Hill represents a remnant of the preglacial Allegheny River valley. During the Pleistocene, the Allegheny, Ohio, Monongahela, and Youghiogheny rivers cut down through the surrounding bedrock, forming the present landscape of Pittsburgh, and leaving the older valley floors high and dry. Similar features, called the Parker Strath (strath is an old Scottish word meaning a wide, flat valley), can be seen at Natrona Heights, the University of Pittsburgh Applied Research Center in Harmarville, the main campus of the Community College of Allegheny County on the North Side, in Bellevue, McKeesport, Homestead, Oakland, and many other places.
1.25	19.65	This stretch of Route 28 has had numerous problems over the decades with landsliding. Notice the number of houseless foundations on the left side of the road.
0.35	20.00	Exit 3 to Millvale. Continue north on Route 28.
0.20	20.20	Pittsburgh and Schenley red beds and intervening strata, including the Ames Limestone, are exposed in the hillside on the left side of the highway for 0.8 mi. Colluvial soils, derived from the red claystones, have a long history of earthflow-type landsliding in southwestern Pennsylvania, causing a great deal of damage and expense annually. This exposure seemed to be more trouble than usual over the years, and in the late 1980s and early 1990s the highway department had to remove a sizable amount of soil and deeply weathered bedrock while attempting to widen the highway.
0.90	21.10	Shaler Waterworks on the left supplies ground water to the North Hills areas from alluvial sand and gravel of the present Allegheny River valley.
0.90	22.00	Bear left onto the exit ramp at Exit 5 and merge with traffic on Route 8. The cliffs on the right expose rocks of the upper Glenshaw Formation to upper Casselman Formation, from the Upper Saltsburg sandstone near

		road level to the Connellsville sandstone at the top. Can you tell where the Ames Limestone is in this section?
0.50	22.50	The roadcut on the right exposes a beautiful little cut-and-fill channel sandstone in the Lower Saltsburg sandstone (middle Glenshaw Formation).
0.40	22.90	Exposure of the Pine Creek limestone on the right, adjacent to the intersection of Route 8 and Catherine Street in Etna. The Pine Creek lies at an elevation of 760 feet above sea level here but rises in elevation as you travel north toward the axis of the Kellersburg anticline at Allison Park. The underlying shales and siltstones grade northward into sandstone (Buffalo) along the length of this outcrop. One historical note: I. C. White, who did the original field work and mapping of this portion of Allegheny County during the Second Geological Survey of Pennsylvania (White, 1878), called the limestone bed at this spot the Brush Creek. What is especially fascinating about this is that White was the author who first described and named the Pine Creek limestone.
0.50	23.40	Flood control project in Pine Creek on the left opposite the intersection of Route 8 and Saxonburg Boulevard. The state Bureau of Flood Protection removed a thick spur of Buffalo sandstone that was responsible for a large meander loop in Pine Creek (it crosses beneath Route 8 near the Burger King restaurant, curls around Shaler Plaza and crosses beneath Route 8 about 100 yards south of the intersection). The spur and loop blocked water flow during times of high runoff, creating floods in this part Shaler Township. The sides of the flood control channel south of the excavation are lined with grouted rip-rap for erosion control.
1.60	25.00	Turn right onto Fall Run Road at the traffic light and cross the bridge over Pine Creek.
0.05	25.05	Turn left into Fall Run Park and drive past the houses on the left into the park.

0.20	25.25	Drive to the end of the access road to the circle and disembark from the bus, Stop 2.

STOP 2
FALL RUN PARK, SHALER TOWNSHIP

As you get off the bus, observe the sylvan beauty of the park. It is rare that land speculators and politicians would save something as wonderful as this from overdevelopment. The park has not been spared completely, unfortunately, as the township saw fit to run a sewer line down the middle of the valley and to let developers build on the hilltops above the park. However, much remains of the natural beauty, including the waterfalls that give the main stream, and thus the park, its name. And as you walk through the park, keep a lookout for rock outcrops, alluvial deposits, rock falls, fossils, and environmental problems. There are a variety of interesting things, geologically speaking, to see.

Geomorphology

Fall Run Park is situated on 92 acres of rugged land in Shaler Township just north of Wittmer (Figure 3-4). It is a long, narrow park that preserves the natural beauty of western Pennsylvania in one of the more rapidly growing suburban areas of Pittsburgh. The park occupies a relatively steep-sided gorge with relief in excess of 200 ft (61 m) at the southern end; the average relief is approximately 130 ft (40 m). In places the slopes exceed 50 percent.

The valley of Fall Run is approximately 1 mi (1.6 km) long and 1,200-1,500 ft (366-457 m) wide. It contains four perennial tributaries of Fall Run, as well as several intermittent ones. The hallmark of this wonderful valley, a waterfall on Fall Run that exceeds 20 ft (6 m) in height (site E on Figure 3-4), occurs just north of the midpoint of the park and separates it into two distinct parts. The upper valley (above the falls) is broad and U-shaped with a grass-carpeted valley floor averaging 150 ft (46 m) wide, and forested valley walls sloping at approximately 20°. The lower valley, in contrast, is canyon-like with a narrow valley floor, about 25 ft (7.6 m) wide, and steeply sloping, rugged, often barren walls. The stream gradient is 182 ft/mi (34.5 m/km)

Stratigraphy

The bedrock underlying Fall Run Park ranges through most of the Glenshaw Formation of the Conemaugh Group, from the shales and fissile siltstones in the middle to upper Mahoning unit near the confluence with Pine Creek to the Pittsburgh red beds near the higher elevations. The Ames Limestone occurs near the hilltops above the park boundaries. As you walk through the park, spend some time examining the relatively

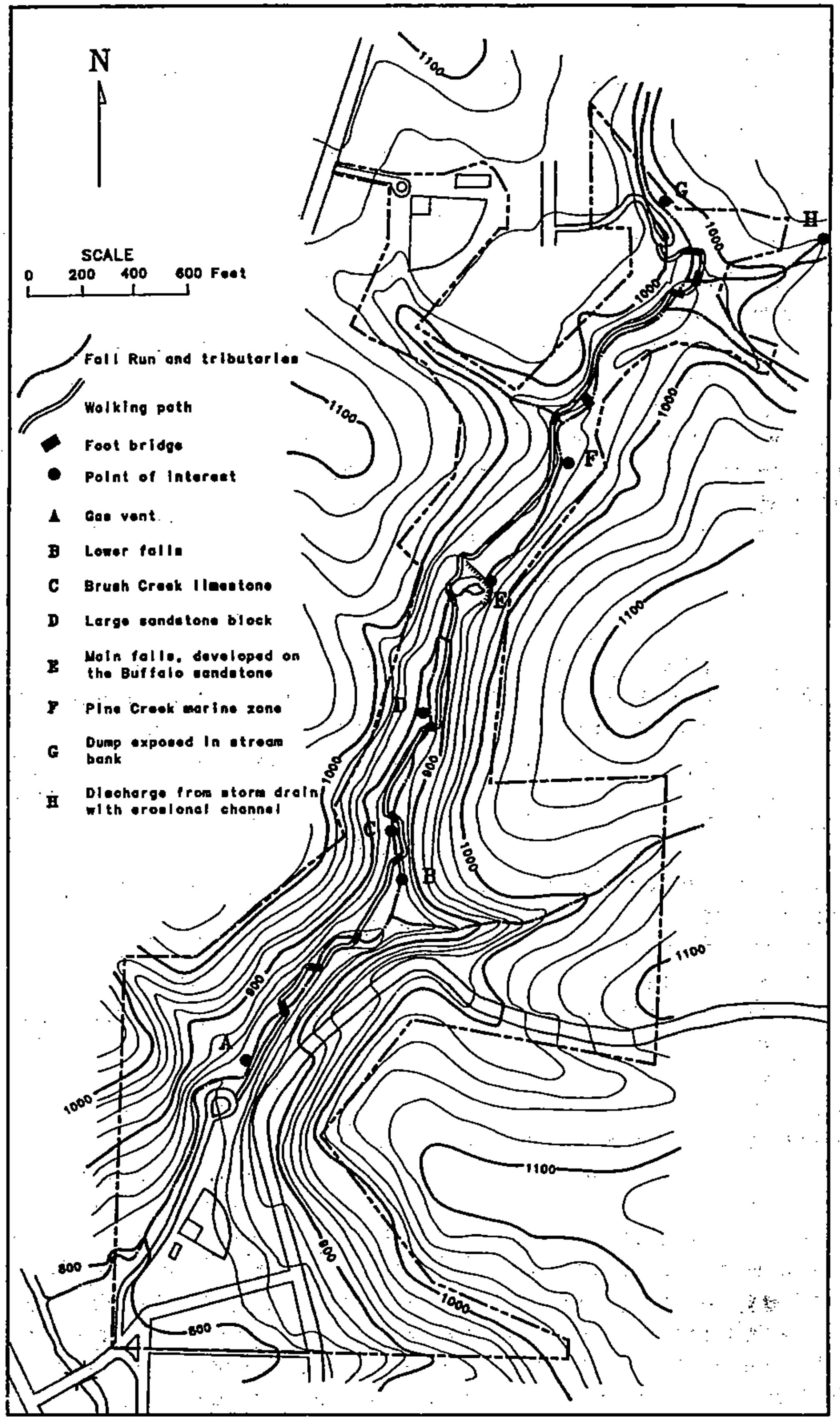


Figure 3-4 Topographic map of Fall Run Park (mod. from R. Mueller Assoc., 1969).

rare outcrops. The creek bed itself provides many of the better exposures. The stream flows over alternating stretches of alluvium and smooth sections of bedrock, typically either shale or limestone. The bedrock slopes gently to the east-northeast. As such, many of the individual beds form questa-like obstructions in the stream, creating many cataracts.

The main waterfall (site E on Figure 3-4), as well as others seen high on the canyon walls within the tributary channels, developed on the Buffalo sandstone. The Buffalo forms a resistant layer in many places in Allegheny County, notably along Route 65 between Emsworth and Glenfield, and at Underhill where Saxonburg Boulevard intersects Route 8.

A small waterfall, more accurately described as a cataract (site B), is situated farther downstream from the main falls. The waterfall has a drop of about 5 ft (1.5 m). It occurs stratigraphically below the Brush Creek limestone (site C) and is developed on what is probably a fissile siltstone of the Mahoning unit.

Gas Vent

Near the lower end of the park, a natural gas seep in the bed of Fall Run bubbles away (site A). We have no conclusive idea as to the origin of the gas, but there are several possibilities: 1) the gas could be leaking from a nearby pipeline; 2) it could be "swamp gas" leaking from the sewer system that runs through the park; 3) it is leaking from abandoned coal mines that used to dot the area (apparently farm banks in the Upper Freeport or Mahoning coal); 4) it is leaking from what used to be Peoples Natural Gas' Mt. Royal gas storage field. Peoples operated the storage field between 1949 and 1980, storing gas in the Thirty Foot sand (Upper Devonian, Venango Group) about 1,650 ft (503 m) below ground level; or 5) it is leaking from one or more abandoned wells. Maps of the area on file at the Pennsylvania Geological Survey show a small collection of historical oil wells just east of Fall Run. No wells are shown in the specific area of the gas bubbles, but that might be simply a lack of good historical information.

Fossils

Two fossiliferous units crop out in Fall Run Park, the Brush Creek limestone and the Pine Creek marine zone. The Brush Creek is a dark-colored argillaceous limestone less than one foot thick that forms the bed of Fall Run at site C. The Pine Creek marine zone occurs above the main waterfall at site F. Like the Ames Limestone at the I-279 locality, the Pine Creek here consists of three layers, a lower fossiliferous, black, calcareous shale, the brown to tan-colored limestone, which is not greatly fossiliferous, and a layer of black shale above that contains ironstone concretions. Shell material, mostly crinoidal hash and brachiopods, is common in some of the float material, but it is difficult to tell which unit created the most debris. The trace fossil *Zoophycos,* the feeding trace of a worm which swept the sea floor in a semicircular pattern, can be seen on the underside of float blocks within the stream channel south of the outcrop. The dark-colored feeding-trace pattern is easily distinguished against the buff-colored weathering of the rock. Other trace fossils noted were *Conostichus,* the anemone resting trace found in the Ames Limestone at Stop 1, and *Rhizocorallium,* a burrow made by some kind of worm that created a U-shaped tube in the mud.

Environmental Aspects

One of the more noticeable aspects of Fall Run Park is the impact of urbanization on the valley itself. The valley wall is ringed with houses from several stages of development, beginning in 1968 before stormwater management was required. This consequently has promoted accelerated headward and lateral erosion of some of the tributaries by funneling stormwater runoff from these developed areas into drainpipes that empty into Fall Run at the tops of the tributaries. Some stormwater also went to the sewer running through the park, causing occasional overflows. Perhaps the worst problem occurred when stormwater runoff was allowed to erode two new "tributaries" to Fall Run at the northern end of the park (site H in Figure 3-4).

Headward erosion represents the grand opus of overdevelopment around Fall Run Park. The two new tributaries at site H occur as a result of letting stormwater drain directly into unprotected colluvium, rather than into existing tributary channels. Runoff has carved V-shaped gullies that measure 8 ft (2.4 m) wide, 5-9 ft (1.5-2.7 m) deep, and 50-200 ft (15-60 m) long. The walls of these gullies are steep and devoid of vegetation, making them ugly scars rather than a picturesque stream valleys. Originally, both drains emptied into concrete enclosures supported by concrete slabs. Because of headward erosion, however, the enclosure around the easternmost drain has since been undermined and fallen into the eroded channel. The second, more northern tributary exposes bedrock at its upper end, creating a sloped waterfall on the valley floor that drops approximately 5 ft (1.5 m). The drain at the head of this gully also is being undermined. Sometimes the discharge has been so powerful that it directly erodes the gully wall 6 ft (1.8 m) beyond the opening of the drainpipe.

Developers building in the area after 1974 have been required by law to install sedimentation ponds. These are designed to protect streams by: 1) trapping sediment behind a dam, rather than letting it be washed away; and 2) collecting excess runoff and allowing it to drain out of the pond to an established tributary at a rate less than or equal to the natural discharge rate for the area. The contrast between the older "piped" tributaries and the more recent "ponded" ones is remarkable. "Unponded" tributaries typically exhibit rough, craggy gullies where the bedrock is exposed, vegetation is sparse, and trees on the slopes above the gullies have been undermined. Unaffected tributaries generally look more natural, with vegetation and forest litter covering the ground. It is unfortunate that the erosion and sedimentation laws aren't retroactive –

Fall Run Park could use some relief from an abundance of precipitation on too much concrete and asphalt.

Road Log Continues from Stop 2

0.20	25.45	Return to Route 8 and turn right.
0.30	25.75	Roadcuts expose the Mahoning sandstone (lower Glenshaw Formation) on both sides of Route 8.
0.40	26.15	Upper Freeport sandstone and shale (upper Allegheny Group) are exposed in the roadcut on the right. The Upper Freeport coal, which is about halfway up the hillside, is only a few inches thick here. The sandstones and shales represent stream channel and floodplain deposits.
0.25	26.40	The hillside on the north side of the warehouse on the left contains a small exposure of the Upper Freeport coal and adjacent shale. The Upper Freeport is 3 ft (0.9 m) thick here, and the rocks represented by the Upper Freeport sandstone and shale at the last outcrop have been replaced by limestones and shales representative of a lake environment.
1.30	27.70	Dirt access road to the left leads to the Allison Park railroad station. The railroad cut here also exposes the Upper Freeport coal and adjacent rock, and the coal has returned to its thickness of only a few inches. The coal is just above road level because the axis of the Kellersburg anticline passes close to Allison Park. The type locality of the Pine Creek limestone is on the hillside up the Pine Creek valley to the left beyond Allison Park.
0.40	28.10	The Upper Freeport sandstone is exposed in the roadcut on the right. Over the next mile, the road rises through the upper Allegheny and lower Conemaugh groups. Route 8 in northern Allegheny County is so heavily developed that few exposures exist north of Talley Cavey.

0.45	28.55	Upper Freeport limestone is exposed in the excavation and roadcut on the left at the junction with Harts Run Road.
2.00	30.55	Turn right onto Wildwood Road.
0.10	30.65	Turn right onto School Road.
0.20	30.85	Turn left onto Topnick Drive.
0.60	31.45	Turn left into Hampton Township Community Park and park on the gravel on the right side of the road and disembark.

LUNCH STOP

0.90	32.35	Return to Route 8 and turn right.
5.65	38.00	Turn right onto the exit ramp to Bakerstown.
0.30	38.30	Turn left onto Bakerstown Road (the Red Belt).
2.05	40.35	Turn left onto Station Hill Road.
0.30	40.65	The bus will pull over to the right and let passengers disembark, Stop 3.

STOP 3
RAILROAD CUT AT BAKERSTOWN STATION

We will get off the bus on the west (railroad tracks) side of the road. Walk down the abandoned loading ramp to the railroad tracks and proceed north along the tracks to the railroad cut below Bakerstown Road.

Around 1915 (Ross, 1933), the Baltimore and Ohio Railroad excavated a deep cut through the drainage divide that separates runoff to the south, through the Pine Creek drainage system, from runoff to the north, through the Connoquennessing Creek drainage system. This cut, just north of Bakerstown Station, replaced a tunnel whose collapsed opening still can be seen adjacent to (directly west of) the cut. The cut exposes what appears to be the most structurally complex area in the exposed surface rocks of the Pittsburgh Low Plateau section of the Appalachian Plateau province. Here we will observe numerous examples of listric-normal faults, tilted blocks, an angular unconformity, and a text-book example of a conjugate joint (fault) set.

Stratigraphy and Paleoenvironmental Interpretation

Ross (1933) examined the Bakerstown Station cut while it was still fairly fresh and was able to establish the stratigraphy before much of the cut was covered by colluvium. He noted that the strata exposed included the middle of the Conemaugh Group, basically from the Pittsburgh red beds at the bottom to the Morgantown sandstone at the top. The red beds and the Ames Limestone have not been exposed for many years at this locality -- Wagner et al., (1970, p. 64; Figure 3-5) made no mention of either of these lithologies in their discussion and diagram of the cut.

Currently exposed strata include small portions of the claystones above the Ames (typically called Schenley when they are red colored) (#3 in Figure 3-5); the Duquesne coal, which is about one ft (0.3 m) thick here (#4); several distinct subunits of the Birmingham shale (#5-#8); and the Morgantown sandstone (#9). The basal part of the Morgantown has numerous, relatively thick lenses of coal that could represent the remnants of the Wellersburg or some very thick floating plant mats. The Morgantown, which commonly is a very resistant sandstone, caps the hill. It might be entirely responsible for the existence of the drainage divide mentioned above, but without further study (and a lot of core drilling) we might never be certain.

Structure

The most prominent structural features at this locality are the tilted blocks offset by normal faults seen on both sides of the cut. Other features that we will examine are joints and faults and their relationship to soft sediment deformation within the lower Morgantown sandstone.

Tilt Blocks and Normal Faults

Figure 3-5 is a redrawing of the spectacular west wall of the railroad cut made by Wagner et al., (1970), based in part on Ross' (1933) unpublished MS thesis. The cut runs north-south and is separated into a southern and northern section on the west side by a 200-ft (61-m) long retaining wall, which is conveniently abbreviated in the diagram. The east side of the cut is more completely exposed because retaining structures are of more modest scope. Trying to match faults from east to west across the tracks should provide lots of fun.

The rock sequence is interrupted by a series of listric-normal faults, most of which apparently dip to the north (to the right in Figure 3-5). The two on the south (or left) dip

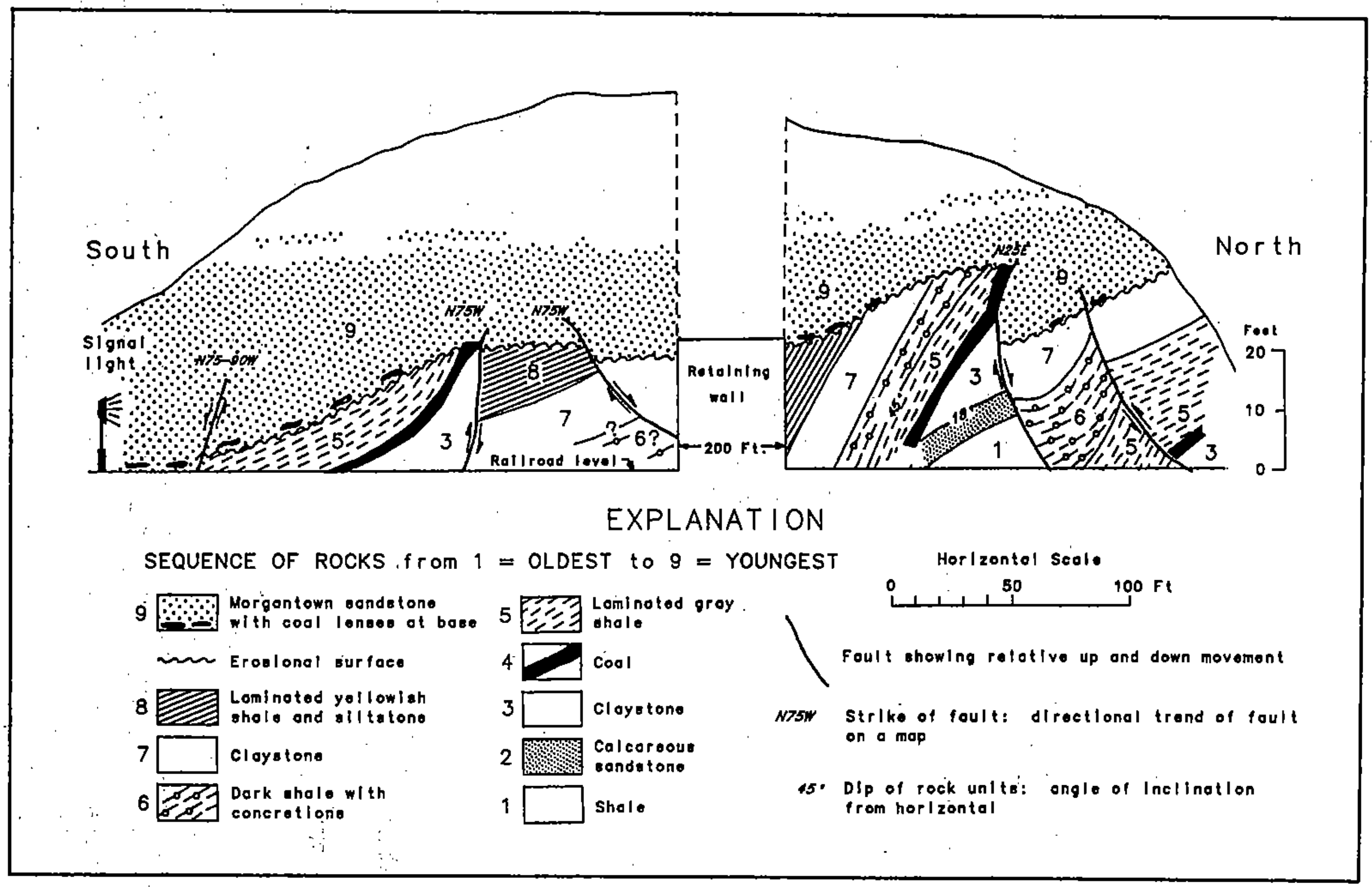


Figure 3-5 Illustration of the west wall of the railroad cut at Bakerstown Station (modified from Wagner et al., 1970, p. 65, fig. 38). Note the vertical exaggeration (2.6X) distorts the dip of strata and faults.

to the south. Between the faults the rock units are tilted so that the beds dip up to 45° S. By matching faults on opposite sides of the tracks Wagner et al., (1970) indicated that the northern faults strike approximately N25E whereas the southern ones have strikes ranging from N75W to N90W.

An angular unconformity at the base of the Morgantown sandstone can be recognized in the field by the occurrence of coal lenses just above the contact and by the truncation of different rock units below the erosional surface. Most of the faults enter and then disappear within the lower few feet of the Morgantown. The main (or first) faulting event took place before Morgantown deposition. Birmingham strata were offset approximately 30 ft (9 m) along the larger of the two northern faults shown in Figure 3-5). After faulting, the rotational blocks were partly eroded and then buried by sandy sediments of the Morgantown River system, forming an angular unconformity. Early in Morgantown time, the faults were reactivated, resulting in a few feet of displacement of the unconformity and lower Morgantown sand. Subsequently, the entire fault complex was buried by the main mass of Morgantown sand.

Richardson (1932) was the first to mention the tilting and faulting at Bakerstown Station, but he offered no explanation of its cause. Ross (1933) speculated that these occurred as a result of ancient landslides, possibly caused by stream erosion. Wagner et al., (1970) proposed an ancient stream lying to the north of the exposure, although the different strikes of the faults suggest a meandering channel lying to the north of the cut. The stream scoured out a channel with steep and unstable banks. Large blocks broke loose from the banks and slid into the channel. Figure 3-6 is a cartoon illustrating a possible sequence of events for the Bakerstown Station railroad cut. Features such as this are not seen very often, according to Laury (1971). Surprisingly, although the geologic record of large-scale stream-bank failures is meager, the Pennsylvanian section in the Appalachian Plateau appears to be relatively well represented.

During late "Birmingham" time, a large stream (the Birmingham River) to the north or northwest had carved a deep channel through the Ames Limestone (Figure 3-6A). The cut bank to the south removed the buttress supporting the sequence of semi-consolidated strata. A series of Toreva (slump) blocks developed suddenly along listric-normal faults (Figure 3-6B), perhaps in response to seismic activity resulting from the Alleghenian orogeny, which was already underway 250 to 300 mi (400 to 500 km) to the east (present cardinal direction). In this sense, it might resemble the Turnagain slide in Anchorage, Alaska that was triggered by the Good Friday earthquake in 1964 (Grantz et al., 1964: Figure 17). Failure might have begun as a block glide above a decollement within the unstable claystones of the Pittsburgh red beds (which even today are responsible for most of the landslide damage in western Pennsylvania), producing a breakaway scarp to the south. This was followed immediately by the development of an antithetic normal fault, dropping a wedge-shaped fault block forming a graben. Erosion of the high ridges on each slump block occurred during latest

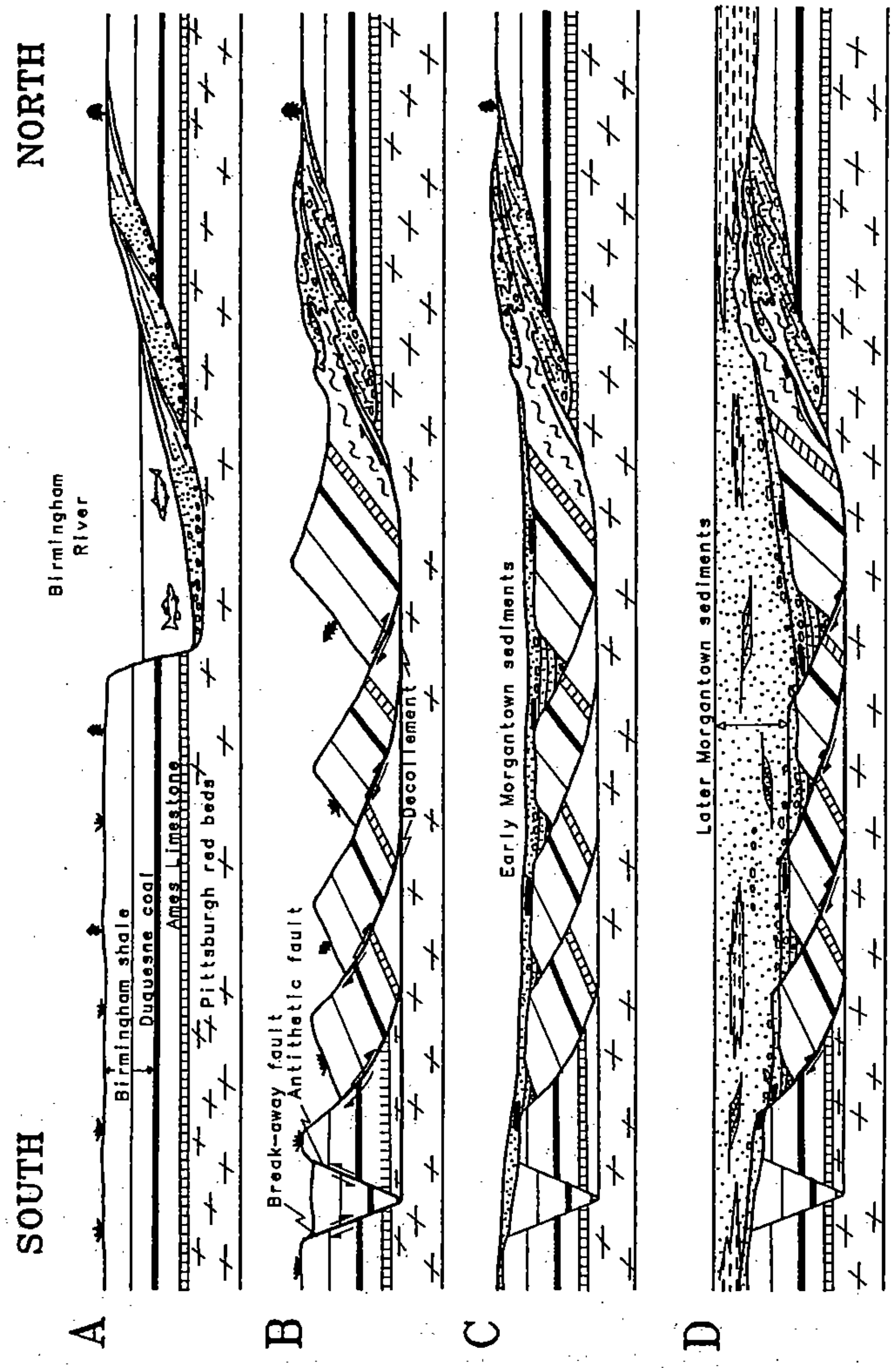


Figure 3-6 Diagrammatic sections of a hypothetical sequence of events in the development of tilted blocks at Bakerstown Station. A) The Birmingham River meandering north of the locality carves a cut-bank into semi-consolidated sediments. B) A disaster, possibly an earthquake, triggers a massive landslide as blocks of the semi-consolidated land surface slide on a decollement in the unstable clays at the base of the section. C) Later, as the Morgantown River system begins crossing the area, the blocks are eroded and filled with sand, logs, rip-up material, and plant mats or segments of semi-lithified peat (possibly Duquesne or Wellersburg). D) Continued loading causes slippage, this time involving the semi-consolidated sandstones.

"Birmingham" time and/or "Wellersburg" time (Figure 3-6C). The dearth of any evidence for the typical dark-colored Wellersburg lithologies could be due to a complete lack of deposition. However, if the coal lenses within the basal Morgantown are the remains of the Wellersburg seam, the erosion must have occurred just prior to initial deposition of sand and silt in early "Morgantown" time. Alternatively, the sandstone with basal coal lenses referred to here as Morgantown might actually be a Wellersburg sandstone. At some time during this sequence of events, the local area underwent a raising of base level, due either to sea level rise or regional subsidence. Whatever the cause, the formerly elevated land surface began to be covered by streams, eroding the slump blocks and leading to deposition of coarse sediment in early "Morgantown" ("Wellersburg"?) time. Differential loading of the slump blocks in the depressions between the original land surface and slip planes (slump scarps) destabilized the Toreva blocks. The inherited instability of the slump material as a foundation for the Morgantown sand deposition led to reactivation of block movement along the faults. Slip planes propagated upward through the early "Morgantown" sediments (Figure 3-6D). The entire complex was subsequently buried by channel deposits later in "Morgantown" time.

Joints and Soft-Sediment Deformation

At the south end of the railroad cut, on the east wall where the excavation is about 25 ft (7.5 m) deep, the Morgantown sandstone exhibits numerous examples of soft-sediment deformation, typically within the basal coal lenses, related to faulting caused by sediment loading. At the time of deformation, the Morgantown was probably semi-consolidated sediment showing a variety of mechanical properties. Figure 3-7 illustrates one portion of the rock in this area, showing the complexities of the local structure on a finer scale.

The Morgantown sandstone exhibits a textbook-quality conjugate-joint set intersecting at about 60°, which produces rhomboid joint blocks. The 60° angle is bisected by the maximum principal stress, the force of gravity, called σ_1 (Figure 3-7A). The joints are parallel to the circular sections of a triaxial stress ellipsoid. At the time the original deformation took place, it is likely that σ_1 was the result of sediment loading within the Morgantown River channel. The individual strata involved are described in Table 2. The coal was probably a peat or very low-rank coal at the time of deformation whereas the other units were all semi-consolidated sand deposits. Under compressive stress near the intersection of what is now the conjugate joint set, unit 3 was mobilized and forced downward, injecting into unit 2. This allowed a block of unit 4 sand to move downward along conjugate normal faults, creating a small graben. Notice that no faulting occurred along the plane of these fractures in the unit 1 sand below the coal. Soft-sediment deformation occurred because of extension in the direction of σ_3 (the least principal stress). Figure 3-7B illustrates that similar structural relationships occur in a 6-8 in (15-20 cm) cross-bedded sandstone about 20 ft (6 m) to the right (south).

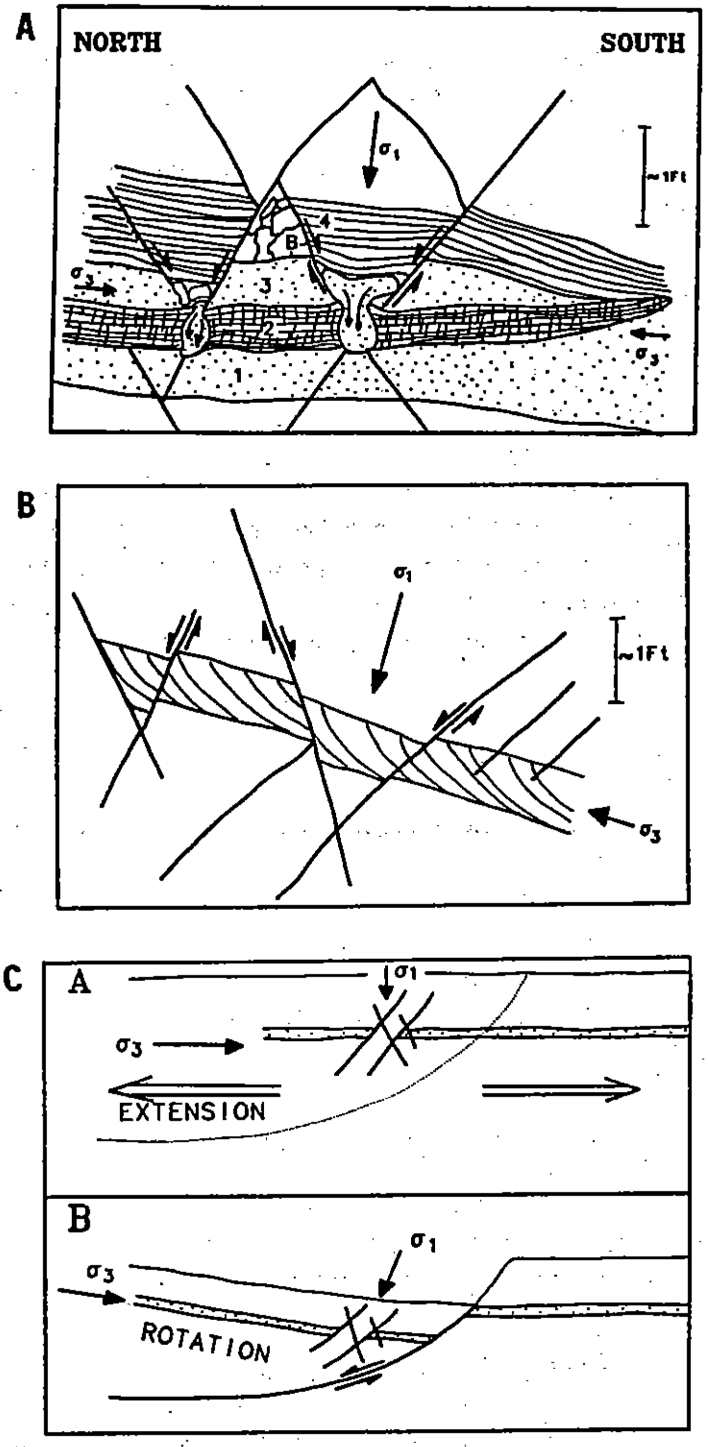


Figure 3-7 Sketches of portions of the southeast wall of the Bakerstown Station railroad cut showing a) joints/faults and related soft-sediment deformation that developed in the basal Morgantown sandstone prior to reactivation of slide failure (D in Figure 3-6) and b) the relationship of faults to a 6-8 in (15-20 cm) thick cross-bedded sandstone layer in the Morgantown sandstone and c) section of a portion of the Bakerstown Station paleo-landslide illustrating the change in orientation of the maximum principal stress (σ_1). Before sliding, σ_1 is oriented vertically (gravity and overburden pressure) and after sliding, rotation of the Toreva block on the listric-normal fault has reoriented σ_1 a few degrees clockwise from vertical. The dashed line represents the future slip surface.

Table 3-2. Description of lithologic units shown in Figure 3-7A and the approximate mechanical characteristics at the time of deformation.

UNIT	LITHOLOGY	MECHANICAL CHARACTER
4	Thin-bedded, rust-colored sandstone	Brittle
3	Massive sandstone, poorly consolidated	Fluid
2	Highly cleated coal	Ductile
1	Massive sandstone, fairly well consolidated	Brittle

You will notice that in Figures 3-7A and B that σ_1 is not vertical. Figure 3-7C (a and b) illustrates the possible sequence of events that would result in the current orientation of fractures and stresses. During early "Morgantown" time, after the lower sandstone and peat/coal had been deposited, the section underwent soft-sediment deformation as described above. Figure 3-7C(a) shows a future slip surface. Later, sediment loading destabilized the semi-consolidated strata, resulting in the formation of a Toreva block (Figure 3-7C(b)). Rotation along the listric-normal fault reoriented all fracture planes and stress directions a few degrees in a clockwise sense.

Road Log Continues from Stop 3

0.30	40.95	Return to Bakerstown Road and turn right toward Bakerstown.
0.10	41.05	Turn left onto State Road.
0.55	41.60	Turn left onto Middlesex Street.
0.10	41.80	Turn left into Witco Corporation's shipping and receiving driveway. Proceed to gate and into parking lot, Stop 4.

STOP 4
WITCO CORPORATION

This will be a relatively short stop on our itinerary. We will get off the bus in the large paved area close to the loading dock. Mr. Daniel J. Green, the Plant Manager, has kindly given us special permission to enter company property. At the request of the Witco Corporation, the taking of photographs is prohibited. ***Please leave your cameras on the bus!***

Geotechnical Aspects

Present here is a classic example of an earth flow caused by failure of the Pittsburgh red beds. The irony is that this stratigraphic unit set the stage for the catastrophic landslide failure we just observed in the railroad cut 1/4 mi (400 m) away, and here, 300 ma later, it is still causing trouble!

The warehouse was constructed in 1980 on a swampy area that was filled. The hillslope was excavated to provide a sufficiently large site and the design called for a single bench; the exposed hillslope was planted in crown vetch to retard erosion. Movement started one or two years after the completion of construction, and now, almost 15 years later, the slope continues to move, albeit at a very slow but inexorable pace.

The most obvious feature, a lobate mass about 200 ft (61 m) long and 3-4 ft (0.9-1.2 m) high, has moved 25-30 ft (8-9 m) out into and under the paved area. A glide plane probably exists at depth, but at present it is occluded ("blind thrust"). The toe is very wet and "juicy." Domes several feet high formed of bituminous concrete pavement appear at the toe. This shows that the movement originates below grade, i.e. this is not a surficial slide or flow. You can observe fine examples of hummocky topography coated with crown vetch behind the toe. With a modest amount of digging beneath the vegetation, you should be able to discover the soft red clay of the moving mass. A crown scarp is present at the head of the flow, giving it a slump-like character.

We invite you to examine the asphalt paving behind the building -- it looks like waves on water. The asphalt is beginning to creep up over the concrete foundation. This area once was wide enough to drive a vehicle through. Thus, while the hillslope behind the building is not involved in the earth-flow lobe, it is indeed gradually moving north toward the building. Red clay is readily obvious at the slope-pavement interface.

Look at the corner of the building at the loading dock. The massive pillar supporting a steel beam seems unaffected, but the horizontal reinforced concrete slab has failed brittley and is being raised. The asphalt pavement, on the other hand, is flowing and behaving in a ductile fashion. Nappe-like folds are evolving in the pavement.

Witco Corporation is very concerned about potential damage to their structure and are looking into remedial activity to prevent further movement. Any suggestions?

Road Log Continues from Stop 4

0.20	42.00	Return to Middlesex Street and turn right on State Road.

0.55	42.55	Turn right onto Bakerstown Road and follow the Red Belt to I-79.
1.30	43.85	The road follows the crest of topography that forms a local drainage divide in this area.
1.50	43.35	Pine-Richland High School on left.
1.60	44.95	Active oil field equipment consisting of a pumper and a stock tank can be seen in the yard on the left. We are crossing the northern terminus of the Keown oil field which produces from the Upper Devonian Venango Group.
3.25	48.20	Junction with US-19. Continue straight on the Red Belt.
0.80	49.00	Turn left onto the entrance ramp to I-79.
0.50	49.50	Merge with traffic on I-79. We will cross the axis of the Brush Creek anticline near the merging lanes. Upper Casselman Formation rocks, particularly the Connellsville sandstone, are exposed in numerous roadcuts between here and the Wexford Exit.
1.40	50.90	Bear right onto the exit ramp at Exit 22 (Wexford Exit).
0.20	51.10	Pull over to the right side of the road. Passengers will disembark here and climb to the top of the hill overlooking I-79, Stop 5.

STOP 5
ROADCUT ON I-79 AT INTERSECTION WITH ROUTE 910

We will spend some time looking at the outcrop across I-79. Those who want to have a look at the outcrop on this side of the highway can walk down the ramp, but must be careful of relatively high-speed traffic on the ramp. A small (approximately 6 ft tall) structure about 200 yd (183 m) north along the ramp can be seen in the outcrop on this side. Can you determine what it is?

Stratigraphy

The rock exposed in this roadcut is the Connellsville sandstone, the youngest recognized sandstone unit in the Conemaugh Group. The top of the Connellsville lies from 60 to 100 ft (18 to 30 m) below the base of the Pittsburgh coal and about 200 ft (approximately 60 m) above the top of the Ames Limestone. The rock typically consists of relatively thin lenses of fine- to medium-grained "dirty" sandstone (arkosic litharenite) interbedded with dark-colored shales. In the Pittsburgh area, the sandstone gets to be about 50 ft (15 m) thick as a unit. Up until the middle part of this century, the Connellsville sandstone was an important source of construction aggregate and flagstone, and in cases where the bedding thickens dramatically, dimension stone (Johnson, 1928). At this locality the sandstone is about 45 ft (14 m) thick.

Paleoenvironmental Interpretation

The roadcut on the east side of I-79 shows the progression of a meandering stream through time in profile. If we could get right up on the rock face to have a look at lithologies and sedimentary structures, we might observe a host of features related to channel deposition and lithification.

The outcrop appears to represent several stages of meandering in a medium-sized river (termed here the Connellsville River) that was shifting position on the floodplain from north to south (left to right as you view it). Meandering river systems have been studied extensively in the modern fluvial environment, in outcrops such as this, and in the subsurface via geophysical logs, cores, and drill cuttings. Excellent reviews of the exhaustive work on meandering streams can be found in LeBlanc (1972) and Walker and Cant (1984), and we urge all interested readers to check out these papers. For this guidebook, we present only the briefest of summaries that you can use to attempt to decipher the I-79 roadcut.

Meandering is a natural tendency of all aggrading streams due to a fundamental instability of flow in the channel (Figure 3-8). Once meandering begins, it is maintained by erosion of the outer bank with concomitant deposition on the inside of the meander loop, at the point bar. Over time, as the meander loop grows "tighter," the point bar accretes in the direction of erosion on the outer bank (Figure 3-8). Point-bar deposits typically consist of fining-upward sequences of terriginous clastic sediment, but the actual grain size of these sediments depends on the current velocity, which keeps sediment grains suspended in the water column. High energy streams can carry boulders -- and when enough energy has been lost, even the finest material will settle out. The total thickness of the point-bar deposit depends on channel depth.

Eventually, all aggrading meandering streams change channels in one of two ways, by cutoff of a loop during normal stream development or by abandoning an entire channel segment due to a major diversion somewhere along the length of the stream. In either case, when a meander is abandoned it gradually fills with finer sediment during times of floods (clay plug). Two primary types of sand deposits occur as a result of meandering streams, the point-bar deposits and the abandoned channel deposits.

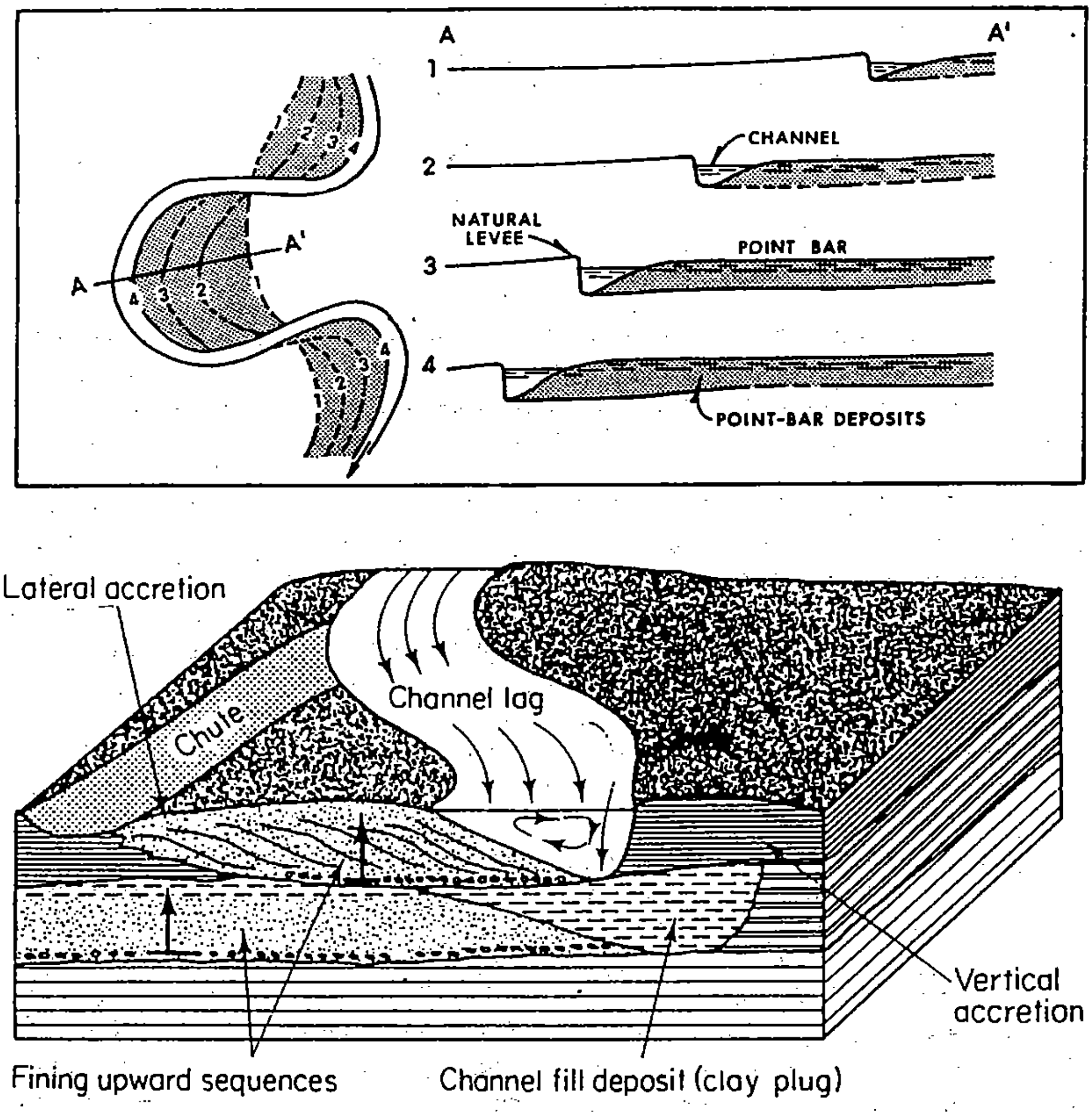


Figure 3-8 **Aggradation of a point bar complex in a typical meandering stream. Top, lateral accretion of a point bar as the stream meander loop begins to tighten (from LeBlanc, 1972, p. 149, fig. 11). Bottom, block diagram of a meandering channel and its floodplain showing vertical accretion of fluvial deposits (from Blatt and others, 1980, p. 634, fig. 19-4).**

Point bar sands generally occur in the lower portion of the bar and may constitute 75% or more of the sand deposited by a meandering stream (LeBlanc, 1972). Abandoned channels might have some sand, but the majority of the fill material probably consists of clay and silt. Outside of the stream channel, deposition occurs on the floodplain during floods. Unlike the stream itself, which builds through lateral accretion, the floodplain builds through vertical accretion.

Using this information see if you can see the various components of the meandering Connellsville River in the I-79 roadcut. Based on some preliminary work done by N. K. Flint and J. D. Stoner in 1983, the predominant lithology is gray to greenish-gray, fine- to medium-grained sandstone that is interbedded with argillaceous sandstones and silty to sandy shales. Individual sandstone bodies range from a several centimeters to a few meters thick. As the Connellsville River shifted, it cut deeply into established channel and overbank deposits, creating discordant contacts dipping at various angles to the normally flat-lying sediments. Various meanders appear in separate places and various stratigraphic levels in the outcrop, indicating the migration of the meander loops laterally and vertically with time. Figures 3-9 and 3-10 show a diagrammatic representation of the I-79 outcrop and a paleogeographic interpretation, respectively.

Road Log Continues from Stop 5.

0.40	51.50	Drive to the end of the exit ramp and turn right onto Route 910 (the Orange Belt).
0.20	51.70	Turn left onto Nicholson Road.
0.05	51.75	Turn right into Carmody's parking lot and disembark.

End of Road Log for Day Three

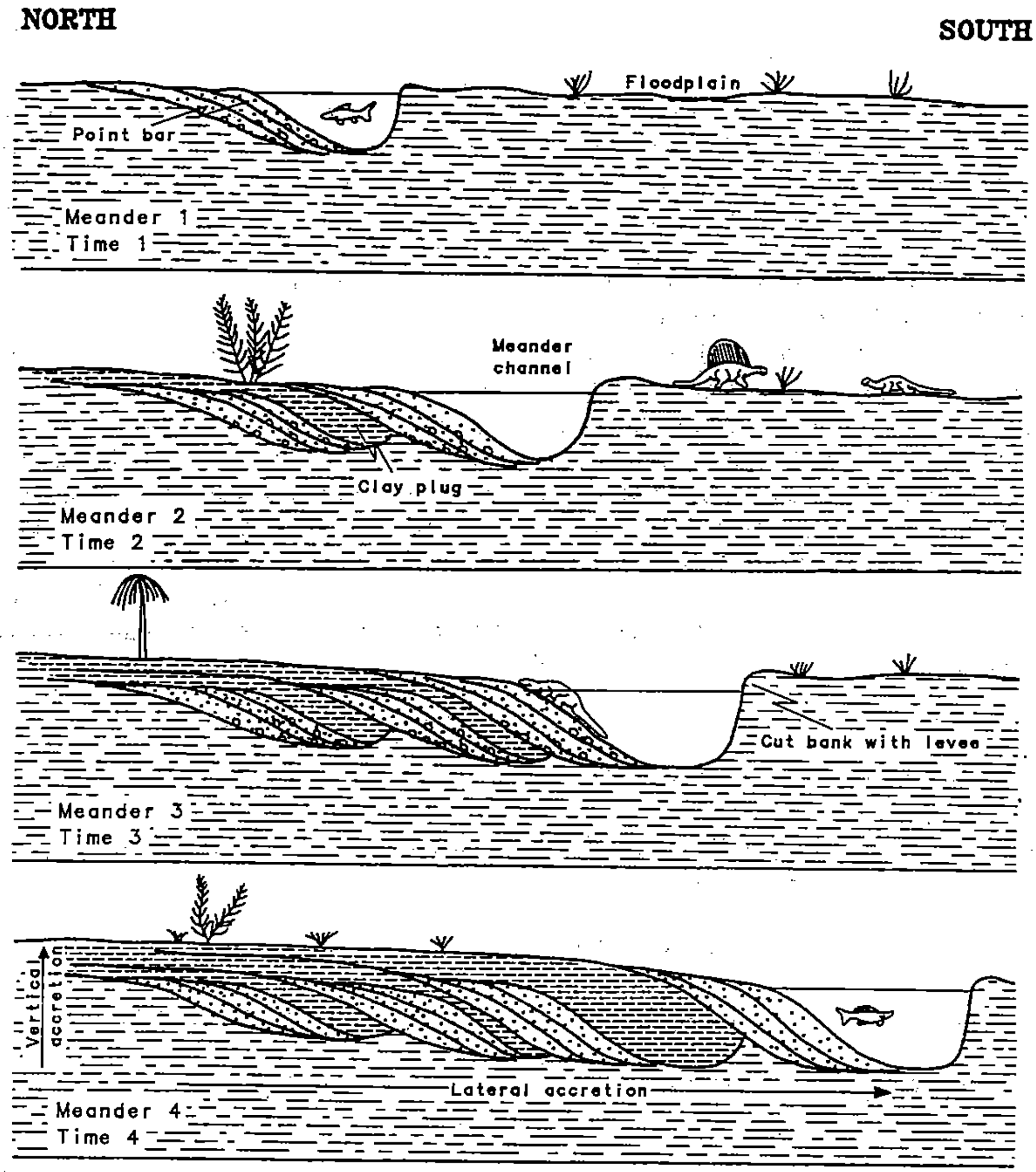


Figure 3-9 Diagrammatic sketch of the roadcut on I-79 just north of the Wexford exit, showing the sequence of vertical and lateral accretion of channel deposits in the Late Pennsylvanian-age Connellsville River system.

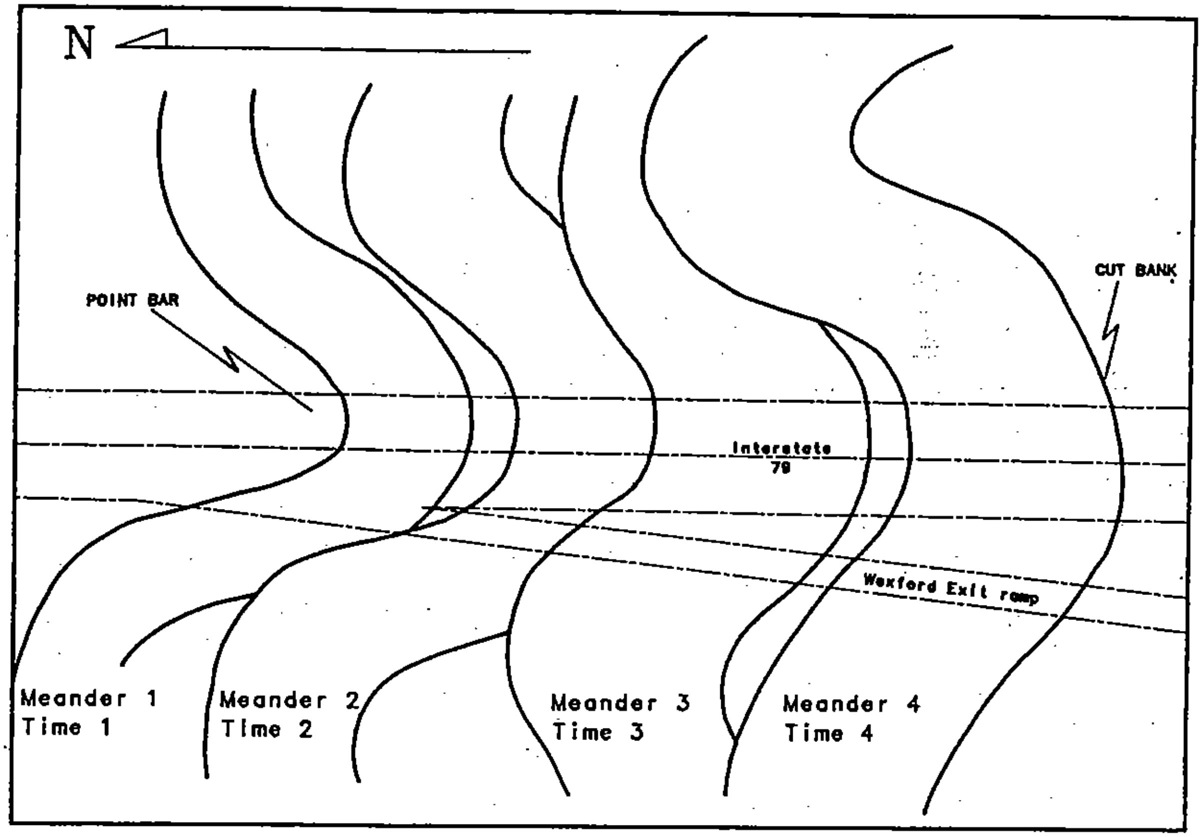


Figure 3-10 Paleogeographic interpretation of meander belt accretion in the Connellsville River system shown in Figure 3-9.