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S U B W A Y, T U N N E L S

A N D S C E N E R Y

"THE TROLLEY THROUGH TIME"

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Excursion on the Light Rail Transit System south from Pittsburgh

April 27, 1991

Leaders

Reginald P. Briggs & Craig D. Parke

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THE PITTSBURGH GEOLOGICAL SOCIETY
with the cooperation of the
CONSOLIDATION COAL COMPANY

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Modified from Field Trip Number 5 of the
ASSOCIATION OF ENGINEERING GEOLOGISTS 33d ANNUAL MEETING
October 1-5, 1990

Included is a facsimile of
THE TROLLEY THROUGH TIME
by Byron Spice, Science Editor of the
PITTSBURGH POST-GAZETTE
as printed on January 21. 1991

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Pittsburgh Post-Gazette

Science

MONDAY, JANUARY 21, 1991

The trolley through time

By Byron Spice
Science Editor, Post-Gazette

The streetcar was named Library, but when we boarded it in Gateway Center station, our destination was not a place. We were taking a trip into the past.

About 35,000 people ride the Port Authority's light rail transit system through the South Hills each week on their way to work, schools or shopping. But my companion this day, geologist Reginald "Pete" Briggs, says a trip on the T also can provide a good introduction to Allegheny County's geology.

It takes 45 minutes to travel from Downtown to the end of the line in Library, but we will traverse rock that took more than 300 million years to form.

At the outset of the trip, the real story lies unseen behind the gray concrete walls of the subway tunnels. Zipping along beneath Liberty Avenue, we are traveling through a 40-foot layer of gravel and sand called alluvium that was deposited during the Ice Age, which ended 12,000 years ago.

The glaciers never made it farther south than what is now Moraine State Park in Butler County, but when they melted, they unleashed huge amounts of water and sediments. Those waters reversed the course of the Allegheny River, which previously had flowed north, and deposited gravel and sand along the river banks during successive floods.

As the subway rises from Wood Street station along Sixth Avenue to Steel Plaza, it leaves the relatively young alluvium and enters bedrock formed almost 310 million years ago — the notorious Pittsburgh redbeds.

Briggs, a consulting geologist who formerly worked for the U.S. Geological Survey, said the redbeds were among the least stable of rocks and often were responsible for the area's many landslides. This shale contains an expandable clay that gets greasy when wet.

Most of the older shales, sandstones and other sedimentary rocks that the trolley traverses were formed of material that eroded from the Appalachian Mountains to the east, which once towered an average of 14,000 feet, according to recent estimates by Penn State University geologists. The Appalachians today are stumps by comparison, rising within Pennsylvania to little more than 3,000 feet.

Exiting the subway tunnel, the T crosses the Monongahela River and enters the 87-year-old transit tunnel through Mount Washington. Concealed near this tunnel portal is a layer of Ames limestone, which

SEE TROLLEY, PAGE 31

Kevin Schlosser

SCIENCE

A ride on the trolley through time

TROLLEY FROM PAGE 30

University of Pittsburgh geologist Michael Bikerman says is the last marine limestone in the area.

Limestones consist primarily of the mineral calcite, which accumulated in lakes and seas. These rocks often contain fossils. The Ames limestone was formed while the area lay beneath a sea very much like the Gulf of Mexico, Bikerman says.

By the time the T emerges from the tunnel, it has risen through virtually all of the Casselman formation, a series of rock layers that took millions of years to form. Leaving the tunnel, an outcrop of Pittsburgh limestone from the top of the Casselman formation can be seen to the left.

Unlike Ames limestone, Pittsburgh limestone was formed in the freshwater lakes that once dotted this region, which was then a coastal delta similar to the Mississippi delta around New Orleans. The climate was warmer than today because this part of the continent was closer to the equator. Only later would the drift of the continents carry Pittsburgh to the north.

If you disembark at South Hills Junction, climb the stairs to the right of the transit tunnel and take the asphalt path that leads to the left. You then will be walking atop the Pittsburgh coal seam — the source of Mount Washington's earlier name, Coal Hill.

Once called the most valuable single mineral resource in the country, the 6-foot-thick Pittsburgh coal bed extended over more than 6,000 square miles and provided the cheap energy that first made the city an industrial titan.

Whereas limestones, claystones and shales developed from sediments that accumulated in lakes and bays, coal beds mark vast ancient swamps, not unlike those found in southern Florida, Bikerman says. Decaying plant matter in these swamps formed peat and, after being buried and compressed, became coal.

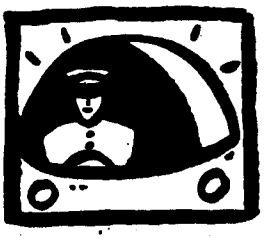
Back aboard the trolley, we cross the Saw Mill Run valley as we head toward Beechview. The T climbs steadily so that by the time it crosses another valley just beyond the Pennant stop, we are riding atop the Pittsburgh coal seam — or what remains of it.

From here south to the county line, the coal bed has been mined out. More than a billion tons of coal have been removed from Allegheny County. Briggs says that was enough coal to fill a train that could encircle the globe five times and enough energy to bring Lake Michigan to a boil.

Between the Westfield stop and Potomac station, the rails ride about 280 feet above the former workings of the old Oak Hill Mine.

Until now, the T has been clinging to hillsides and crossing over steep-walled valleys. But once it makes the turn onto Broadway in Beechview, it is riding along a ridge top that is 1,200 to 1,400 feet high.

By peeking between buildings and along intersecting streets, such as Pauline Avenue, you can see deep into the 300-to-600-foot-deep valleys but only as far as the adjoining ridge tops. "You almost never see a distant horizon," Briggs observes.



That is because this and the other ridges are at the top of the Pittsburgh Plateau, a smaller section of the Appalachian plateau. The dramatic hills and valleys here are not the result of uplift, but of erosion of this plateau.

So each ridge top is about the same height as the next. Panoramic views are impossible from the ridge tops because we are, in a sense, standing amid flatland.

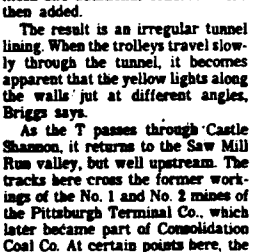
South of Potomac station to the Arlington stop, the T route is over several old mines of the Pittsburgh Coal Co.

Beyond Dormont station, the T enters the Mt. Lebanon tunnels, which were burrowed through rocks of the upper Monongahela group. These rocks date back about 290 million years, a time at which the local climate was becoming drier and, as a result, the rock strata contain less coal.

The Mt. Lebanon tunnels do not employ conventional steel frame supports and reinforced concrete. Instead, newly excavated portions of the tunnels were sprayed with concrete and then allowed to flex and seek their own natural shape, so that the ground around the opening became a load-carrying ring. Wire mesh and additional concrete were then added.

The result is an irregular tunnel lining. When the trolleys travel slowly through the tunnel, it becomes apparent that the yellow lights along the walls jut at different angles, Briggs says.

As the T passes through Castle Shannon, it returns to the Saw Mill Run valley, but well upstream. The tracks here cross the former workings of the No. 1 and No. 2 mines of the Pittsburgh Terminal Co., which later became part of Consolidation Coal Co. At certain points here, the mined-out coal bed is 110 feet below surface.



Old mines are prone to collapse, which can cause the land above to sink, or subside. A rule of thumb is that damage from land subsidence becomes more likely when the distance between the mine and the surface is less than 150 feet, Briggs says.

Washington Junction station is the former site of the entry shaft to Pittsburgh Terminal Mine No. 3. One of the old brick machine shops still stands at the edge of the parking lot and the large, frame duplex houses just south of the station once constituted the company town. The T stop ahead near the houses is still called "Mine 3."

Atop the hill to the east of Washington Junction across Library Road is the mine's "bony" pile. "Bone" was the name miners gave to coal-poor bits of rock within the coal seam that were discarded. The bone likely was hauled to the top of the hill by a cable system and dumped, Briggs says.

These piles, which sometimes smolder, are found at former mines throughout the county, he notes. Inside the gray piles, the rock is reddish where the iron in them has rusted.

Mine 3's bony pile, much of it hidden by trees, is seen most easily when approaching Washington Junction from the south.

Proceeding through Bethel Park on the way to Library, the T rails run parallel to Brightwood Road for a time. Along this stretch, it becomes obvious that the steep-walled valleys near the river have given way to more gently rolling hills. That is because erosion cuts less deeply into the countryside as we move away from the major rivers.

Between the Center and Lytle stops, the trolley passes under a bridge of the old Montour Railroad, which served Consol's defunct Montour mines.

From the Lytle to the Beagle stop, we rumble 150 to 350 feet above the former workings of Pittsburgh Terminal Mine 8. From Beagle to the West Library stop, the trolley route lies over the eastern portions of the old Montour No. 4 mine and the zigzag barrier separating it from the Montour No. 10 mine. At the Hicks stop it passes under another old Montour Railroad bridge.

Montour 10 was mined out and closed at the end of 1979. Water flooded the old mine when pumping stopped. The next August, a barrier between Montour 10 and Montour 4 failed and water from Montour 10 drained into the still-operating mine. Montour 4, most of which was within Washington County, was abandoned in September 1980.

The closing of Montour 4 and 10 marked the end of underground commercial mining of the Pittsburgh coal bed within Allegheny County.

Just as the coal mining era could not continue forever, neither can the rails nor our trip. In Library, Montour 10's former surface buildings can be seen to the east as the trolley pulls up to Simmons Loop — the end of the line.

SUBWAY, TUNNELS, AND SCENERY
("The Trolley Through Time")
Excursion on the Light Rail Transit System south from Pittsburgh

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9:30 AM, Saturday April 27, 1991

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Leaders: Reginald P. Briggs & Craig D. Parke

To get on board - This trip will start from the Station Square Station of the "T", the Light Rail Transit (LRT) System of the Port Authority of Allegheny County (Figure 1), located on the south side of the Monongahela River, diagonally across Carson Street from the Station Square commercial complex. At the station we will assemble on the outbound platform, which is labelled "To South Hills Village", etc.

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Locating where you are on the tour - The lines to be travelled have no conspicuous mile posts or other distance indicators. Accordingly, this log mostly makes do with names of Stations and Stops, which were plotted on topographic maps from which intervening mileages were measured. All indicated distances thus are approximate, though probably most are within 0.1 mile or so of true. From downtown Pittsburgh, including Station Square Station, through Washington Junction and out to South Hills Village, Stations and Stops are well marked with large very visible signs. On the line from Washington Junction to Library, though, Stops are at simple shelters that are mostly at street intersections. Small white-on-blue signs on the shelters are the only Stop labels, so one must keep one's eyes peeled. In the guide occasional landmarks also are identified to help the user. Names of Stations and Stops except those between Washington Junction Station and Library are shown on Figure 1, a schematic diagram of the system. In the descriptive log, Station and Stop names are underlined, and Stations are labelled as such. Most scheduled trolleys stop at all Stations, whereas stops at Stops are by waving from the platform or by push-button request if on board.

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FUTURE USERS - SEE NOTE AT THE END OF THE TRIP GUIDE

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Introduction to Public Rail Transit in the Pittsburgh Area

The Port Authority of Allegheny County operates the public transportation system of Pittsburgh and vicinity, which includes many miles of bus routes and the Monongahela Incline in addition to the Light Rail Transit System. Why Port Authority? In Pennsylvania,

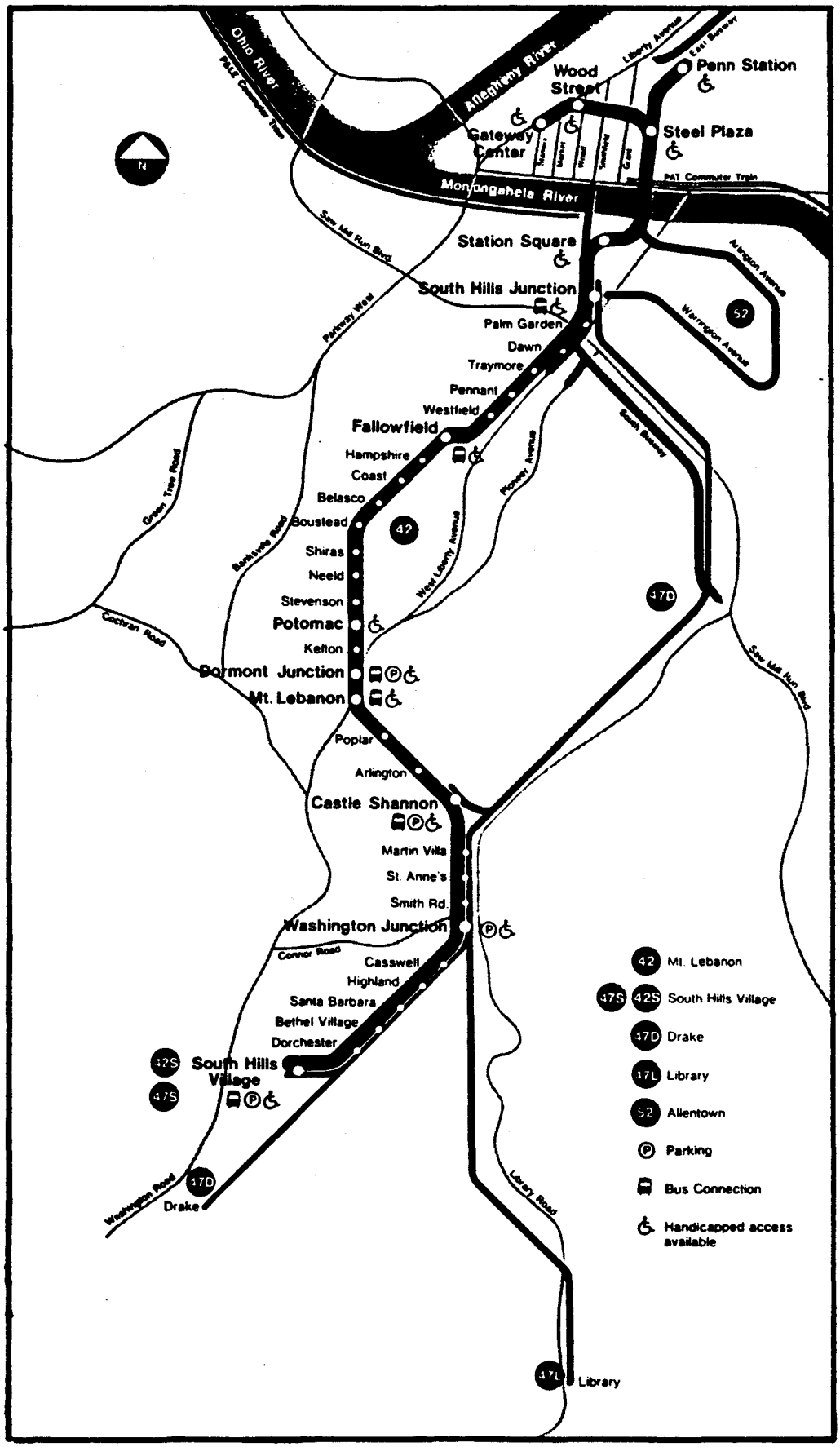

FIGURE 1. — Schematic map of the Light Rail Transit System. This Field Trip starts at Gateway Center follows the western route, 42, to Washington Junction, then 47L (now 42L) to Library and return to Washington Junction, then 42S to South Hills Village, then return to Pittsburgh.

it takes an act by the legislature to approve creation of a municipal authority. At the time that a transit authority was proposed for the area, there was an already approved but dormant Port Authority that had not been activated for the name purpose. Rather than go through the lengthy process of establishing a new authority, in 1959 the statute for the existing one was amended to include transit operations, and the rest is history. In practice, the Port Authority and the services it offers usually are called PATransit, or simply PAT.

The Light Rail Transit System, LRT, has been formally nicknamed the "T", but a lot of people still say, "I'm going to take the trolley". In fact, people have been saying pretty much the same thing since the the Citizens Passenger Railway first put horse cars on Pittsburgh's streets in 1859. The last horse-car line survived until 1923. Electric traction and cable cars were introduced almost concurrently, in 1887 and 1888, respectively, but cable cars didn't last long, only till 1897. Presumably, most Pittsburgh routes were less steep than those in San Francisco, so wheel friction sufficed for traction here, whereas in San Francisco the direct pull of the cable was (and is) a necessity. The early urban lines were owned by a number of companies, but most of them merged into the Pittsburgh Railways Company in 1902, with the last merger in 1932.

The first interurban line from Pittsburgh was in 1903, to Charleroi and Allenport on the Monongahela River in Washington County, and by 1909 interurban electric cars also operated in other directions to Butler, New Castle, and Washington, Pa. and other distant points. At the height of trolley operations in the 1920's, interconnected routes through and from Pittsburgh may have totalled well over 500 miles of track. With the arrival on the scene of large and economical motor busses, trolley service gradually was abandoned. By 1953, the last of the interurban lines had been discontinued or greatly abbreviated, and much urban trackage was pulled up or was no longer in use. By the time the Pittsburgh Railways Company and 30 private bus companies were amalgamated by PAT in 1964, trolley service had declined still further, and by 1971 there was trolley service only between downtown Pittsburgh, where trolleys mingled with other traffic on the streets, and points in southern Allegheny County.

The concept of a subway for Pittsburgh dates back a long way, with the first known responsible proposal made in 1906. A number of plans and proposals followed over the years, with the final and effective one in 1977, when PAT included a downtown subway in its overall reconstruction of the existing trolley lines into a modern LRT system. Construction of the subway began in 1981 and it was opened for service in July 1985. Stage 1 of the reconstruction south from the city, 10.5 route miles, was opened in May, 1987. Stage 2, reconstruction of the remaining 12 miles of older track, is in planning, but may never come to fruition. At least until petroleum becomes too valuble to use as fuel, it probably will be cheaper to run busses than trolleys.

The LRT Trolleys

Almost surely the most numerous type of trolley constructed in the United States, and perhaps in the world, was the PCC (President's Conference Committee) car, developed during the 1930's. The Pittsburgh Railways Company took delivery of its first PCC car in 1936 and its last in 1949. All in all, 666 PCC cars once ran on Pittsburgh routes and the interurban lines, and all of PAT's trolleys were old but still serviceable PCCs until the LRT system opened for business in the mid 1980's. Just 12 largely rebuilt 18-ton PCCs now remain in service, chiefly because bridges and trestles on two segments of the system have not been rebuilt to a standard suitable for the larger new trolleys, which weigh almost 40 tons. Reportedly four more PCCs also will be rebuilt, and a few others are still stored as sources of parts for the operating PCCs. The rest of the 666 PCCs were scrapped or otherwise disposed of.

PAT's rail fleet now is mostly composed of 55 articulated light rail vehicles. They were manufactured by the West German partnership of Siemens-DÜwag and were assembled at Blawnox just north of Pittsburgh. They are 84 feet long, and they can seat 64 or carry more than 200 seated and standing. They have been very well received by Pittsburgh trolley riders.

The track gauge, distance between the inside of the rails, of the Pittsburgh trolleys still is 5 feet 2-1/2 inches, 6 inches broader than the almost worldwide standard gauge of railways, 4 feet 8-1/2 inches. Why this departure? The story goes that this had its origins a century ago, when trolley tracks and railroad tracks intermingled on the streets of booming cities of the industrial revolution. Trolley operators found that railroads were sometimes using the trolley tracks, and trolley tracks were not built to handle heavy loads of coal, iron ore, and so forth. The result was crushed and misaligned track. Accordingly, trolley operators laid new track at the different gauge, too broad for railroad use.

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Cumulative mileage	Incremental mileage	Location/description
0.0		Station Square Station - Crossing the Monongahela River near here is the Smithfield Street bridge, built in 1883. It is a "double-bowstring lenticular truss" bridge and is the only survivor of its type in the country. Before the LRT subway was constructed, trolleys crossed the Monongahela on this bridge, rather than the Panhandle Bridge just upstream, which formerly carried Pennsylvania Railroad/Conrail tracks.

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Mount Washington Trolley Tunnel

Leaving Station Square Station, the route turns sharp left and enters the Mount Washington tunnel which was opened for service in 1904. It is 3,492 feet long, and it rises to the south at a continuous gradient of 6.1 %. The Ames Limestone Member at the top of the Glenshaw Formation in the lower Conemaugh Group lies concealed near the tunnel's lower end near the Station Square Station, and the Pittsburgh coalbed in the base of the Pittsburgh Formation of the Monongahela Group crops out just above the south portal. Accordingly, the tunnel rises through almost all of the Casselman Formation of the Conemaugh Group (Figure 2). The rock face at the north portal has been reinforced with shotcrete and steel mesh. In 1976 the tunnel was renovated, including paving the floor, so the tunnel now is used by busses as well as trolleys, and in 1984 new lighting and ventilation were provided.

This is one of four tunnels (actually six, as two of the others have two tubes each) that penetrate Mount Washington. The Liberty Tunnels (locally usually called "Tubes"), a short distance to the east, are 5,920 feet (1.12 miles) long, and at the time of their completion in the mid-1920's they were the longest land (as opposed to underwater) vehicular tunnels in the country. Even today they are the fourth longest, surpassed only by two tunnels in Colorado and the Allegheny Mountain tunnel on the Pennsylvania Turnpike. The Fort Pitt tunnels, opened in 1960 and 3,560 feet long, are on I-279/US-22/US-30 about a mile to the west of the trolley tunnel. The former Wabash Railroad tunnel, about 3,400 feet long, is located about halfway between the Fort Pitt tunnels and the trolley tunnel. Opened in 1904, it has not been in service since 1946, when the Pittsburgh Terminal of the Wabash Railroad was destroyed by fire. During the 1970's the Wabash tunnel was renovated for use in the stillborn "Sky Bus" rapid transit scheme, which ultimately failed to materialize. PATransit has since used the tunnel to store equipment.

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Cumulative mileage	Incremental mileage	Location/description
	0.8	
0.8		South Hills Junction Station - Located near the crest of Mount Washington and just outside the south portal of the tunnel, this is, or will be, a four-way trolley junction. Coming downhill from the left, northeast, is the end of an unopened trolley line that leaves the main line at the south end of the Panhandle bridge over the Monongahela River. When opened following completion of ancillary construction in or about 1992, this line will loop up to the top of Mount Washington for a remarkable view of the city. Heading more or less straight ahead to the southeast of the Mount Washington tunnel portal is the

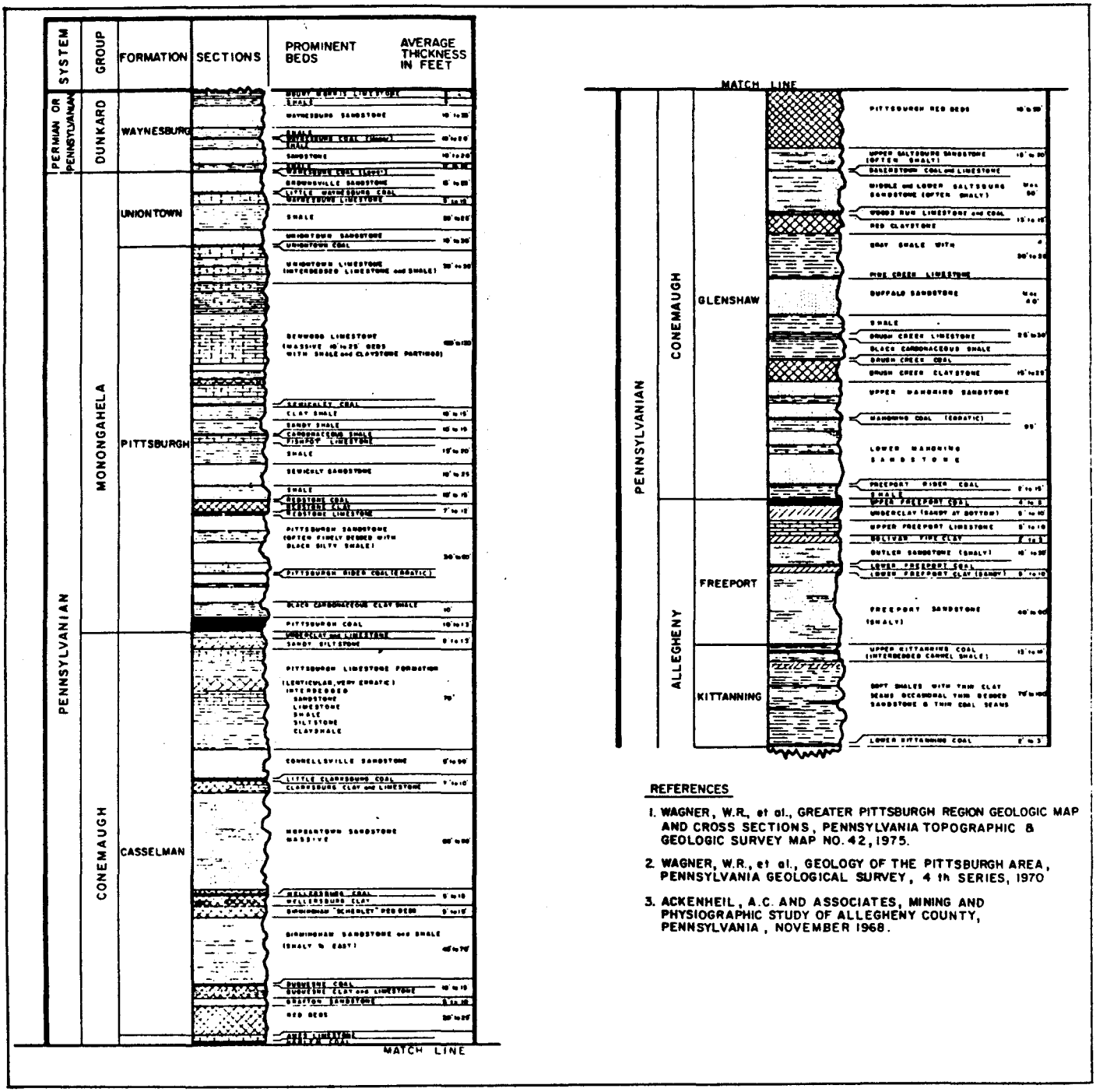

FIGURE 2. — Bedrock geologic column in Allegheny County and vicinity.

Overbrook route to Castle Shannon, currently unreconstuct- and so travelled only by PCC cars. Bearing gently off right, we will follow southward the Beechview line to Castle Shannon which has been reconstructed for use by the new trolleys. Overbrook and Beechview lines meet again and coalesce at Castle Shannon and proceed south.

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Areal Geology and Geologic Structure

To this point, bedrock under the rails has been entirely in the Glenshaw and Casselman Formations of the Pennsylvanian Conemaugh Group. However, visible on the left at the South Hills Junction Station is an outcrop of strata in the uppermost Casselman Formation, and, as has been noted, strata of the Pittsburgh Formation lie close above the tunnel portal (Figure 2). Shortly the rails will climb higher in the section, near Pennant Stop 0.9 miles farther on, and Conemaugh strata will be encountered again only at the extreme south end of the field trip route (Figure 3).

The structure of the LRT area in southern Allegheny County may be described as a gentle south-westerly-dipping homocline modified by gentle north-northeast striking folds, the amplitudes of which increase eastward (Figure 4). Dips are low and commonly are described in feet per mile rather than in degrees, and dips as large as 5 degrees are rare. Faults also are rare.

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Cumulative mileage	Incremental mileage	Location/description
	0.4	
1.2		Palm Garden - From this stop, the Beechview line crosses over the Saw Mill Run valley on a bridge designed to carry trolleys and busses exclusively. Visible from the bridge to the east, left, are the south portals of the Liberty Tubes.
	0.2	
1.4		Dawn - From here through Traymore to Pennant Stop the slope to the west, right, is retained by soldier piles and concrete lagging.
	0.1	
1.5		Traymore - The track climbs at a grade of 4.6 % near here.
	0.2	
1.7		Pennant - Across the valley just after this Stop the climbing trolley route crosses over the con- concealed outcrop of the Pittsburgh coalbed and onto higher strata in the Pittsburgh Formation in the Monongahela Group (Figure 3).

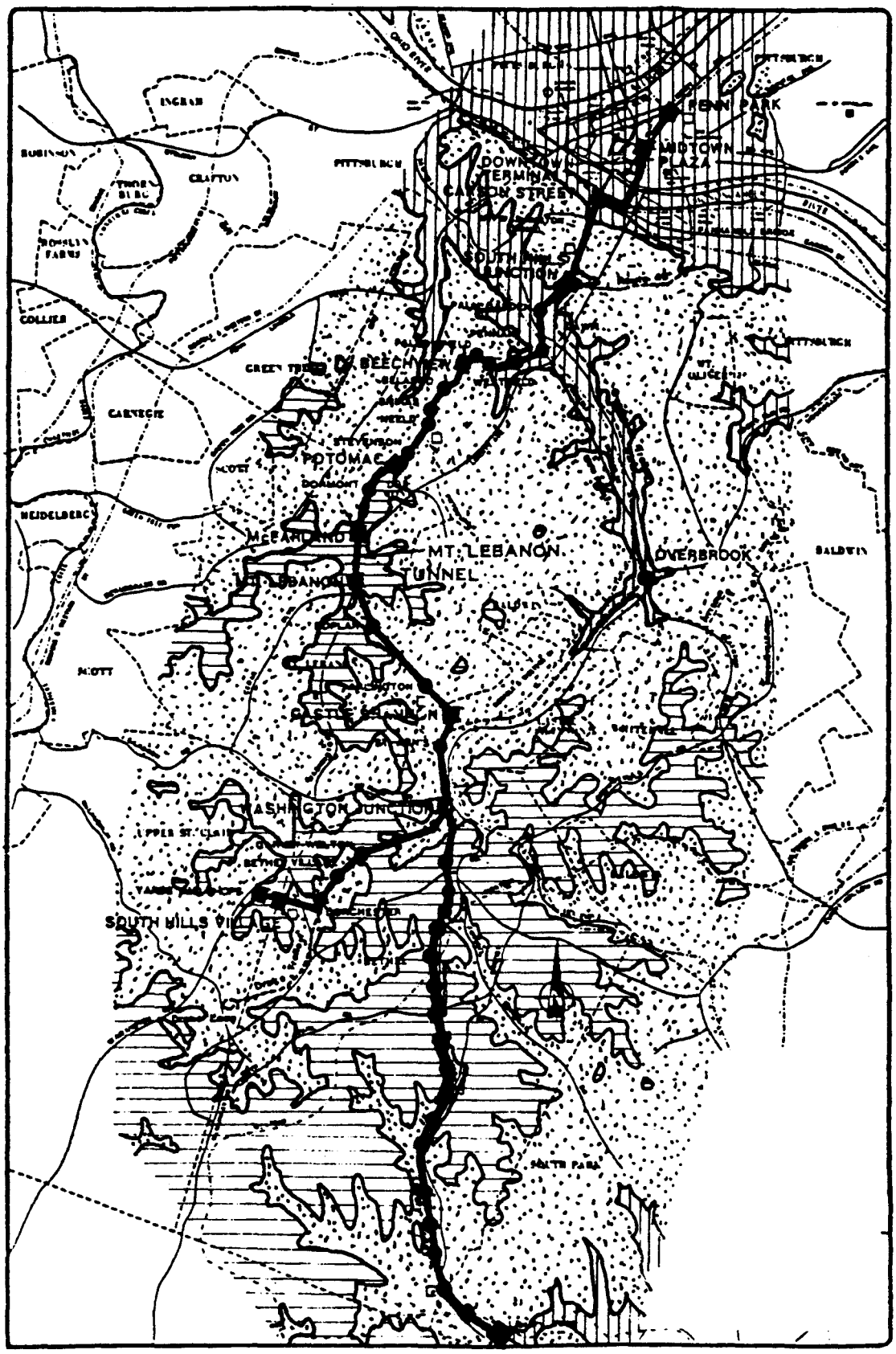

FIGURE 3. — Generalized geologic map of the LRT area, southern Allegheny County. Vertical lines - Conemaugh Group. Stippled - Monongahela Group. Horizontal lines - Dunkard Group. Scale 1 inch equals about 2.3 miles.

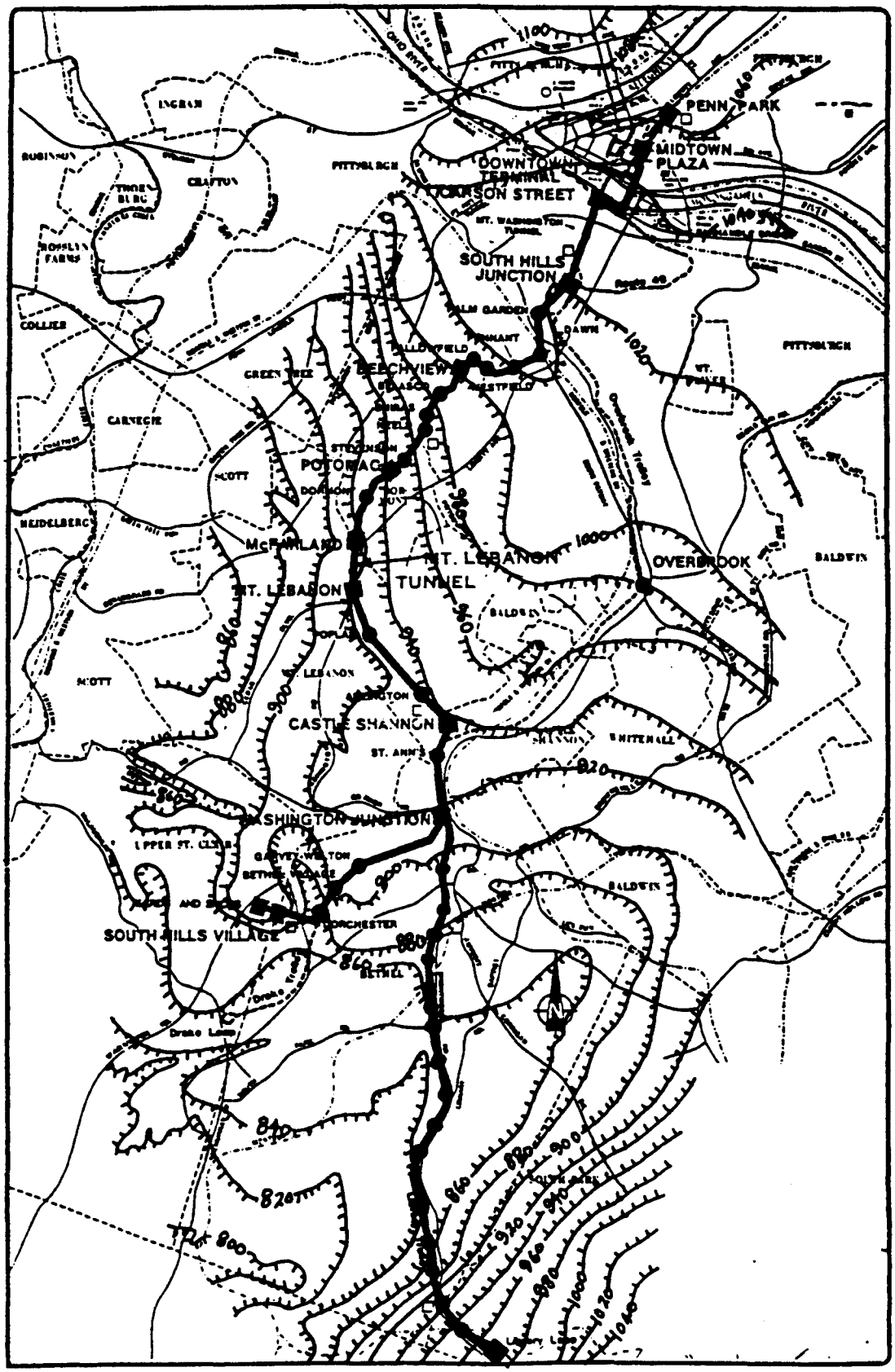

FIGURE 4. — Geologic structure of the LRT area, southern Allegheny County. Datum — base of the Pittsburgh coalbed, lowest unit in the Monongahela Group. Contour interval 20 feet. Ticks on down-structure side. Scale 1 inch equals about 2.3 miles.

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Coal Mining and Surface Subsidence

From about this point southward, the rails ride almost entirely on strata overlying mined-out workings in the Pittsburgh coalbed. Once labelled the most valuable single mineral resource in the country, perhaps the World, the Pittsburgh coalbed was uniformly more than six feet thick over more than 6,000 square miles. In Allegheny County alone more than 1,000,000,000 tons of coal have been mined from the Pittsburgh bed, enough to bring Lake Michigan to a boil and to occupy a coal train longer than five times around the world. The amazing thing is that there is so little evidence now to be seen of this mining activity, which was going full bore just a few decades ago.

Mine subsidence is the common term for surface subsidence owing to creation of voids by underground mining. Mine subsidence has been a widespread problem in Allegheny County, though with underground coal mining close to finished here, the number of incidents per unit time has decreased substantially. However, subsidence probably will never cease altogether. Regional experience is that overburden thickness must be at least 150 feet to have reasonable assurance from subsidence damage. This is by no means a perfect rule; structural damage has occurred where overburden is greater than 800 feet thick. Essentially the entire area from here south beyond Library has been undermined, so mine subsidence of course was an appreciable source of concern in design of the LRT system.

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Cumulative mileage	Incremental mileage	Location/description
	0.4	
2.1		Westfield - From about here to Potomac Station, about 1.5 miles, the route lies over former workings of the old Oak Hill Mine, with overburden thickness ranging from very little on the north to about 280 feet on the south. There were several verified instances of mine subsidence in this general vicinity.
	0.2	
2.3		Fallowfield Station
	0.1	
2.4		Hampshire

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Physiography

Allegheny County is in the Pittsburgh Plateau section of the Appalachian Plateaus physiographic province. The section hereabout is characterized by generally flat-topped ridges about 1,200 to 1,400 feet in elevation, separated by steep-walled valleys commonly 300 to 400 feet and locally as much as 600 feet deep. The top of each

ridge is at about the same elevation as its near neighbors, with the result that one rarely has a distant horizon in view. Farther away from the mainstem rivers and principal tributaries, ridge-top elevations are little different than here, but stream incision is less, so local relief also is less.

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Cumulative mileage	Incremental mileage	Location/description
	0.1	
2.5		Coast - From about this Stop onward for about 1 mile the rails run southward on the top of a ridge, affording a good feeling, as glimpsed between buildings, for the essential concordance of elevations from ridge to ridge.
	0.2	
2.7		Belasco
	0.1	
2.8		Boustead
	0.2	
3.0		Shiras
	0.1	
3.1		Neeld - Between this and the next Stop, the bridge over Wenzel Avenue utilized embankments 15 feet thick.
	0.3	
3.4		Stevenson
	0.2	
3.6		Potomac Station - From here to about Arlington Stop, about 2.1 miles, the route is over former workings of various mines of the Pittsburgh Coal Company, with overburden averaging about 280 feet to Mount Lebanon Station, then thinning to about 150 feet at Arlington.
	0.2	
3.8		Kelton
	0.3	
4.1		Dormont Junction Station

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Mount Lebanon LRT Tunnels

The Mount Lebanon Tunnels consist of two parallel tubes, each approximately 2,800 feet long, oval in section, and each averaging 18 feet in diameter. They were driven through rock of the Uniontown Formation in the upper Monongahela Group an average of 90 feet below the surface. Rocks at ground surface above the tunnels are a thin skin of lowermost Waynesburg Formation (Dunkard Group) strata, overlying the Uniontown (Figures 2 and 3). The roof of each tunnel was mostly in the "Waynesburg limestone" in the Uniontown Formation. Figure 5 is a profile of one tunnel, showing the horizontal character of strata and suggesting the lateral variability of facies that were encountered. Figures 6A, 6B, and 6C

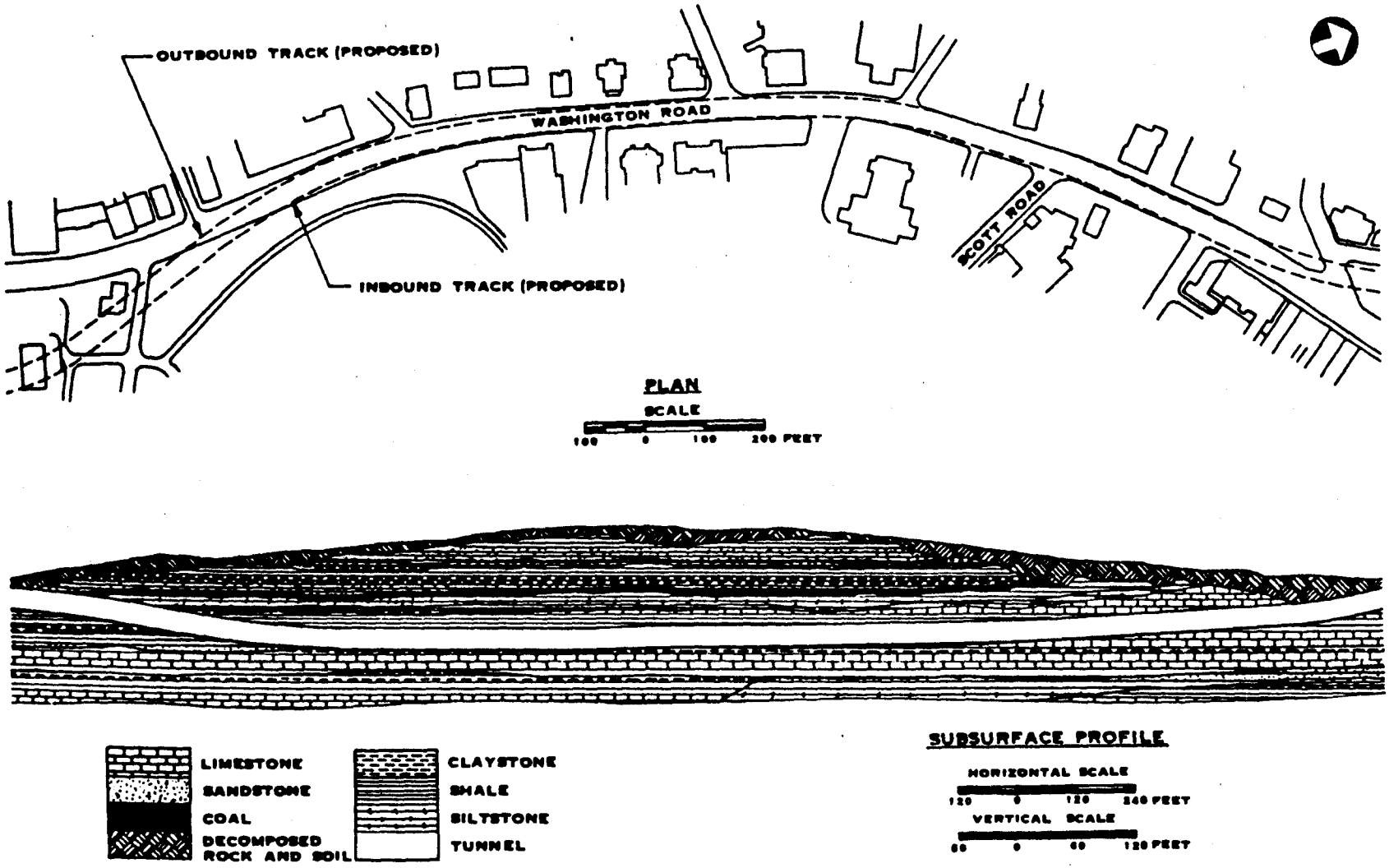


FIGURE 5. — Plan and subsurface profile of the Mt. Lebanon LRT tunnel. Arrow in upper right indicates north.

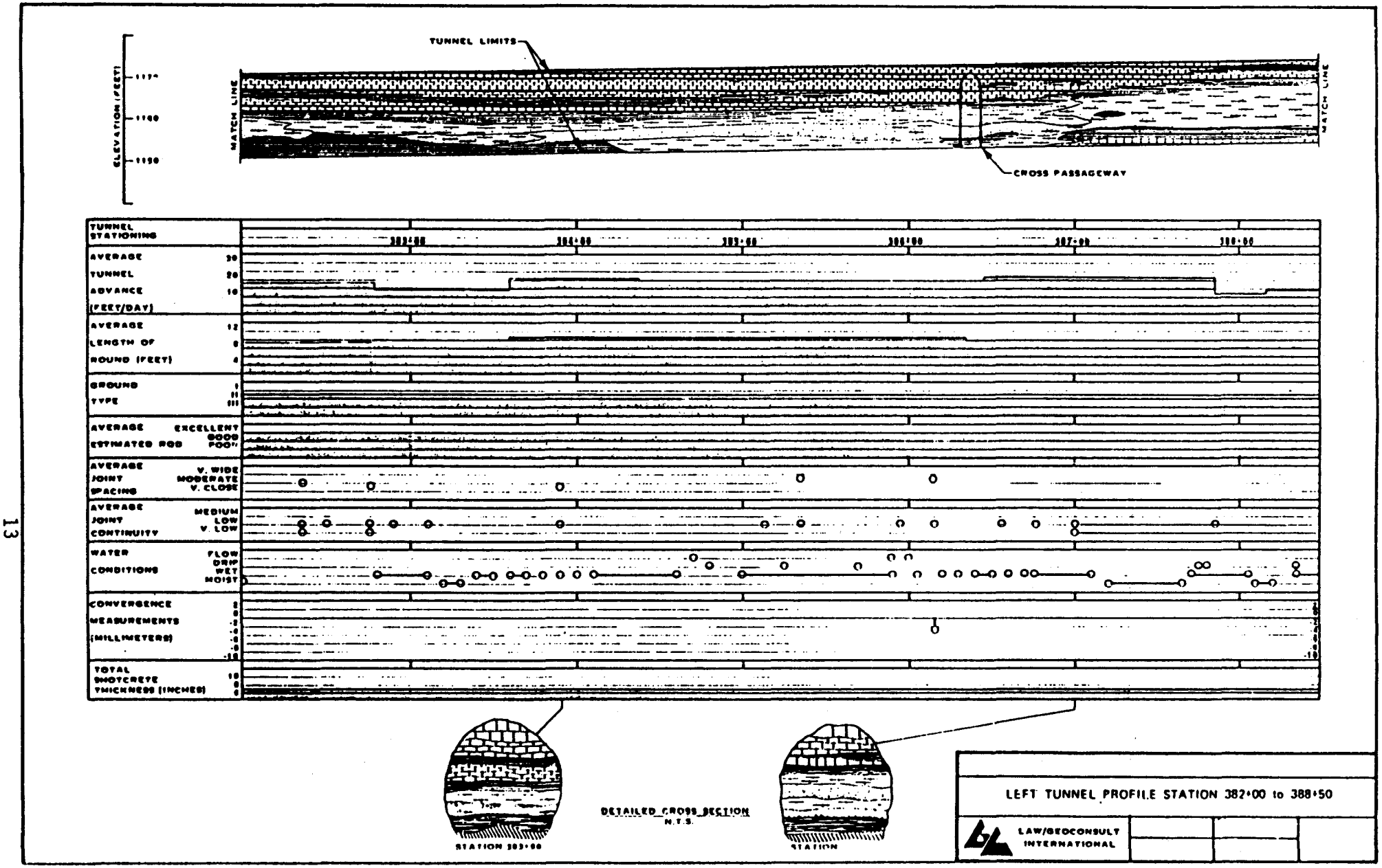


FIGURE 6A. — Profile of a segment of the left tunnel at Mt. Lebanon showing lithology and other information. Scale 1 inch equals 80 feet.

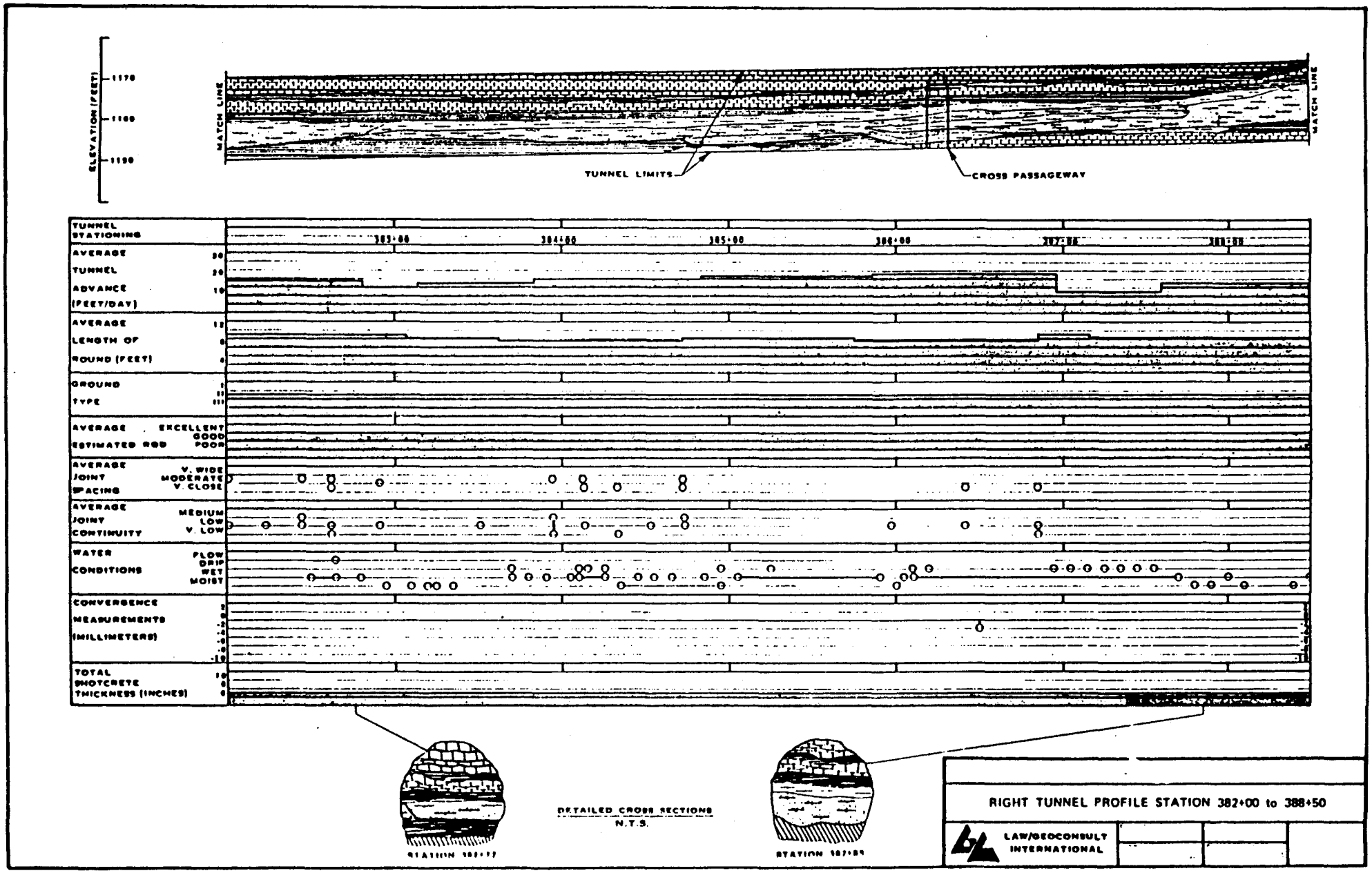


FIGURE 6B, — Profile of the segment of the right tunnel that matches the left tunnel segment of Figure 13A, Mt. Lebanon. Scale 1 inch equals 80 feet.

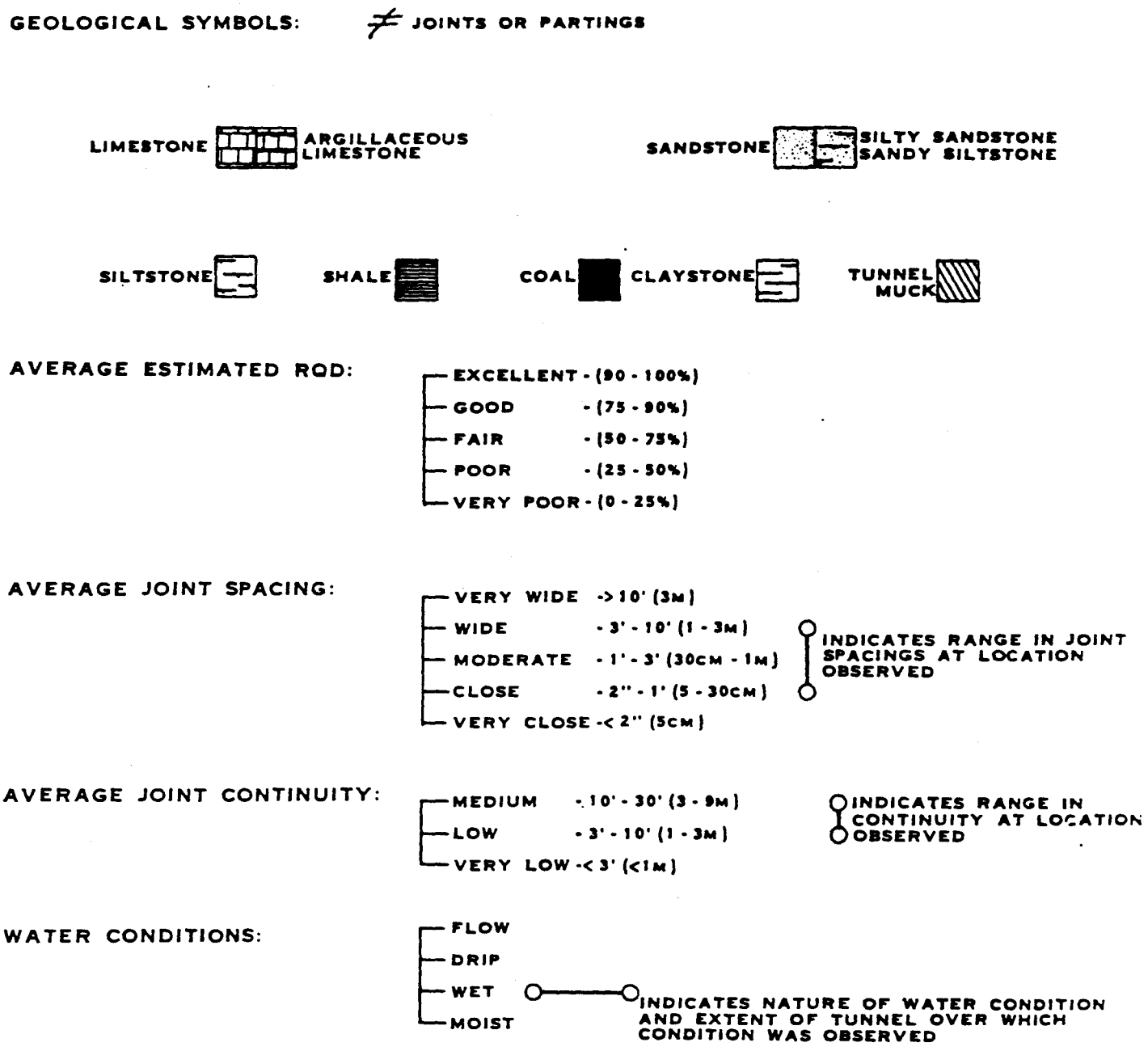


FIGURE 6C. — Explanation of Figures 13A and 13B.

show at a larger scale matching segments of the two tunnels, further illustrating variability in rock types, and providing some examples of other conditions encountered and rates of tunneling advance. Figure 7 shows sections in representative headings.

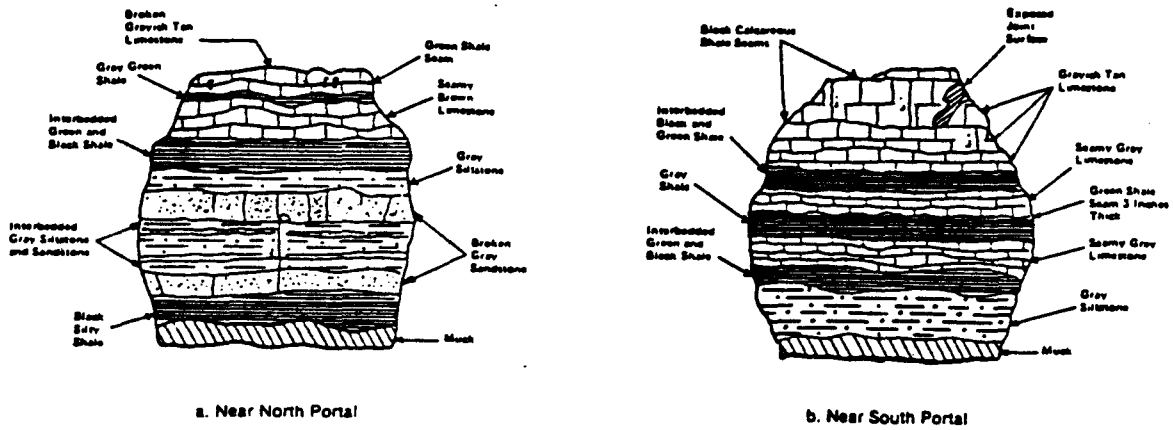
The tunnels were constructed using the New Austrian Tunneling Method (NATM), and they were the first significant application of this technique in this country. The technique relates to how tunnels are supported, rather than how they are driven. Conventional tunneling relies chiefly on steel frame supports and reinforced concrete (Figure 8). In contrast, NATM applies a layer of shotcrete directly to the rock, and this with ancillary support (chiefly roof bolts) is allowed to flex to a degree, so that the ground around the opening is converted to a load-carrying ring. Wire mesh is laid over the first shotcrete layer and a second layer is applied (Figure 9). The NATM with shotcrete and mesh directly on the rock surface leaves an irregular tunnel lining, which can be seen from the trolley when away from the portals, which are of conventionally applied reinforced concrete. The average total thickness of shotcrete was about 8 inches. Conventional support would have required about 12 inches of concrete, which, with steel arches vs. wire mesh, meant substantial differences in costs of materials. The winning construction bid on the tunnels for NATM work was just under $18,000,000, compared to more than $21,000,000 bid for conventional work.

Excavation of both tunnels began in January 1984. One tunnel was purposely kept 50 feet in advance of the other, and both tunnels holed through before the end of the year. During construction, ground movement was monitored using settlement-reference points, convergence pins, and multipoint borehole extensometers. The mined-out Pittsburgh coalbed was about 240 feet below the tunnels. Though a concern, no subsidence problems were encountered. Of related concern is the possibility that natural gas from coalbeds, "methane", may rise along subsidence fractures and joints to accummulate in the tunnels. Accordingly the tunnels now have methane sensors. The tunnels are also equipped with sump pumps, though water inflow has been slight.

The interiors of the tunnels are illuminated by yellow-orange lights spaced about 30 feet apart. When travelling slowly through the tunnels the orientation of these lights as seen from both ends of the trolley clearly show the irregular surfaces of the tunnel linings that resulted from the NATM method of construction.

==========

Cumulative mileage	Incremental mileage	Location/description
	0.7	
4.8		Mount Lebanon Station - The west, right, wall of the station is reinforced concrete, backing on the built-up area upslope. From here to Poplar Stop, to keep the two new tracks in the narrow formerly single-track



a. Near North Portal

b. Near South Portal

FIGURE 7. — Typical geologic sections at tunnel headings, Mt. Lebanon, each about 20 feet high.

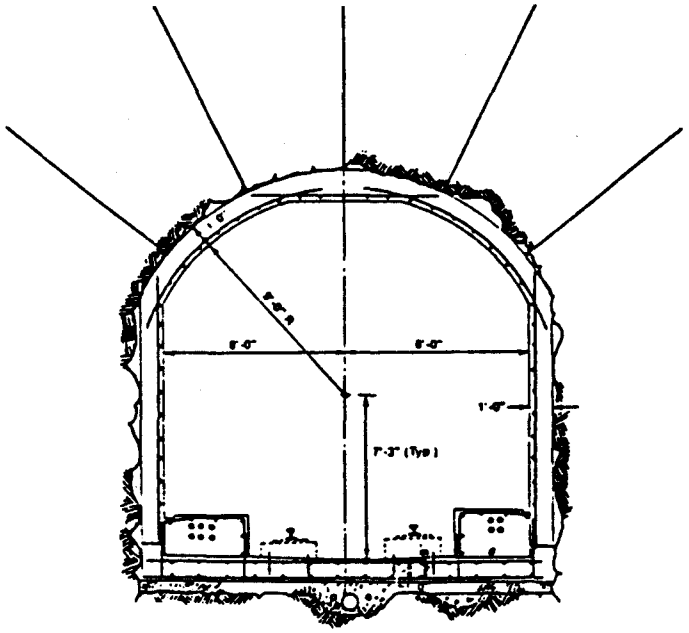


FIGURE 8. — Tunnel Section constructed by conventional method.

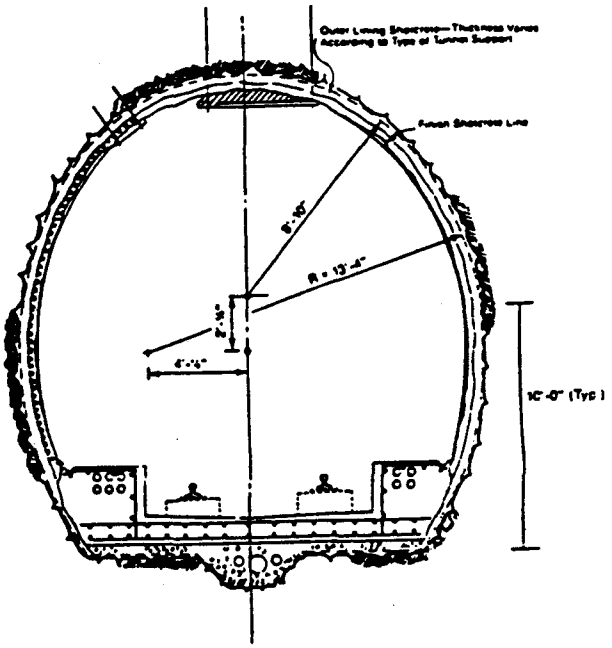


FIGURE 9. — Tunnel Section constructed by New Austrian Tunneling Method.

right of way, soldier piles and concrete lagging were used extensively to allow essentially vertical slopes on both cuts and the sides of embankments.

0.5

5.3 Poplar

0.4

5.7 Arlington - From here to about Martin Villa Stop, 0.7 mile, the route is over former workings of the Pittsburgh Terminal Coal Company No. 1 & No. 2 Mines, with overburden thickness ranging from about 150 feet down to 110 feet.

0.2

5.9 Castle Shannon Station - Within about a mile northeast, to the left, of here, there were a number of verified damaging subsidence incidents, mostly where overburden thickness was less than 150 feet. After the station and shortly before the next Stop, the Overbrook PCC-car line comes in from the left. We are again in the Saw Mill Run valley, but well upstream from the crossing near the Liberty Tubes.

0.5

6.4 Martin Villa - From about here to Washington Junction Station and south beyond it to Lytle Stop on the Library LRT line, about 2.2 miles altogether, the route lies over former workings of the Pittsburgh Terminal Coal Company No. 3 Mine, with overburden thickness ranging from about 110 feet to about 170 feet at Washington Junction Station, then thickening to about 350 feet at Hillcrest Stop and Lytle.

0.2

6.6 St. Anne's - Between here and Smith Road Stop across the run a zone of potential landsliding was identified during geotechnical investigations. Although instability of slopes is a regional concern, it was not a large factor in LRT reconstruction, owing to the few significant excavations involved (Mount Lebanon tunnels and downtown subway aside). However, fairly recently the Overbrook line was blocked by a landslide.

0.3

6.9 Smith Road - Just past this Stop, the tracks go under a new bridge on Connor Road.

0.3

7.2 Washington Junction Station - Just past the station, the trolley route divides. The route to the right goes to South Hills Village, and this is the one we take now. The straight ahead route goes to Library, which we will take later.

==========

Pittsburgh Terminal Coal Company Mine 3

The Washington Junction Station marks the approximate location of the shafts and other surface facilities of the Pittsburgh Terminal Coal Company Mine Number 3. There are few obvious relics of this

mining activity. However, visible on the hill to the left, east, of the Library trolley line there remain occupied and in use a sizable number of adjacent large frame houses typical of the two-family dwellings erected by the coal industry in their "company towns" or "coal patches". This is shown as an isolated "development" on the 1906 edition of the topographic map surveyed in 1903-1904, though of course it is now completely engulfed by suburbs. A few other brick and frame structures nearby probably also date from the time of active mining. PA Hwy 88 is on the left at the station, and just beyond it is the Norfolk Southern Railway line from Pittsburgh to Connellsville. Labelled the "West Side Belt RR" on the 1906 map, it surely handled the bulk of the coal from the mine. According to the 1911 geologic map, the mine shaft was located on the slope just on the other side of of the railroad, with tipple and coal sidings adjacent. Visible only from favorable angles, on the slope east of the railway is a huge waste pile doubtless emplaced by a cable-and-bucket way from the mine.

==========

Cumulative mileage	Incremental mileage	Location/description
	0.5	
7.7		Casswell - On the South Hills Village line.
	0.3	
8.0		Highland - Here soldier piles and concrete lagging restrain weathered soft gray shale of the lowermost Waynesburg Formation. Except for the Waynesburg in this immediate vicinity, the Washington Junction-South Hills Village line is entirely on Monongahela Group strata (Figure 3) overlying former workings of Mine 3.
	0.2	
8.2		Santa Barbara
	0.3	
8.5		Bethel Village
	0.3	
8.8		Dorchester - Just south of this Stop there is a wye in the track, at which we bear off right and up hill. The other track goes straight ahead down Graesers Run about 1.3 miles to a terminus at Drake Loop. This short branch once had larger importance. From 1909 to 1953, it ran an additional 18 miles from Drake Loop southwest to Washington ("Little Washington"), Pa. Thus the name for Washington Junction Station 1.6 miles back. That was where the interurban route to Washington branched off from the earlier route to Library and Charleroi.
	0.3	
9.1		South Hills Village Station - As you can see, South Hills Village is not a place but a mall, about half in the Borough of Bethel Park and half in the Township of Upper St. Clair. Upper St. Clair now is a "posh" suburb, but as recently as fifty years ago, until after

World War II, both municipalities were mostly pretty rough-and-ready farming/coal-mining areas, with only the parts close to the trolley lines representing early suburbs.

==========

South Hills Village Station Construction

The site of this station formerly was a valley tributary to Graesers Run. During earth work for the mall in or about 1968, this area, away from mall building construction, was used for waste earth and rock. Test holes drilled later for the LRT system showed this material to be poorly compacted with many voids, unsuitable for foundations. Accordingly, the material at the station was reexcavated for a width of 100 feet normal to the right of way. Rocks removed were broken down to small sizes or wasted elsewhere, and earth and rock were reemplaced as an engineered compacted fill. This embankment is about 50 feet thick above the former valley bottom, where it rests on strata of the upper Monongahela Group. Ground level at the station approximates the level of the Waynesburg coalbed in the base of the Permian-Pennsylvanian Dunkard Group, which rests on the Pennsylvanian Monongahela Group (Figures 2 and 3). The Waynesburg coalbed crops out not far away to the south, just west of the Car Storage and Maintenance Area.

==========

From South Hills Village Station we make a loop of about one mile to the southwest around and through the LRT Car Storage and Mainteance Area. Note the number of PCC cars stored to be cannibalized for parts for those still in service. Then we again pass through the station and head back to Washington Junction.

==========

Cumulative mileage	Incremental mileage	Location/description
	1.4	
10.5		Casswell - To the front right is a good view of the Pittsburgh Terminal Coal Company Mine 3 town.
	0.5	
11.0		Washington Junction Station

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At Washington Junction Station our direction is reversed to allow us to take the line to Library.

==========

Cumulative mileage	Incremental mileage	Location/description
	0.3	
11.3		Mine 3 - The stop of course is named for the former underlying coal mine and serves the old "company town". About here the trolley route climbs above the Pennsylvanian Monongahela Group into strata of the Permian and Pennsylvanian Waynesburg Formation. It runs on Dunkard strata until past South Park Stop (Figures 2 and 3).
	0.2	
11.5		Hillcrest
	0.3	
11.8		Lindermer
	0.4	
12.2		Center
	0.2	
12.4		Lytle - From here to about Beagle Stop, about 2.3 miles, the route is over former workings of the Pittsburgh Terminal Company No. 8 Mine, with overburden thicknesses ranging from about 350 feet here down to 150 feet at Beagle.
	0.2	
12.6		Mesta
	0.2	
12.8		South Park
	0.3	
13.1		Monroe - About here the route descends from Dunkard strata into Monongahela Group strata again.
	0.2	
13.3		Latimer
	0.4	
13.7		Sarah
	0.3	
14.0		Logan
	0.2	
14.2		Kings School - From here to Sandy Creek Stop, the track follows Sandy Creek gently down stream through an area of sporadic suburban development. Keep an eye out for deer, which seem to consider trolleys as part of the habitat.
	0.5	
14.7		Beagle - From here to about West Library Stop, about 0.5 mile, the trolley route lies partly over easternmost former workings of the Consolidation Coal Company's Montour No. 4 Mine and partly along the zigzag barrier between that mine and Consol's Montour No. 10 Mine. The overburden thickness ranges from about 150 feet down to 110 feet at West Library Stop.

==========

Flooding of Montour No. 4 and Mine Subsidence

Montour No. 10 Mine was mined out and closed at the end of 1979. Pumping was stopped, and the mine became flooded. Montour No. 10 was located on the northwest flank of the Amity anticline, up dip from Montour No. 4 (as is shown by structure contours in the southeast part of Figure 4, and indicated by the thinning of overburden as the trolley route approaches Montour No. 10). Montour No. 4 continued as an active mine in 1979-1980. In August 1980, however, the barrier between the mines failed and lower parts of Montour No. 4 rapidly were flooded, fortunately without loss of life. Because remaining reserves of coal in Montour No. 4 were limited (less than two years), a decision was reached not to attempt rehabilitation. Montour No. 4 was formally closed and abandoned and largely is flooded today, although some pumping is believed to continue, in order to control the quality of mine drainage to the environment.

About four years after Montour No. 4 was flooded, damage attributable to mine subsidence took place over sections of the mine, all within a relatively short period of time. One school complex was so damaged that it had to be abandoned as unsafe, and another school, a church, a telephone building, and several residences suffered significant but reparable damage. The time of subsidence damage coincided very closely with the time of the arrival under the damaged structures of the rising pool in the flooding mine. This coincidence makes it arguable that they were somehow related, and this is a current subject of litigation.

==========

Cumulative mileage	Incremental mileage	Location/description
	0.2	
14.9		Leonard - Along this general reach of Sandy Creek, note the occasional use of gabions to reinforce stream banks along the right of way.
	0.1	
15.0		Sandy Creek - Between Sandy Creek and West Library Stops, the trolley track crosses PA-88, Library Road, at grade.
	0.2	
15.2		West Library - Between here and Simmons Loop, about 0.75 mile, the route lies wholly over the former workings of Montour No. 10 Mine, with overburden thickness ranging from about 110 feet down to zero, concealed outcrop, in the vicinity of Pleasant Stop and Simmons Loop.
	0.4	
15.6		Hicks - The bridge over the trolley line here formerly carried the Montour Railway, which served Montour No. 4 and Montour No. 10 as well as other Consol

mines. With the mines abandoned, the railway also was closed. Track has been torn up, and in Peters Township just to the southwest, the right of way now is a hiking/biking path.

0.3

15.9 Pleasant

0.05

15.95 Simmons Loop (Library Station) - This is the terminus of this branch of the LRT System. It wasn't always this way. From 1903 to 1953 this line ran about 20 miles farther south to Charleroi on the Monongahela River, extended another about 7 miles south to Roscoe in 1910. Its early name was the Charleroi Electric RR. Concealed here are uppermost Casselman Formation rocks, immediately beneath the Pittsburgh coalbed, also concealed.

==========

The Borough of Library was the headquarters for the Montour No. 10 mine, and most of the mine's surface installations were just east of Simmons Loop. Although its mines in the vicinity are no longer producing, Consolidation Coal Company continues to pursue part of its research and development operations at Library, located just east of Simmons Loop. Through the kind cooperation of Consol, those attending the April 27, 1991 LRT field trip will be given an introduction to this facility.

From Simmons Loop walk a few yards south to Brownsville & Library Road, where there is a war memorial highlighted by a missile. Turn left there and walk about 0.2 mile east along the road to the well-marked entrance to the Consol facility, turn left, and enter. We will eat lunch following the tour of the facility, and then return to Simmons Loop.

==========

Consolidation Coal Research and Development

Established 45 years ago, Consolidation Coal Research and Development (Consol R&D) is the world's largest private facility devoted to coal research. Located at Library, Pa., and Morgantown, W.Va., Consol R&D investigates and develops advanced technologies related to coal mining, transportation, processing, and combustion and to environmental protection.

Employing about 160 scientists, engineers, and analysts, Consol R&D over the years has developed coal liquefaction and gasification, synthetic metallurgical coke, coarse-coal pipeline transportation, advanced robotic mining systems and a suite of air-pollution-control technologies.

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Once again at Simmons Loop, we reboard our trolley and head inbound toward Washington Junction.

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Cumulative mileage	Incremental mileage	Location/description
	2.65	
18.6		Latimer Stop

==========

Provisional Stop - Gabions, photos, etc.

If weather cooperates and those on board wish, we will stop in this vicinity to look at this and that and savor the feeling that the trolley is indeed "ours", to control as we wish, within limits of course.

==========

Cumulative mileage	Incremental mileage	Location/description
	2.0	
20.6		Mine 3 -Looking forward and to the right from between the Mine 3 stop and Washington Junction Station, one can get a view of the Mine 3 waste dump.
	0.3	
20.9		Washington Junction Station
	1.3	
22.2		Castle Shannon Station
	1.1	
23.3		Mount Lebanon Station - New Mount Lebanon LRT tunnels. Again observe the irregular shape of tunnel linings.
	0.7	
24.0		Dormont Station
	0.5	
24.5		Potomac Station
	1.3	
25.8		Fallowfield Station
	1.5	
27.3		South Hills Junction Station - Mount Washington trolley tunnel.

==========

Provisional Stop - Pittsburgh coalbed and Casselman Formation

Weather, trolley traffic, and majority wishes permitting, we will park our trolley here and take a look at the uppermost Casselman

Formation, Conemaugh Group, as related to the elevation of the Pittsburgh coalbed in the base of the Pittsburgh Formation, Monongahela Group (Figure 2).

==========

Cumulative mileage	Incremental mileage	Location/description
	0.8	
28.1		Station Square Station - After this station, at the near, south, end of the Panhandle bridge the yet-to-be-opened new loop of the LRT up Mount Washington branches off to the southeast. We cross the Monongahela River on the Panhandle bridge and shortly enter the subway, almost under the Manor Building on Forbes Avenue.

==========

Subway Construction - I

Here the subway occupies a former Pennsylvania Railroad tunnel built in 1865 and used for rail traffic until 1981 (Figure 10). The tunnel was constructed with sandstone-block walls and a brick arch, and it was and is wide enough for two tracks (Figure 12). It was reinforced during conversion for the LRT, and its floor was lowered to allow the necessary height for cars powered by overhead electrification.

==========

Cumulative mileage	Incremental mileage	Location/description
	0.8	
28.9		Steel Plaza Station - From this station a short branch runs north to the old Pennsylvania Railroad Station (now Conrail/Amtrak), using the same former railway tunnel. Another old tunnel also is nearby, the Pennsylvania Canal tunnel of 1837 (Figure 10), which was exposed in a nearby excavation (Figure 11) and was encountered in borings for the subway (Figure 14).

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Subway construction - II

From Steel Plaza Station down Sixth Avenue to Wood Street Station and along Liberty Avenue to Gateway Center Station (Figure 15) construction was by cut and cover (Figure 16), involving excavation and removal of close to 200,000 cubic yards of material, mostly Pleistocene and Holocene alluvium, but including substantial quantities of old fill, and near Steel Plaza Station, bedrock was encountered. The uppermost bedrock unit labelled in Figure 13 is the Ames Limestone Member of the Glenshaw Formation in the

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Until the 1830's, a 45-feet-deep natural body of water called Hogg's Pond lay between the sites of Steel Plaza and Woods Street Stations. Filled in with 19th-century tunnel waste, on excavation for the subway the former pond was found to contain weak bog-like material, which had to be dug out and replaced with more competent subgrade material.

During subway excavation in a relatively old urban area such as Pittsburgh, particular care had to be taken with underground util-

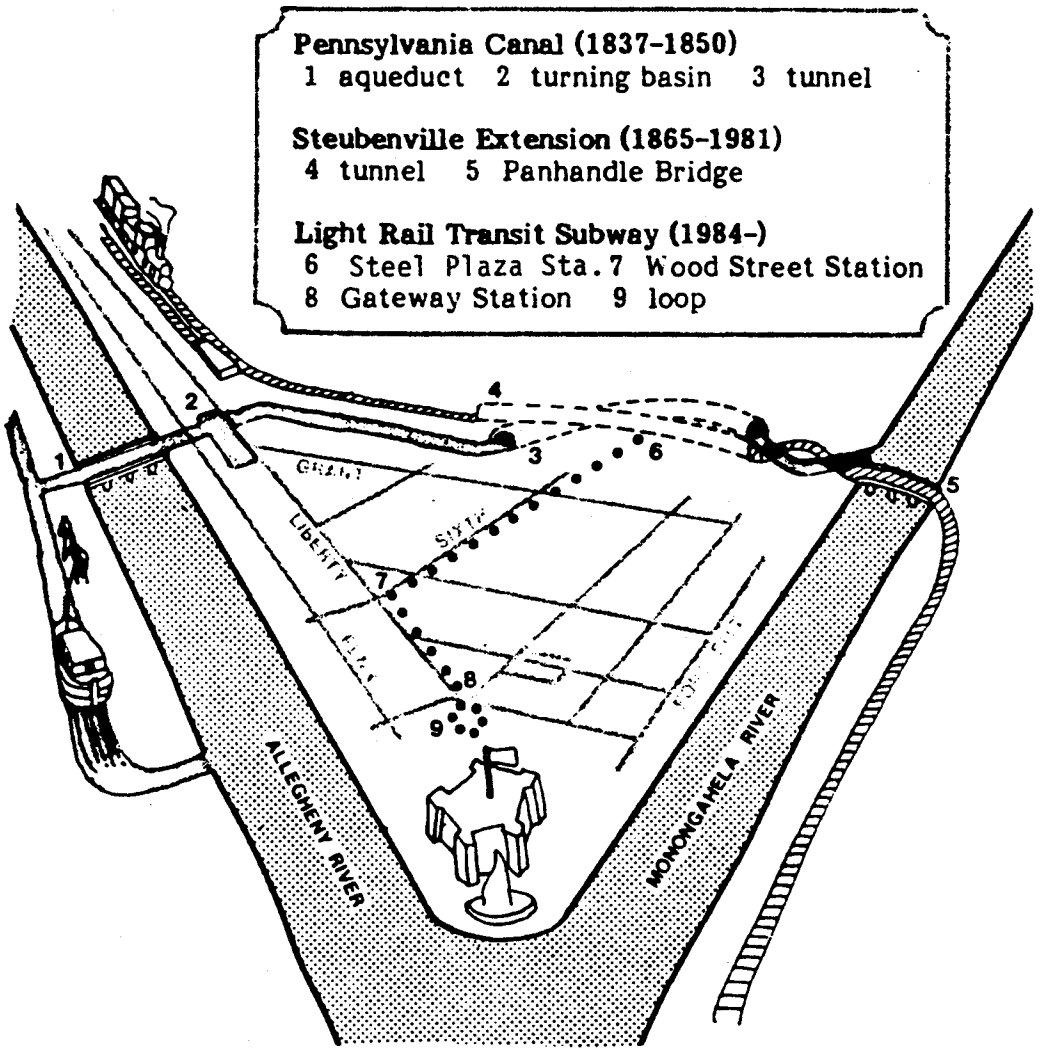

FIGURE 10. — Perspective sketch showing relations of old tunnels and the LRT subway.

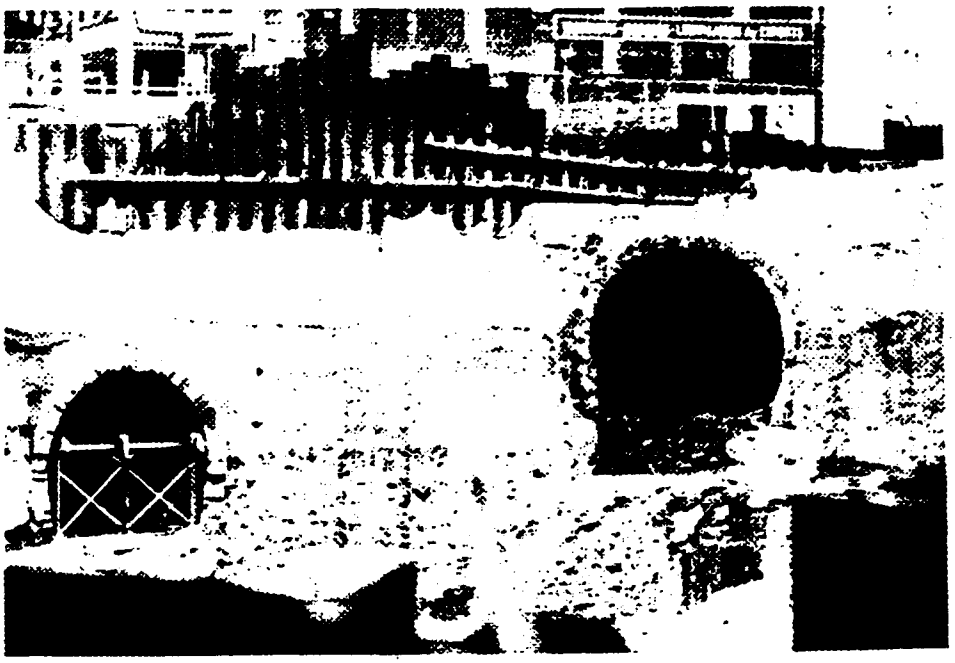

FIGURE 11. — Excavation for the USX Tower (formerly the U.S. Steel building - Figure 2), just north of the Steel Plaza Station exposed both canal (left) and railroad (right) tunnels.

FIGURE 12. — Old railroad tunnel exposed during excavation at Steel Plaza Station.

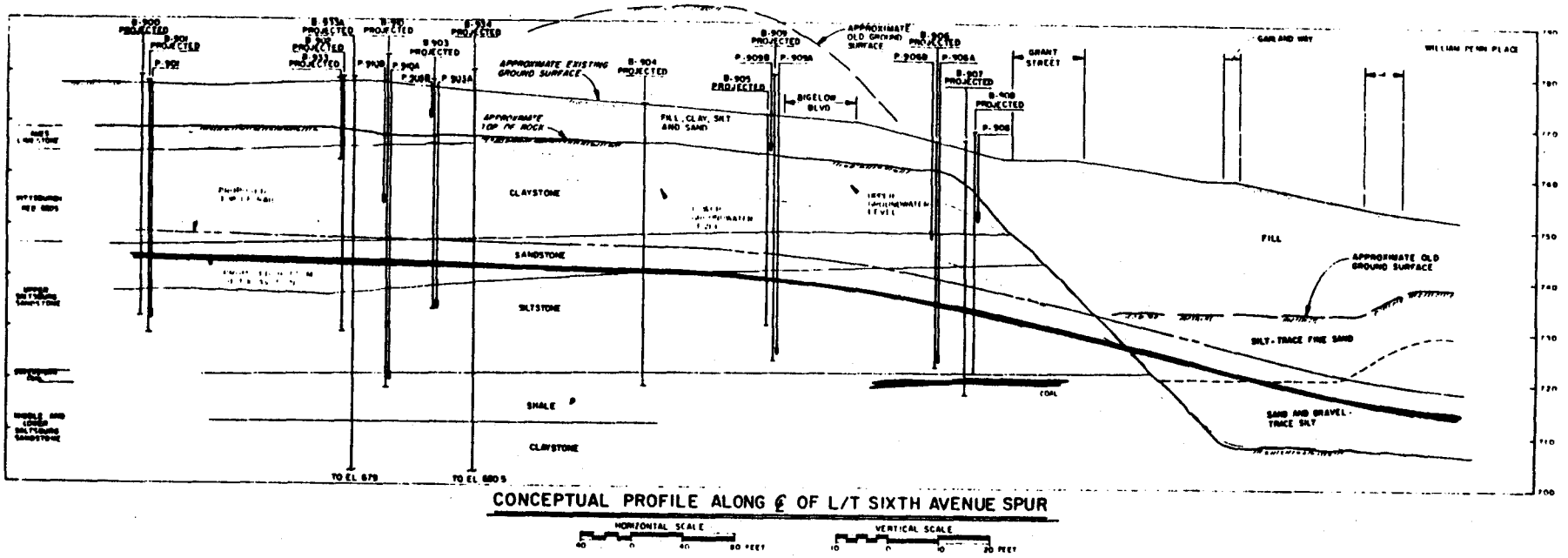

FIGURE 13. — Subway section along upper Sixth Avenue (Figure 2). Heavy line is approximate bottom of excavation. Left-right approximates east-west.

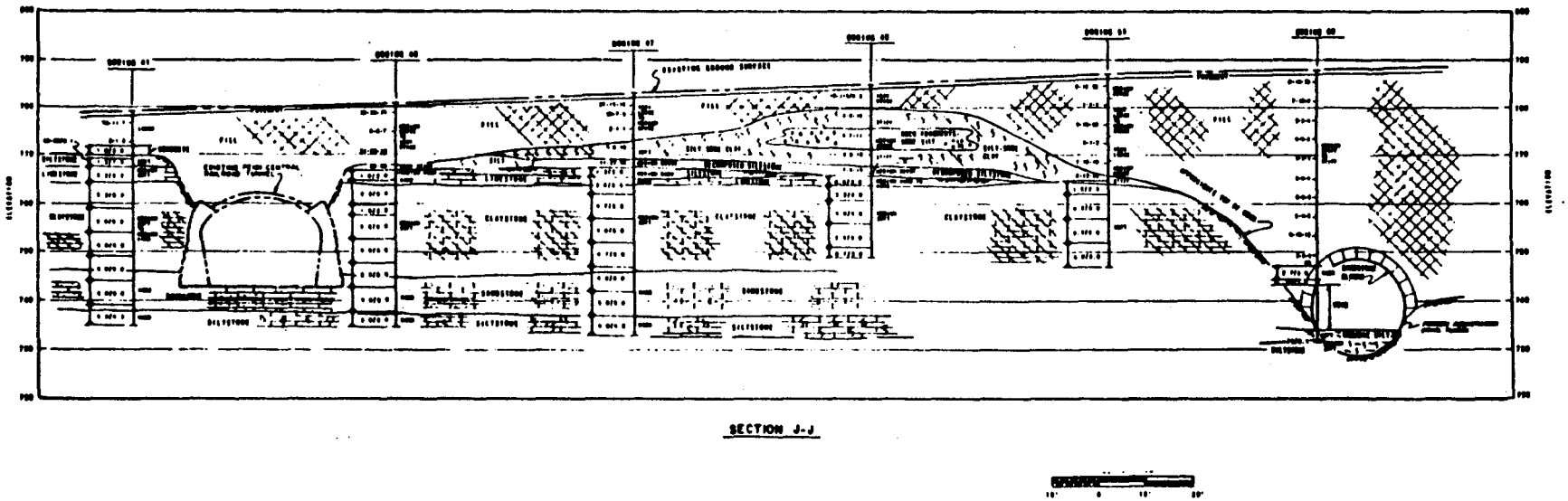

FIGURE 14. — Section through the Steel Plaza Station area (Figure 2) showing relations of old railway tunnel (left) and old canal tunnel (right). Left-right equals about southwest-northeast. Scale 1 inch equals about 36 feet.

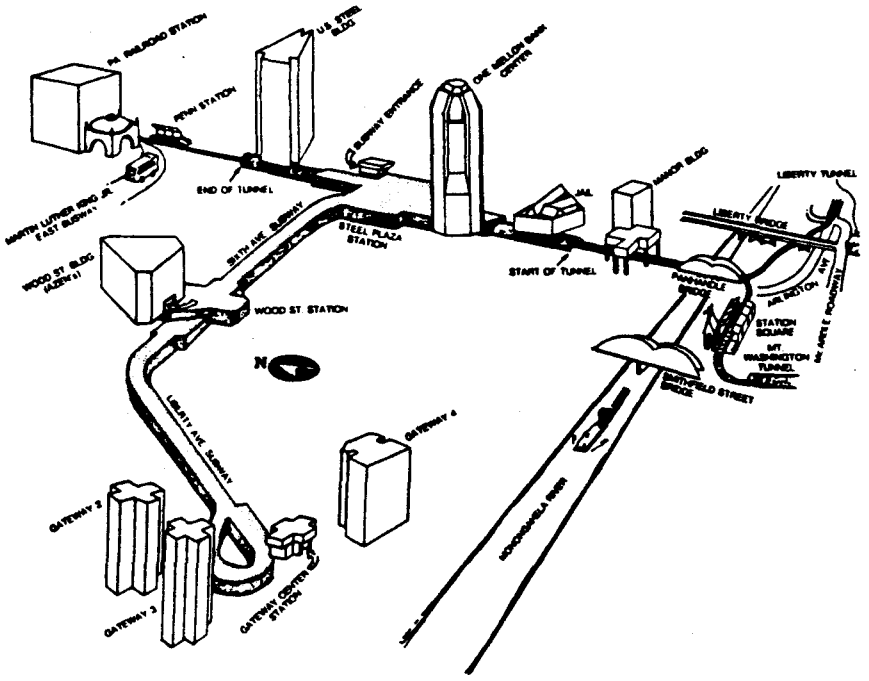

FIGURE 15. — Perspective sketch of the LRT subway through downtown Pittsburgh, looking generally to the east.

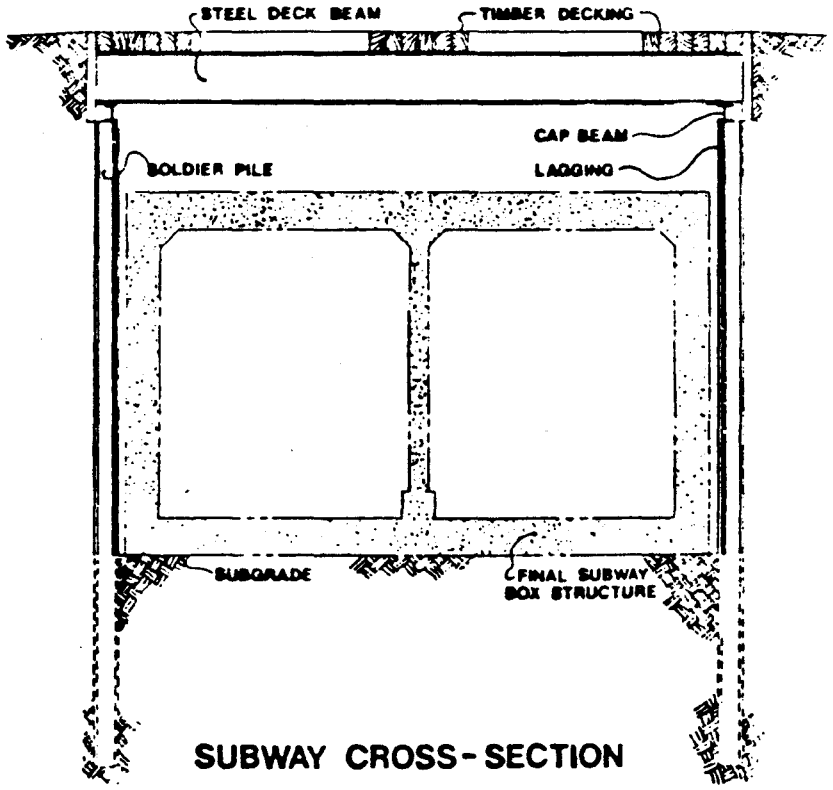

FIGURE 16. — Typical cross section showing cut and cover subway construction. The concrete subway "box" is about 35 feet wide and 22 feet high. The average depth of excavation was about 40 feet.

Pennsylvanian Conemaugh Group (Figure 2). In Figure 14 siltstone and sandy clay of the basal Casselman Formation rests on the limestone. The bulk of rock excavation was in the Pittsburgh redbeds in the upper Glenshaw, which are well known regionally for their proneness to landsliding on even moderate slopes.

Until the 1830's, a 45-feet-deep natural body of water called Hogg's Pond lay between the sites of Steel Plaza and Woods Street Stations. Filled in with 19th-century tunnel waste, on excavation for the subway the former pond was found to contain weak bog-like material, which had to be dug out and replaced with more competent subgrade material.

During subway excavation in a relatively old urban area such as Pittsburgh, particular care had to be taken with underground utilities, known and unknown, and with potentially weak foundation conditions of elderly structures adjacent to excavations.

==========

Cumulative mileage	Incremental mileage	Location/description	
	0.3		
29.2		Wood Street Station	0.3

==========

Subway construction - III

The water table under the part of the subway route from the vicinity of Wood Street Station along Liberty Avenue to Gateway Center Station is about 35 feet down, in permeable Allegheny River alluvium. With excavation for the subway designed to about 40 feet below ground surface in this reach, wells were installed and pumped sequentially, lowering the level of groundwater to about 50 feet as required.

==========

Cumulative mileage	Incremental mileage	Location/description
	0.3	
29.5		Gateway Center Station - The track at this terminal point is laid in a loop to accommodate the PCC cars, which can only run forward (Figure 15). As you have seen, the new articulated cars have controls at both ends and can run in either direction. During excavation for the station six water wells dating from the 19th century were uncovered. Artifacts recovered from them included food materials and wood, glass, metal, ceramic, and leather items, well preserved by immersion.

Cumulative mileage	Incremental mileage	Location/description
	0.3	
29.8		Wood Street Station
	0.3	
30.1		Steel Plaza Station
	0.8	
30.9		Station Square Station

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END OF FIELD TRIP

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Acknowledgements

Many thanks to Thomas J. Dillon, Manager of PAT's Downtown Service Center, and to James R. Walter, Engineering and Construction Division of the Port Authority. Mr. Dillon arranged for the Light Rail Transit vehicle for this Field Trip and directed the trip leader to Mr. Walter, who kindly supplied the copious technical data and information adapted for the field trip guide.

This field-trip guide is chiefly modelled after but significantly reorganized from a trip I prepared for and led at the Association of Engineering Geologists Annual Meeting in Pittsburgh during October 1990. The original itinerary appears in the Guide to Field Trips of that meeting -- RPB.

The "Trolley Through Time" article was prepared by Byron Spice based on his interview with Michael Bikerman at Pitt and an enjoyable "run" of the trip by Byron and me. Unfortunately for us, but of course fortunately for him, Mike was cicumnavigating the World when the PGS trip was run in April 1991 -- RPB.

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References and Sources of Illustrations

Bushnell, Kent, 1975, Map showing depths to the Pittsburgh coal bed, mining activity, and related surface subsidence, Allegheny, Washington, and Westmoreland Counties, Pennsylvania: U.S. Geol. Survey Misc. Field Studies Map MF-693A.

Butler, G.L.; Cavan, B.P.; Mussger, F.K.; Rhodes, G.W.; and Whitney, H.T., 1984, Pittsburgh's Mt. Lebanon tunnels - a case history: International Conf. on Case Histories in Geotechnical Engineering, Rolla, Missouri 1984, vol. II, p. 817-826.

References and Sources of Illustrations (cont.)

Cavan, B.P.; Rhodes, G.W.; and Wolosick, J.R., 1986, Application of NATM to Port Authority of Allegheny County's Stage I, Light Rail Transit System Mt. Lebanon tunnels: Atlanta, Georgia, Law/Geoconsult International, Inc. [available through the National Technical Information Service].

D'Appolonia Consulting Engineers, 1978, Preliminary assessment of subsurface conditions based on TERL geotechnical data [Stage I LRT, Port Authority of Allegheny County, Pennsylvania]: Pittsburgh, Pennsylvania, Parsons Brinckerhoff-Gibbs & Hill.

D'Appolonia Consulting Engineers, 1981, Assessment of subsurface conditions - Midtown Station [Stage I LRT, Port Authority of Allegheny County, Pennsylvania]: Parsons Brinckerhoff-Gibbs & Hill, Geotech. Rept. vol. IX, pt 1.

Port Authority of Allegheny County, various dates 1981 to 1985, public information releases titled "Evolution of a Subway", "LRT in Pittsburgh", "LRT Subway Guide", and "Sidewalk Superintendent": Pittsburgh, Pennsylvania.

Shaw, E.W., and Munn, M.J., 1911, Burgettstown-Carnegie Folio, Pennsylvania: U.S. Geological Survey Geol. Atlas of the United States Folio No. 177.

Wagner, W.R.; Craft, J.L.; Heyman, L.; and Harper, J.A., 1975, Greater Pittsburgh region geologic map and cross sections: Pennsylvania Geol. Survey, 4th ser., Map 42.

Wagner, W.R.; Heyman, L.; Craft, J.L.; Edmunds, W.E.; and Harper, J.A., 1975, Greater Pittsburgh region structure contour map: Pennsylvania Geol. Survey, 4th ser., Map 43.

Whitney, Harold T., and Butler, Gilbert L., 1983, The New Austrian Tunneling Method - a rock mechanics philosophy: 24th U.S. Symposium on Rock Mechanics Symposium, Proceedings, p.219-226.

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FUTURE USERS - SEE NEXT PAGE

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FOR FUTURE USERS

This guide is written with the intent that it will remain useful to those who may want to do the tour some day on their own. For these future riders, from Station Square Station take an outbound trolley labelled "42S South Hills Village", which runs every 5 to 10 minutes. You will arrive at South Hills Village in about 30 minutes. From there return on the same line (or 47S for a PCC car, instead of 42S) to Washington Junction Station, maybe 10 minutes later. Get off and there take a car labelled "42L Library via Beechview", headed south, outbound to Library, a trip of about 15 minutes. During non-rush hours trolleys to and from Library run about every 30 minutes, so you may have to wait a bit at Washington Junction Station and will have time for a walk around

Library, before reboarding the 42L trolley inbound. When you reach Station Square Station inbound, stay on board and take the downtown subway loop back to Station Square. If in all cases you take the very next car that comes along, the whole tour should take less than three hours.

Of course one can get on anywhere and take all or a part of the route. If you want to vary the scenery inbound or outbound, you can take a 47S PCC car on the Overbrook route between Washington Junction Station and South Hills Junction Station on Mount Washington.

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