BURIED VALLEY OF THE
SUSQUEHANNA RIVER
ANTHRACITE REGION OF PENNSYLVANIA

By S. H. Ash
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BURIED VALLEY OF THE SUSQUEHANNA RIVER
ANTHRACITE REGION OF PENNSYLVANIA

By
S. H. Ash

Summary

A clay, sand, and gravel deposit known as the "buried valley" of the Susquehanna River is situated in the Northern field of the anthracite region of Pennsylvania near Wilkes-Barre.

The presence of this buried valley and the uncertainty regarding the extent and physical condition of the water-bearing valley-fill deposits have made great care necessary in mining operations to avoid breaking the strata between the mine workings and the valley-fill deposits to the extent that inundation of the mine workings would follow. The principal factor that threatens to cut short the life of the anthracite industry, to curtail production, and to affect the economic structure of the people and business dependent on anthracite for their livelihood is inundation of anthracite mines (6, 7).

A vast tonnage of anthracite has been mined beneath the buried valley, and a large tonnage of anthracite remains unmined. Present and future operators of mines in this area must be familiar with the water-bearing deposits so that they can conduct their operations safely (4).

Boreholes drilled from the surface of the ground in this area through the valley-fill deposits have revealed the rock bottom of this great depression to be below 250 feet altitude at several points. Near Berwick, approximately 18 miles downstream from West Nanticoke, rock crosses the river at 450 feet altitude. At no place farther downstream is the rock below 250 feet altitude until Middletown, Pa., is reached, nearly 90 miles downstream from Berwick (9).

It appears quite evident that basins or channels were excavated in the sandstones, shales, slates, and anthracite beds of the anthracite measures by glacial action, as well as by water erosion.

Potholes are present in the area comprising the buried valley; these were formed by swirling currents of water carrying abrasive materials during the advance and retreat of glaciers. They extend below the normal bottom of the buried valley. Some large potholes are visible at the surface of the ground in the Scranton area (9).

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1 Work on manuscript completed April 1950.
2 Chief, Safety Branch, Health and Safety Division, Bureau of Mines, Washington, D. C.
3 Italicised numbers in parentheses refer to items in the bibliography at the end of this report.
Geographically, the buried valley of the Susquehanna River is in the Wyoming Basin of the Northern field of the anthracite region and extends from West Nanticoke upstream to a little above West Pittston, a distance of 15 miles, where the Susquehanna River enters Wyoming Valley (4). The Lackawanna River enters the Susquehanna River at West Pittston. Valley-fill deposits of the buried valley are also found, to some extent, up the Lackawanna River drainage basin.

The materials that constitute the deep valley-fill deposits, as revealed by boreholes and shafts, are water-depositional sediments consisting of alternating layers of gravel, sand, clay, and admixtures of all three. Under Kingston lies a bed of clay 80 to 100 feet thick, an evidence of local ponding.

In some respects mining beneath water-bearing valley-fill deposits is similar to submarine mining. No one can predict the volume of water and water-soaked materials and the movement of broken strata that might be encountered if the rock cover fails. A valley-fill deposit having a deep layer of clay covering the bedrock is favorable for sealing small fissures; however, where the bedrock is bare or covered by only a thin mantle of mud and silt and the valley-fill deposit is composed largely of sand and gravel, rapid inundation of the mine workings is possible if the rock cover is broken (2, 11, 22, 24, 28).

Mining is conducted with the primary object of extracting as much of the anthracite beds as possible with safety (1, 4, 5, 7, 26). Although it may be safe to remove a definite portion of the beds, too little attention has been paid to the effect of such mining on the problem of mine drainage; this causes much of the mine-water problem in this field (1, 4, 5, 7, 8).

Mining has been conducted with regard to preventing rapid inundation of the mines; however, no coordinated scheme deals or has dealt with the problem uniformly as it relates to plans, barriers and dams, and methods of approach of mine workings toward the buried valley (1, 6, 8, 12, 26).

In their study of the mine-water problem concerned with the buried valley, the engineers of the Federal Bureau of Mines have ascertained, wherever possible: (a) The accuracy of plans, or maps, and the unreliability of old plans; (b) the size and thickness of barriers or barrier pillars requisite to hold water safely in different circumstances, the effect of faults parallel to or across barriers, the porosity of barriers or of the strata and possible erosion of barriers, and the effect of subsidence on a barrier; (c) the method of approach to abandoned or flooded mine workings under different circumstances, the effect of faults and variation in throw of faults, the presence of overlying and underlying water and water ahead at a higher level, the circumstances where boreholes are necessary, the methods of boring and distribution of boreholes, and the precautions to be observed in and after tapping water; and (d) the building of dams to restrain water (1, 4, 5, 6, 7, 17, 18, 19, 21, 25, 29).

Where a major disaster is possible if the above-mentioned strata fail, special consideration must be given to: (a) The depth at which mining is conducted, (b) the nature of the rock cover, (c) the number and thickness of the beds being worked in the area underlying the buried valley, (d) any faults or dislocations of the strata that may be present in the area, (e) the method of mining, (f) the proportion of the beds that must be left in place, and (g) the thickness of rock cover that must be maintained (1, 5, 13, 18, 29).

Where potholes are present in the bottom of the buried-valley area, they are extremely hazardous to mining operations, and any information that would tend to reveal their presence is of great value.

Since anthracite mining began in the Northern field, numerous instances have occurred where mine workings have broken into the valley-fill deposits unexpectedly, some causing loss of life and all causing damage to surface and mining properties (8).

The main channel of the buried valley reaches its greatest depth near Plymouth, Pa., where the rock reaches a minimum altitude of 201 feet. The overlying mantle of valley-fill deposits is 320 feet deep at this spot.
INTRODUCTION

Buried valleys are quite common in regions that have been overridden by glaciers. Such valleys, when preglacial, often were nearly at right angles to the direction of ice movement and were generally filled by debris from the melting ice. This paper deals only with the buried valley in that portion of the drainage basin of the North Branch of the Susquehanna River that overlies the anthracite measures in the Wyoming Valley and the lower part of the Lackawanna Valley. The present river channel is much above the level of the channel of the ancient waterway, which has been filled with clay, sand, and gravel; these valley-fill deposits are water-bearing and irregular in trend and depth (1, 4, 5, 6, 7, 12, 13, 15). (See figs. 7 to 13 (box)).

Anything that would tend to increase water inflow into a mine, either slowly or rapidly, through cracks or fissures in the rock cover, cave holes caused by subsidence, porous earthen materials, or valley-fill deposits deserves serious consideration.

If an opening should be driven from mine workings beneath the buried valley into the water-bearing deposits or if, because of subsidence, a cave should occur and water from the Susquehanna River flow suddenly into the mine workings, a major catastrophe could result. It is probable that a stream the size of the Susquehanna would resist all efforts to contain it in time to avert a large loss of life and could result in the loss of a major portion of the Northern field.

PURPOSE OF REPORT

The purpose of this report is to furnish data on the buried valley of the Susquehanna River that will be useful in solving the anthracite mine-water problem.

The information presented will provide better understanding of the problem involved and thereby be of practical assistance in conserving anthracite reserves and promoting safety of the men employed in the mines in this area if ample precautions are taken to prevent inundation (8).

SCOPE OF REPORT

This report (a) discusses the physical characteristics and the influence of the buried valley of the Susquehanna River on anthracite mining in the Wyoming Valley area of the Northern field, (b) correlates pertinent data relating to the buried valley, (c) presents accurate contour maps showing the position of the top of solid rock underlying the water-soaked valley-fill deposits in the buried valley, and (d) presents cross sections at regular intervals across the buried valley showing the irregularities in trend and bottom as well as the thickness, configuration, and nature of the materials composing the water-bearing valley-fill deposits.

The information in this report was obtained and correlated by studying geological maps and cross sections, mine maps and cross sections showing underground mine workings, borehole records, and other pertinent data obtained from anthracite mining companies and from previous reports (13, 14, 15, 17, 18, 19, 21, 29) on the subject.

Twenty-nine boreholes were drilled by the United States Bureau of Mines in significant areas where data were lacking. Logs of 12,100 boreholes were listed, checked, and then plotted on 125 maps to develop the rock-surface contours underlying the buried valley; however, extensive field work was necessary (a) to establish the position of outcrops of the anthracite measures that protrude through the clay, sand, and gravel deposits to the surface, and (b) to correlate data obtained from several mining companies.

The gathering and correlation of the above-mentioned data were begun in June 1946 and completed in April 1950.

ACKNOWLEDGMENTS

The author acknowledges his indebtedness for aid in collecting and incorporating data for this report to officials of the mining companies in the Northern field; mine inspectors of the Pennsylvania Department of Mines; engineers of the Federal Bureau of Mines who collected the data, prepared the maps, and assisted in preparing the manuscript for publication (W. M. Romisher, D. O. Kennedy, H. D. Kynor, W. L. Eaton, R. G. Waters, R. W. Fatzinger, R. G. Stott, R. H. Whaite, J. F. Emery, J. S. Weir, G. A. Reese, J. J. Rosella, E. Roberts, and J. D. Smith); draftsmen of the Federal Bureau of Mines who assisted in preparing the maps; and others who furnished information on the subject.
ORIGIN OF BURIED VALLEY
WYOMING-LACKAWANNA VALLEY

The Wyoming-Lackawanna Valley is structurally a long, synclinal trough with a canoe-shaped bottom (25). The synclinal axis plunges eastward from the western (lower) end and southwestward from the northeastern end. Generally, the axis of the downfold trends with the valley center. The valley or basin begins above the northeastern end of the anthracite field, where the prow of the canoe-shaped bordering mountains is breached and the Lacka-

![Diagram](image)

Figure 1.—Generalized sections, showing thinning of Mauch Chunk formation eastward with loss of twin rim (after Itter).
wanna River enters the valley (20). It extends southwestward approximately 65 miles to where the Pocono sandstone ridges, which form the encircling mountain rims, meet and terminate the valley.

The three bottom formations of the Carboniferous—the massive Pocono and Pottsville sandstones separated by the Mauch Chunk red shale—dip toward the basin and outcrop at rather steep angles, forming twin ridges, with an intervening depression, that encircle the trough. This physiographic feature is more prominent in the southwestern half of the region, where the relatively less-resistant Mauch Chunk red shale formation is thickest. The Mauch Chunk shale changes in physical character from fairly soft red shale in the southwestern end to a harder gray or buff rock with a sandy or pebbly texture in the northeastern end (20). As a result of the thinning of the Mauch Chunk shale and its change in character, the twin ridges virtually coalesce, and the two-ridge character of the valley rim is lost toward the northeast. (See fig. 1.)

The overlying, relatively softer rocks are the anthracite measures, which are composed of sandstones, shales, slates, and anthracite beds and dip toward the interior of the basin. These rocks occupy the inner or central portion of the trough and at places are cut down to lowlands; elsewhere, they form broken uplands in which ridges and valleys have no definite pattern (14). (See fig. 2.)

![Figure 2.—Sketch section across coal basin, showing general relations of soft rocks of anthracite measures to hard, underlying Pottsville-Pocono rocks (after Darton).](image)

**NORTHERN FIELD**

The portion of the Wyoming-Lackawanna Valley that comprises the Northern field is 62 miles long and has a maximum width of 5 miles, extending northeasterly from Shickshinny to Forest City (6, 15). The anthracite measures have an area of approximately 176 square miles.

Although some local folding and faulting is present, in general the center of the trough is wide and flat-bottomed, with gradually increasing dips, that become quite steep as the limbs of the syncline approach the outcrops. Faults and minor dislocations, in general, parallel the main course of the basin, but some are diagonal to it. The topography of the area is a wide rolling valley with sides rising not quite as steeply as the underlying anthracite measures.

The lowest anthracite bed in the coal measures outcrops near Shickshinny at the western end of the field. At Askan, near Wilkes-Barre, it is 1,500 feet below sea level and thence rises northeasterly along the synclinal axis to 700 feet below sea level at Kingston, 200 feet above sea level at Pittston, and 500 feet above sea level at Old Forge, when it again plunges to slightly below sea level at Olyphant. At Archbald, the main axis of the basin is displaced to the north, and from there the basin becomes much shallower until it rises to the outcrop near Forest City at the eastern end of the Northern field (6).

Along the flanks of the Northern field, the lowest anthracite bed outcrops mostly on the mountain slopes on each side of the syncline at altitudes ranging from 1,000 feet at Shickshinny to 1,800 feet at Forest City (15).

**CONTINENTAL ICE SHEETS**

During the glacial epoch (Pleistocene), much of northeastern Pennsylvania was covered by a series of great continental ice sheets (Jerseyan, Illinoian, and Wisconsin). These ice sheets advanced and retreated throughout the area (20).
Figure 3—Geologic map of Northern field.
deposits left in this manner show that there were three periods of invasion by glaciers, interrupted by warmer periods. The last of these ice sheets, the Wisconsin, must have lingered for thousands of years in the region, reaching its southern limits some 15 or 20 miles southwest of Wilkes-Barre (20). (See fig. 3.)

The Wisconsin ice sheet—at the time of its greatest development—is believed to have been several thousand feet thick and to have moved slowly southward (20). In the Wyoming-Lackawanna region, the ice must have been thick enough to fill the valley and cross the mountains to the south, as shown by the striae, or scratches, on the mountains; however, the ice at the bottom of the valley moved along the trend of the basin. The surrounding mountains and the valley itself had much the same form as at present; the ice sheet merely modified minor features in the area.

The erosive action of the ice sheet as it moved across the region and the subsequent deposition of the valley-fill deposits are responsible for the buried valley of the Susquehanna River and its minor extensions as it now exists. The main mass of the ice must have moved diagonally southward across the valley while the ice in the bottom of the valley was deflected along the axis of the valley (20).

The overdeepening of the rock basins in the bottom of the buried valley may be explained by a combination of glacial scouring and plucking of the rocks in the valley bottom by the ice tongue as it moved along the trend of the valley, and further erosion by gravel-and-sand-laden melt waters in confined channels that formed streams under the ice itself in the bottom of the valley (13).
BURIED VALLEY OF THE SUSQUEHANNA RIVER

The broad, relatively flat plain of the Northern field, over which the present North Branch of the Susquehanna River flows, blankets a great depression in the surface of the bedrock. This depression is not an ordinary valley having a bottom with a continuous down grade, which is usually made by a stream in its attempt to reach base level, but consists of a series of elongated basins, which are terminated by rock at both ends. The depression does not have a continuous down grade, for the deeper sub-basins decrease in depth downstream (13).

It appears quite evident that basins or channels were excavated in the sandstones, shales, slates, and anthracite beds of the anthracite measures by glacial action as well as by water erosion.

Potholes are in the area comprising the buried valley; these were formed by swirling currents of water carrying abrasive materials during the advance and retreat of glaciers. They extend below the normal bottom of the buried valley. Some large potholes are visible at the surface of the ground in the Scranton area (9).

Boreholes drilled from the surface of the ground in this area through the valley-fill deposits have revealed the rock bottom of this great depression to be below 250 feet altitude at several points. Near Berwick (approximately 18 miles downstream from West Nanticoke), rock crosses the river at 480 feet altitude. At no place farther downstream is the rock below 250 feet altitude until Middletown, Pa., is reached, nearly 90 miles downstream from Berwick (9).

GEOGRAPHIC POSITION

Geographically, the buried valley of the Susquehanna River is in the Wyoming Basin of the Northern field of the anthracite region and extends from West Nanticoke upstream to a little above West Pittston, a distance of 15 miles, where the Susquehanna River enters the Wyoming Valley (4). The Lackawanna River
enters the Susquehanna River at West Pittston. Valley-fill deposits of the buried valley are also found, to some extent, up the Lackawanna River drainage basin. (See fig. 4.)

The term “riverwash” is used synonymously for the valley-fill, or alluvial-fill, deposits of the buried valley by engineers of some of the mining companies operating in the vicinity of the buried valley.

**TYPES OF DEPOSITS**

Three general classes of deposits are found in the Wyoming-Lackawanna region: (a) The deep valley-fill deposits, (b) terrace deposits that flank the valley, and (c) glacial-till deposits.

The materials that constitute the deep valley-fill deposits, as revealed by boreholes and shafts, varying levels at which the terraces occur. The Tilbury Plain at West Nanticoke is at 680 feet altitude; terraces either side of Toby's Creek, near Luzerne, at 705 and 750 feet altitude; at Pittston, 710 feet altitude; and at Campbell Ledge, 610 feet altitude. (See fig. 5.)

The terrace deposits that flank the valley and the glacial-till deposits are described in detail by Darton (19) and Itter (20).

**RECENT SURFACE MODIFICATIONS**

The surface of the present valley floor overlying the buried valley of the Susquehanna River has been modified to some extent by man since anthracite-mining operations began.

Scattered throughout the area, large refuse banks are noted at nearly every colliery. These refuse banks are of different types and, accord-

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**Figure 5.**—Diagram showing development of deltas and stream deposition along the valley walls in the Wyoming Valley (after Itter).

are water-depositional sediments consisting of alternating layers of gravel, sand, clay, and admixtures of all three. Under Kingston lies a bed of clay 80 to 100 feet thick, an evidence of local ponding.

The terrace deposits that flank the valley are found generally from 60 to more than 200 feet above the flood plain of the present river. Studies of the structure of these terraces, as revealed in sand or gravel pits, indicate that they were formed by ponding of side streams against stagnant ice, also by deposits laid down by streams flowing between the bank and such a mass of ice left in the waning stages of the glacier (9). This explanation satisfies the riverbed type of deposit with cross-bedding as exposed in the sand pits and also accounts for the ing to the material they contain, may be classified as follows:

1. Tunnel rock and gob rock.
2. Coarse breaker.
3. Fine breaker.
4. Combination tunnel rock, coarse and fine breaker.
5. Cinder, from colliery steam or electric power plants.
6. Cinder, from large commercial electric power plant.

Tunnel-rock- and gob-rock-refuse banks contain material taken from a mine because of sinking a shaft; driving a tunnel in rock to intersect different beds; driving a gangway in which rock must be taken from the top, bottom, or ribs toprovide adequate height or width; and sinking a slope in rock or any rock unmixed with anthracite that is dumped on the refuse bank without being handled at the breaker.
Coarse-breaker-refuse banks contain the larger pieces of rock and "bony" (carbonaceous shale or rock that contains thin layers of anthracite), removed from mine-run anthracite at the breaker.

Fine-breaker-refuse banks contain the fine materials removed from mine-run anthracite during the process of preparation at the breaker.

Cinder-refuse banks contain the ash and cinders produced in boiler plants for generating steam power or heating.

Refuse banks may be placed in two general categories—culm and cinder banks. Culm banks are those that contain mine refuse such as tunnel or gob rock, breaker refuse, or both, whereas cinder banks contain cinders from boiler plants.

Spoil banks from strippings or open-pit mines are not uncommon (6). These spoil banks contain material excavated to uncover the anthracite beds before the anthracite is recovered by open-pit mining. As the overburden is removed by dragline shovels, it is deposited in parallel rows along the strike of the anthracite beds, resulting in a series of long parallel ridges.
PROBLEMS ATTRIBUTED TO THE PRESENCE OF THE BURIED VALLEY

The presence of the water-soaked valley-fill deposits of the buried valley overlying the anthracite measures in the Northern field increases to a large degree other hazards inherent in Pennsylvania anthracite mining.

In some respects, mining beneath water-bearing valley-fill deposits is similar to submarine mining. No one can predict the volume of water and water-soaked materials that might descend and the movement of broken strata that might be encountered if the rock cover fails. A valley-fill deposit having a deep layer of clay covering the bedrock is favorable for sealing small fissures; however, where the bedrock is bare or covered by only a thin mantle of mud and silt and the valley-fill deposit is composed largely of sand and gravel, rapid inundation of the mine workings is possible if the rock cover is broken (2, 11, 22, 24, 28).

Darton has covered faults in the region that contains the buried valley (15). The worst disaster in the history of undersea mining—namely, the complete flooding in 2 hours of the Higashimisome colliery, Japan, in 1915, with the loss of 237 lives—was attributed to a fault (17). The risk of inundation is increased by the presence of deep channels filled with loose material (as in the Wyoming Basin) and of faults, which, if not themselves affording an easy ingress to water, may provide such when subsidence has taken place (1, 4, 5, 7, 11, 16).

Experience confirms the fact that inaccurate plans or maps or their absence has been the primary cause of the largest number of accidents caused by inundation of water or water-laden materials (3, 8, 10, 27, 28). Neglect of precautions is the second cause, followed by errors of judgment.

Mining is conducted with the primary object of extracting as much of the anthracite beds as possible with safety (1, 4, 5, 7, 26). Although it may be safe to remove a definite portion of the beds, too little attention has been paid to the effect of such mining on the problem of mine drainage; this causes much of the mine-water problem in this field (1, 4, 5, 7, 8).

Mining has been conducted with regard to preventing rapid inundation of the mines; however, no coordinated scheme deals or has dealt with the problem uniformly as it relates to plans, barriers and dams, and methods of approach of mine workings toward the buried valley (1, 6, 8, 12, 26).

In their study of the mine-water problem concerned with the buried valley, the engineers of the Federal Bureau of Mines have ascertained, wherever possible: (a) The accuracy of plans or maps and the unreliability of old plans; (b) the size and thickness of barriers or barrier pillars requisite to holding water safely in different circumstances, the effect of faults parallel to or across barriers, the porosity of barriers or of the strata and possible erosion of barriers, and the effect of subsidence on a barrier; (c) the method of approach to abandoned or flooded mine workings under different circumstances, the effect of faults and variation in throw of faults, the presence of overlying and underlying water and water ahead at a higher level, the circumstances where boreholes are necessary, the methods of boring and distribution of boreholes, and the precautions to be observed in and after tapping water; and (d) the building of dams to restrain water (1, 4, 5, 6, 7, 17, 18, 19, 21, 26, 29).

MINING HAZARDS

Extreme care must be used at all times in mining the area beneath and adjacent to the buried valley. Companies that operate mines under or adjacent to the buried valley endeavor to maintain a rock cover of 30 to 80 feet between the mine workings and the valley-fill deposits (25). To do this, it is necessary for the mining companies to drill numerous boreholes to establish definitely and accurately the trend, extent, and thickness of the water-bearing valley-fill deposits before they can mine with any degree of safety in this area.

Where a major disaster is possible if the above-mentioned strata fail, special consideration must be given to: (a) The depth at which mining is conducted, (b) the nature of the rock cover, (c) the number and thickness of the beds being worked in the area underlying the buried valley, (d) any faults or dislocations of the strata that may be present in the area, (e) the method of mining, (f) the proportion of the beds that must be left in place, and (g) the thickness of rock cover that must be maintained (1, 5, 12, 18, 29).

Where potholes are present in the bottom of the buried-valley area, they are extremely hazardous to mining operations, and any information that would tend to reveal their presence is of great value.
It is of vital importance that an adequate rock cover or adequate strata be kept between the valley-fill deposits of the buried valley and the mine workings. If a major break should occur in these rock strata, no one can foretell to what extent the water-soaked valley-fill deposits would flow into the mine workings. It is reasonable to expect that this flow would continue until the angle of repose or subsidence line of the material composing the valley fill would be reached. If the Susquehanna River should gain access to the mine workings through a break in the rock cover underlying the buried valley, it is impossible to estimate the amount of damage that could occur, because sealing it off would be a stupendous task, with no guarantee of ultimate success.

**ACCIDENTS CAUSED BY INRUSHES OF SAND AND GRAVEL**

Since anthracite mining began in the Northern field, numerous instances have occurred where mine workings have broken into the valley-fill deposits unexpectedly, some causing loss of life and all causing damage to surface and mining properties (8).

Table 1 lists some of the accidents where failures in the rock strata underlying the valley-fill deposits of the buried valley allowed sand, gravel, and water to enter the mine workings (12).

Accident 1 occurred on July 4, 1872, in a breast in the Hillman bed (12). The exact position of the failure in the rock strata is unknown; however, the cave is believed to have occurred under the old canal south of the Burroughs shaft. The canal bed over these old workings, which were also known as the Enterprise workings, was approximately 68 feet above the Hillman bed. No boreholes were drilled to the top of the rock along the old canal bed in this vicinity before this time; consequently, nothing is known as to the probable thickness of rock strata over the Hillman bed at the point of failure.

Another cave occurred in the Hillman bed in 1876 near Port Bokley, a short distance downstream from the Burroughs shaft, causing a depression on the surface 100 feet in diameter. The bed dips 15° and was mined by chambers or breasts to a point afterward discovered to be within 15 feet of the top of the rock strata. At this point a break in the rock strata was encountered. Eventually the roof collapsed over the width of the chamber. The opening was 20 feet in diameter and allowed a large volume of sand and gravel to be deposited in the lower gangways, filling the mine workings to the shaft level.

In October 1882 another cave occurred in the Hillman bed of the Mitchell shaft workings within 1,500 feet of the cave mentioned above. The Susquehanna River had risen high enough to cover the river "flats" with water in the vicinity of the cave; and, while this condition existed, the cave occurred. The opening on the surface of the ground was 150 feet long and 50 feet wide. On March 29, 1913, when the river had again risen to flood height and inundated this same territory, a cave, 110 feet long and 90 feet wide, occurred in the identical spot. Again on March 30, 1914, the river flooded this area, and another cave occurred in the same locality.

Later borehole records proved that the bed had been worked very nearly to the top of the rock strata in this vicinity, and the records showed the rock to be very soft. It is evident that the 68 feet of overlying water-bearing valley-fill deposits were too heavy for the small amount of rock cover to withstand the additional weight of the flood water.

Accident 2 (12) occurred in the face of a breast in the Red Ash bed. One man was killed some distance away in the gangway by the inrush of sand and water. The breast in which the cave occurred was approaching the crest of an anticline and was approximately 115 feet below the surface. It was later determined from borehole records that an eroded channel filled with sand was on the axis of the anticline. This deposit of sand was 150 feet wide and extended 40 feet below the level of the surrounding top of bedrock, or 65 feet below the surface. This would indicate a thickness of 30 to 30 feet of rock strata over the Red Ash bed at the point of inrush of sand and water. It is presumed that the breast broke into a pothole, which extended below the eroded channel.

Accident 3 (12) occurred in the face of a rock plane being driven from the Eleven-Foot bed to the Six-Foot bed that broke into sand and water, which in a few hours filled the mine and shaft to within approximately 65 feet of its collar, or to a vertical height of 90 feet in the shaft. A borehole 300 feet from the break indicates a depth of rock strata of 14 feet over the bed, so the presumption that the bed was eroded at the face of the rock plane is probably true.

The distance from the surface to the top of the rock strata was 160 feet, and the depression produced on the surface of the ground was 150 feet in diameter. A number of attempts were made, without success, to seal the rock plane by injecting cement grout through boreholes. The altitude at which the water stood in the shaft indicated that the level of the water in the water-bearing strata in the cave hole was approximately 65 feet below the surface of the
<table>
<thead>
<tr>
<th>Accident No.</th>
<th>Date</th>
<th>Mine</th>
<th>Borough or city</th>
<th>Bed</th>
<th>Tapped by</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>July 4, 1872</td>
<td>Burroughs</td>
<td>Plainsville</td>
<td>Hillman</td>
<td>Breast</td>
<td>A pumpman, only man in mine at time, easily escaped.</td>
</tr>
<tr>
<td>2</td>
<td>June 30, 1874</td>
<td>Wanamie No. 18</td>
<td>Wanamie</td>
<td>Red Ash</td>
<td>do</td>
<td>Gangway and workings in vicinity filled for some distance from break. 1 man killed.</td>
</tr>
<tr>
<td>3</td>
<td>January 1882</td>
<td>Maltby</td>
<td>Swoyerville</td>
<td>Rock plane</td>
<td>do</td>
<td>Gangways filled; also shaft for vertical height of 90 feet.</td>
</tr>
<tr>
<td>4</td>
<td>Apr. 23, 1884</td>
<td>Fuller</td>
<td>Swoyerville</td>
<td>Six Foot</td>
<td>Slope</td>
<td>Slope filled to top for distance of 900 feet.</td>
</tr>
<tr>
<td>5*</td>
<td>May 1885</td>
<td>do</td>
<td>Archbald</td>
<td>Archbald</td>
<td>do</td>
<td>Slope filled to top for distance of 900 feet.</td>
</tr>
<tr>
<td>6</td>
<td>Dec. 18, 1885</td>
<td>No. 1 slope</td>
<td>Nanticoke</td>
<td>Ross</td>
<td>Breast</td>
<td>Gangways in vicinity completely filled in less than 1 hour; 26 men killed.</td>
</tr>
<tr>
<td>7</td>
<td>Aug. 1889</td>
<td>Fuller</td>
<td>Wyoming</td>
<td>Pittston</td>
<td>Breast</td>
<td>Plane and all workings tributary to it filled with sand and water.</td>
</tr>
<tr>
<td>8</td>
<td>Mar. 1, 1897</td>
<td>Mt. Lookout</td>
<td>Wyoming</td>
<td>Cooper</td>
<td>do</td>
<td>Gangway on lower level filled to height of 2 feet for distance of 300 feet. Depression on surface, 100 by 75 feet.</td>
</tr>
<tr>
<td>9</td>
<td>Dec. 30, 1898</td>
<td>Wanamie</td>
<td>Wanamie</td>
<td>Hillman</td>
<td>do</td>
<td>Large area of the workings filled; no men at work at time.</td>
</tr>
<tr>
<td>10</td>
<td>Feb. 2, 1899</td>
<td>Franklin</td>
<td>Wilkes-Barre</td>
<td>Kidney</td>
<td>do</td>
<td>Gangways filled for several thousand feet. Breasts had been worked 26 years previously. No men working in vicinity.</td>
</tr>
<tr>
<td>11</td>
<td>Apr. 13, 1899</td>
<td>No. 2 slope</td>
<td>Nanticoke</td>
<td>Hillman</td>
<td>do</td>
<td>Surface depression, 70 to 80 feet deep. Gangways and tunnel in vicinity filled tight to roof. Conical depression on surface, 60 feet in diameter and 40 feet deep.</td>
</tr>
<tr>
<td>12</td>
<td>Apr. 25, 1899</td>
<td>Bliss</td>
<td>Hanover</td>
<td>do</td>
<td>do</td>
<td>Gangways and two slopes filled several feet deep for a distance of approximately 2,500 feet. Depression on surface, 250 feet long, 175 feet wide, and 90 feet deep.</td>
</tr>
<tr>
<td>13</td>
<td>February 1905</td>
<td>Kingston Coal</td>
<td>Edwardsville</td>
<td>Bennett</td>
<td>Chamber</td>
<td>Tunnel filled several feet deep for distance of 500 feet.</td>
</tr>
<tr>
<td>14</td>
<td>March 1910</td>
<td>Kingston Coal</td>
<td>Courtdale</td>
<td>Tunnel Bennet-Ross</td>
<td>Tunnel</td>
<td>Gangways and tunnels filled tight to roof. Depression on surface, 150 feet wide, 210 feet long, and 90 feet deep. Mill Creek flowed into mine through cave hole in stream bed 550 feet long, 150 feet wide, and 70 feet deep.</td>
</tr>
<tr>
<td>15</td>
<td>June 10, 1914</td>
<td>Sugar Notch No. 9</td>
<td>Sugar Notch</td>
<td>Kidney</td>
<td>Breast</td>
<td>Gangways filled 3 feet deep a distance of 250 feet. Surface depression 50 feet in diameter and 35 to 45 feet deep.</td>
</tr>
<tr>
<td>16</td>
<td>Dec. 19, 1915</td>
<td>Midvale-Prospect colliery</td>
<td>Miners Mills</td>
<td>Abbott</td>
<td>Breast</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Nov. 5, 1922</td>
<td>Delaware</td>
<td>Plains</td>
<td>Five Foot</td>
<td>do</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>May 9, 1947</td>
<td>Butter Tub</td>
<td>West Wyoming</td>
<td>Pittston</td>
<td>do</td>
<td></td>
</tr>
</tbody>
</table>

*This mine is in Lackawanna Basin.
ground at this point. Variation in the altitude of the water in the shaft might naturally be expected to occur with any variation in the level of water in the water-bearing strata.

Accident 4 (12) occurred in the face of a slope immediately after a shot was fired. The inrush of sand and water filled the slope to the shaft level, which was virtually at the same altitude as the surface of the ground above the face of the slope. Boreholes in the vicinity indicate that there may have been 20 feet of rock strata over the bed at the point of failure. The vertical distance from the face of the slope to the surface of the ground was 100 feet.

Accidents 5 and 6 (12) were due to the presence of potholes nearly 1,000 feet apart. One of the potholes was 38 feet deep, 24 feet wide, and 42 feet long at the surface of the ground, and 17 feet wide and 14 feet long at the top of the anthracite bed. The pothole is in slate and sandy shale, and the face of the rock is extremely smooth.

Accident 7 (12) occurred December 18, 1885, when a large body of quicksand and water broke through the roof into mine workings in the Ross bed, No. 1 slope, Susquehanna Collieries Co., Nanticoke, Pa. The Ross-bed mine workings were inundated, and 26 men were killed. This inrush of quicksand and water entered the mine workings near the face of a counter gangway close to an anticlinal.

Before the accident, conditions on the surface of the ground and in the mine workings at the point the cave-in occurred did not indicate the presence of such a body of quicksand and water. The surface of the ground (+650 feet altitude) was the top of a dry sand hill; however, it was covered by a culm bank, 47 feet high. Exposures of solid rock 900 feet to the north of the cave-in are higher than +640 feet altitude. At the creek bank 900 feet to the southeast, solid rock is exposed at +565 feet altitude and lower.

On the surface of the ground, above the point of inrush, a cone-shaped depression, 300 feet in diameter, developed in the culm bank.

The pillars were large and regular, and the roof appeared strong and safe in the mine workings in the vicinity where the cave-in occurred. Nearly 1 1/2 miles of mine workings in the same bed (Ross) had been completed at higher altitudes in the pitch workings; these were nearer the outcrop and did not encounter trouble of this nature. Furthermore, no crushing of the pillars or any other warning was given before the disaster occurred.

Before the inrush of quicksand and water occurred it was believed that 262 feet of cover, of which 200 feet was solid rock, was over the anthracite bed at the point where the quicksand and water broke into the mine workings.

A borehole was drilled near the caves from the surface of the ground soon after the inrush of quicksand and water; this revealed solid rock (top of rock) at altitude +436 feet. As the roof of the underground workings at the point of inrush was at +388 feet altitude, it is apparent that a deep and unsuspected gorge was filled with quicksand and water under the hill of sand and was probably deepened further by a large pothole.

The inrush of quicksand and water was so rapid that, within less than an hour after the cave-in, the gangway was completely filled from floor to roof for a distance of over 2,000 feet out by the No. 1 slope and also part way up the chambers, or breasts, leading from this gangway.

Accident 8 (12) was in the face of a rock plane dipping 14° that was being driven upgrade from the foot of a slope in the Eleven-Foot bed to the Six-Foot bed. The plane had been driven 225 feet, and its face was at a point 1,300 feet south of where accident 4 happened. The record does not indicate that the plane reached the Six-Foot bed; however, considering the altitude to which the plane had been driven, it appears that the bed was eroded at the point of inrush of quicksand and water instead of having 40 feet of rock cover, as believed. The distance from the surface of the ground to the face of the plane is 100 feet. The inrush of quicksand and water filled the Eleven-Foot bed workings and the shaft to a point 10 feet above the Six-Foot bed.

The Six-Foot bed in the shaft is 15 feet lower than the surface of the ground above the face of the rock plane; this would indicate that the water in the shaft was at the same altitude as the water-bearing strata in the vicinity of the cave-in.

It is believed that a local depression in the valley bottom was the cause of erroneous conclusions in mining that caused this accident, as well as accident 4. A short distance north of these caves, the rock cover is ample.

Accident 9 (12) occurred in the face of a breast approaching an anticlinal. The breast had become very wet after a shot, and the miner went to obtain oilskin clothing. Five hours later an inrush of sand, gravel, and water filled a large area of the mine workings. No men were in these mine workings.

The breast was being driven 24 feet wide in the Pittston bed, which is 6 feet thick. Later, eight brick dams were constructed to guard against any future inrush of this kind, and an area of 18 acres was sealed off.

Accident 10 (12) occurred in the face of a breast in the Cooper bed, which had just been started off a counter gangway. Five men were
at work nearby, but all escaped. The Hillman bed dips 50°, and the counter gangway from which the breast was started is 95 feet below the surface. A dangerous deposit of sand and water was never suspected, as rock strata outcrop only 100 feet south of the counter gangway. A borehole, drilled later from the surface near the inrush, revealed 55 feet of sand and 40 feet of rock strata over the counter gangway.

The inrush of sand and water entered the breast 15 feet above the counter gangway. This would indicate the presence of a pothole or a local depression of the buried-valley bottom on or near the outcrop of the Hillman bed.

Accident 11 (12) happened at 2 a.m. in the face of a breast in the Kidney bed, which dips 25° at this point. The face of the breast had become very wet, and work was stopped 2 to 3 days before the inrush of the debris occurred. This accident could have been much more serious. At least 100 people were ice-skating on a pond overlying the affected area shortly before the accident. Large pieces of ice were carried into the underground workings with mud and other debris that filled the gangways to a depth of 3 to 4 feet. Some large pieces of ice were found in mine workings 1,000 feet from the cave. After the accident, breasts were retimbered and batteries constructed across the chambers near the faces as a safeguard against another accident.

A borehole from the surface 80 feet west of the cave revealed that rock strata over the bed at the face of the breast were no more than 15 feet thick. The distance between the surface and the face of the breast was 67 feet.

On February 27, 1908, a second cave-in occurred at the same place and was attributed to the failure of a battery erected 9 years before near the face of the breast. The second cave caused a cone-shaped depression 40 feet deep and 140 feet in diameter to form on the surface. Accident 12 (12) occurred in an old breast of the Hillman bed, which had been driven in the late 1880's. The surface was 127 feet above the face of the breast, and 50 feet of rock was thought to be over the anthracite bed; however, less than 20 feet of rock cover was between the face of the breast and the valley-fill deposits.

This accident occurred 1,200 feet from where accident 7 happened. The depression at the surface had an area of 3½ acres because of the inrush of alluvial material (clay, gravel, and quicksand) into the mine workings. The cave was near the junction of Forge and Newport Creeks, and water from both streams washed additional material into the mine that normally would not have entered. The flow of water and debris was finally checked by placing brush, timbers, and hay in the cave hole and erecting temporary dams across the two creeks.

Accident 13 (12) occurred immediately after a blast in the face of a breast in the Hillman bed at the Bliss colliery. The workings nearby were completely filled to the roof with sand, gravel, and water. A conical depression, 60 feet in diameter and 40 feet deep, was formed on the surface of the ground.

All men in the mine escaped without injury. Accident 14 was caused by an inrush of quicksand into a chamber in old workings in the Bennett bed above No. 5 plane. The accident happened in the afternoon at the end of the day shift. No one was injured. The quicksand flowed into adjacent mine workings for a distance of 2,500 feet. When the inflow was arrested finally, there was 10 feet of sand at the foot of No. 2 shaft.

The area near the cave was sealed by use of batteries.

A hole 175 feet wide, 250 feet long, and 90 feet deep was later filled with breaker refuse. Accident 15 (12) was caused when the roof failed in a tunnel being driven from the Bennett to the Ross bed. Quicksand entered the tunnel through a hole 18 inches in diameter in the roof and flowed downgrade in the tunnel for 500 feet to the intersection with the main haulage level. Baffle cribs were built in an effort to stop the flow of quicksand but without success.

A hole on the surface, 50 feet in diameter, was caused by the cave-in. The flow of quicksand into the mine was stopped by plugging the hole with baled hay and mine timbers. This accident occurred 100 feet north of Luzerne Avenue and several thousand feet northeast of the scene of accident 14.

Accident 16 (12) occurred immediately after a blast in the face of a breast at 11 a.m. in the Kidney bed. Men working nearby were notified immediately and escaped from the mine. The first evidence on the surface was a conical hole that continued to increase in size for 5 to 6 hours until it was 210 feet long, 150 feet wide, and 60 feet deep. The material carried into the mine was sand and clay in a semifluid state because of a swamp over the caved area. Almost 20,000 cubic yards of material was carried into the mine. Several thousand feet of underground workings was filled or partly filled; this required months to clean up.

Accident 17 was caused by Mill Creek breaking into a chamber near the outcrop of the Abbott bed. At this point the chamber was directly under and 70 feet below the creek bed. The rock cover failed, and water from the creek and a large volume of surface materials entered the mine workings. The underground work-
nings at the foot of the Midvale slope were flooded.

The course of Mill Creek was changed to stop the flow of water into the mine. The opening into the mine was blocked by the construction of batteries in the end of the line chamber involved.

A depression 550 feet long, 150 feet wide, and 70 feet deep was created in the northwest corner of Hollenback Park by the cave-in.

Accident 18 occurred at the face of a breast in the Five-Foot bed. The hole in the roof at the breast was originally only 2 feet square, but through this opening enough valley-fill material passed to form a depression on the surface 90 feet in diameter and 35 feet deep. A house was completely engulfed in this cave-in.

The surface material, being loose, was confined to the underground workings near the cave-in.

Accident 19 occurred May 9, 1947, when a face caved in a chamber in the Pittston bed, Butter Tub Coal Co., West Wyoming. The face of the chamber was at the outcrop beneath the valley-fill deposit of the buried valley and Abrahams Creek. Previously a number of chambers had been driven until they encountered the alluvial deposits. These were found to be dry and stable, and no inrush of water and alluvial materials occurred.

In this instance, when the chamber being mined broke into the alluvial deposits, the material was wet. Water immediately commenced to flow into the workings and continued to do so for nearly 2 hours. No inrush of debris (sand, gravel, boulders, and clay) occurred until one-half hour after the alluvial deposit was broken into, when the chamber filled completely and the gangway from which it was driven was filled to a depth of 3 feet for a distance of 250 feet by a sudden inrush of these materials.

Because of the time lag between the time the debris was struck and its inrush into the mine, the men employed in this area were able to escape, and none were killed. However, some mining equipment was lost.

**SUBSIDENCE**

Subsidence of strata overlying mine workings beneath the buried valley definitely aggravates the possibility of damage to existing surface structures. The effects of sinking can be seen readily, and gradual subsidence in the ground surface is taking place in localities overlying the buried valley where the anthracite beds have been extracted, especially where second and third mining has been conducted.

It is true, regardless of the nature of an underground excavation and the means of roof support, that subsidence of the ground above the excavation is very likely to be the final incident in mining (7, 11).

Because of the presence and the nature of the valley-fill deposits (alternating layers of gravel, sand, clay, and admixtures of all three), an area of subsidence at the surface of the ground tends to be enlarged beyond that which normally would occur if only the rock strata were present over a mined area. This statement is especially true when quicksand is present in the river wash, often causing subsidence at points remote from the mine excavations that normally cause the subsidence at the surface of the ground (23).

Extensive lenses of clay occur in the valley-fill deposits; and, because of the impervious nature of this material, a perched water table may be found. If overlying layers of fine sand are present, an ideal condition exists to form a quicksand deposit. If this quicksand deposit was disturbed by mining beneath the valley-fill deposits or if the clay deposit was punctured by other means, the fluid nature of the quicksand would allow it to flow through the hole in the clay bed into the interstices of the coarser materials below. Removal of the quicksand, which may cover an extensive area, could cause surface subsidence over a wide area.

Some mining operations beneath the buried valley have affected the water table in some areas to the extent that much of the water infiltrates into the mine workings because of the pervious nature of most of the valley-fill deposits and the cracks and fissures that have developed in rock strata underlying the buried valley. Deposits of fine sand have been drained in places, which left them in a firm, nonfluid state. Evidence of this condition is given in a comparison of records of boreholes drilled at an early date with those drilled later in the same areas. Records of early boreholes show quicksand, whereas the records of later boreholes indicate fine sand near the same horizon.

The deposits of fine sand may become potential hazards with the addition of water under pressure; this may occur during the flood stage of a stream following a heavy run-off or after heavy local precipitation. The water table may be raised temporarily, and the deposits of sand become saturated. Under suitable conditions, such deposits become bodies of quicksand. If during mining operations these deposits of fine sand are encountered, they present a serious hazard if they are admixed with water, but they present less of a hazard if they are dry.

A large, sandstone, masonry building was damaged by subsidence when no actual mining was being done under it; however, an anthracite bed, which is 620 feet below the surface and 9 to 11 feet thick, was being robbed 500 feet north
of the building. Records show that 420 feet of rock strata and 200 feet of riverwash are between the bed and the surface.

Pillars were also being extracted in another anthracite bed in workings 300 feet west of the building. This bed, which is 7 feet thick, lies 180 feet below the first-mentioned bed, or 800 feet below the surface. Records show the formation above the mine workings to be 600 feet of rock strata and 200 feet of riverwash.

No squeeze in the mine workings or subsidence of the surface was visible before cracks appeared in the walls of the masonry building.

The opinion when the subsidence occurred was that the rock strata over the robbed areas settled, forming slight depressions at the top of the rock strata and allowing the riverwash to shift and fill the depressions. Inasmuch as the masonry building was by far the heaviest structure in the area, any movement in the riverwash beneath it could affect its stability.

Railroad roadbeds in this anthracite-producing area show positive evidence of gradual subsidence that has taken or is taking place. Railroad maintenance crews frequently can be seen raising the tracks to keep them on grade. In many instances, subsidence is apparent where borough streets and State or county highways cross the railroads, as the railroad tracks were originally at the same level as the streets or highways; now the railroad tracks are higher than the surrounding area because of the constant work of railroad maintenance crews in raising and realining the tracks as the surface of the ground settles. Short and fairly steep grades are necessary at crossings in the areas where streets or highways cross the railroads.

Railroad and highway bridges also show evidence of subsidence. Occasionally it is necessary to elevate the bridge superstructures and place shims between the abutments or piers to maintain smooth roadbeds.

UNDERGROUND STREAM

An underground stream in some areas of the buried valley can cause aggravating surface subsidence where bodies of quicksand may be disturbed and carried away by its sluicing action.

This underground stream has been identified by boreholes along most of the length of the buried valley. Following is the list of boreholes beginning at Coxton Yards and ending in Hanover Township:

1. Coxton Yards on the north side of the Susquehanna River.
2. North end of Scovell Island.
3. Exeter Borough between Wyoming Avenue and the Delaware, Lackawanna & Western Railroad near Sullivan Street.

5. Wyoming Borough between Wyoming Avenue and the Delaware, Lackawanna & Western Railroad near Eighth Street.
6. West Wyoming Borough on Park Street near the Delaware, Lackawanna & Western Railroad.
7. Wyoming Borough on Stites Street near the Delaware, Lackawanna & Western Railroad.
8. Swoyersville Borough on Warsaw Street near the Delaware, Lackawanna & Western Railroad.
9. Forty Fort Borough near the intersection of Murray Street and Tripp Street.
10. Forty Fort Borough near the intersection of Murray Street and Yeager Avenue.
12. Kingston Borough near Eley Street between Wyoming Avenue and the Delaware, Lackawanna & Western Railroad.
13. Kingston Borough near the intersection of Rutter Avenue and Hoyt Street.
14. Eastern end of Richards Island.
15. Central part of Richards Island.
16. Hanover Township near the southeast end of Breslaw bridge.
17. Hanover Township between the Susquehanna River and Solomons Creek near their confluence.

If the positions of the above-given boreholes are plotted on contour maps of the rock surface of the buried valley, it is seen that this underground stream follows closely the deep channel of the buried valley.

Generally, this underground stream flows between large boulders, which are piled in such a manner that the layer of smaller gravel above is unable to fall between the interstices to block the flow of water. In some places the bed of boulders is more than 20 feet thick. Above the gravel is a layer of rock flour commonly called blue clay. This bed of clay varies in thickness from 5 to more than 100 feet. Above the bed of clay are pools of quicksand that vary in thickness and extent. If the clay bed should be broken, the surface of the ground could subside over a large area.

A fall of roof in a mine in the Wyoming Valley 50 years ago permitted quicksand to rush into the mine workings until clay and gravel blocked the hole. A circular hole 40 feet deep and 300 feet in diameter was formed. The break in the roof was large enough to allow quicksand to enter with a rush, and the surface settled evenly.

In other places where the fissures in the clay deposit are small, the surface may settle over a larger area but to a lesser depth and for a longer time. An example of this follows: While a borehole was being drilled in West Wyoming Borough in October 1939, an underground stream was struck at a depth of 111 feet from the surface. At this depth, the sound of running water was clearly heard at the surface of the ground. One hour after the drive pipe
STREAM-BED LEAKAGE

Infiltration of surface water into mine workings underneath the buried valley is aggravated further by the presence of major surface streams that flow over the pervious alluvial fill. The North Branch of the Susquehanna River flows downstream over these deposits from Coxton to West Nanticoke, where the river leaves the valley. The Lackawanna River, a chief tributary stream, flows down the Lackawanna Valley and enters the Susquehanna River at Pittston. A considerable volume of mine water originates at the headwaters of these streams, especially during the period of flood stage. The water from the streams enters the mines through the pervious valley-fill deposits, cracks, and fissures in the underlying rock strata caused by subsidence over mined areas, bedding planes in the rock strata, natural cleavage planes, and faults (6).

A number of creeks that flow throughout the entire year cross the vicinity of the buried valley. Because of the size of most of these creeks, some provisions have been made to prevent excessive infiltration through their beds into the mine workings. Mining operations under the major stream beds have been conducted in a manner to prevent an increase in the stream-bed leakage and thereby prevent an increase in the amount of infiltration into the mine workings. However, this cannot be true of many of the small tributary streams, because the presence of dry beds of thousands of former small watercourses give evidence that the water, which had once drained off in them, is now infiltrating into the underground workings (6, 25).

GENERAL SURFACE LEAKAGE

Fissures in the rock strata, cave-ins, and fissures in outcrops and strippings either on the flood plains of streams or in the drainage areas provide easy ingress for surface water to enter the mine workings (6). Strippings, especially, contribute much to this because of the removal of the overburden and because of the longitudinal extent of the strippings along the outcrop of the anthracite beds, usually at right angles to the direction of natural drainage. Many fissures and cave-ins are not easily visible because they are hidden from sight under refuse banks or are partly filled with dirt; nevertheless, these openings contribute much to water seepage.

Many anthracite beds outcrop beneath the valley-fill deposits of the buried valley and provide ingress for surface water to enter the mine workings.
CONTOUR MAPS AND CROSS SECTIONS

The contour maps (figs. 7 to 13 (box)) in this report show the contours of the top of rock surface underlying the valley-fill deposits of the buried valley of the Susquehanna River and its ramifications in the area along the Susquehanna River from West Nanticoke to West Pittston and in the area along the Lackawanna River from West Pittston to the Luzerne-Lackawanna County line near Duryea.

Figure 6 is a key map of the buried valley. This map shows the seven subdivisions into which the area containing the buried valley is divided for the preparation of the contour maps. Each contour map has a number that identifies it and gives its respective position on the key map.

The contour maps show political subdivisions to afford reference to any given locality, the names and surface boundaries of the properties of the mining companies, limits of the anthracite beds, the trace of each of the cross sections made across the buried valley, some pertinent surface features, the boundary of the river warrants, and a color scheme to show the variant depths within limits of the valley-fill, terrace deposits, and glacial till overlying the surface of the rock strata constituting the bottom of the buried valley.

The river warrants are areas of land under the Susquehanna River that were surveyed, patented, and warranted by the Commonwealth of Pennsylvania to early settlers around 1800. At the same time, land abutting the river was certified to the settlers for a nominal fee, provided the lands so certified were situated for a specified time. Only the mineral rights became vested in the warrantee having river warrants, whereas both surface and mineral rights became vested in the warrantee having abutting certified lots. However, when these grants were made, the existence of coal or other minerals was not definitely established.

The datum used for all contour maps and cross sections is 6.67 feet below mean sea level. This datum was adopted because it is the datum used by the city of Wilkes-Barre. It was accepted by the United States Corps of Engineers, Department of the Army, for the Susquehanna River Flood-Control Project and is used by some of the mining companies operating in the Wyoming Valley that have furnished data used in preparing the contour maps. The work of preparing the maps was greatly facilitated by adopting this datum.

The contour interval is 10 feet, with heavy-line contours at 50-foot intervals. A dashed line represents an approximation in contour position because of large distances between borehole locations.

When developing the contours of the rock surface of the bottom of the buried valley, any soft or broken stratum or anthracite bed that contacted the valley-fill deposits was considered part of the valley-fill deposits. This was done as a precautionary measure to keep an adequate solid-rock cover between the valley-fill deposits and mine workings. Also, where a choice was justifiable in the interpolation of the rock contours for the top of the solid-rock surface, the interpretation that lowered the top of rock was utilized. Inasmuch as movement of the glacial ice in the bottom of the valley paralleled the trend of the valley, this factor was considered, especially where the spacing of boreholes was so great that a choice in spacing contour lines was available. Erosion on the rock surface under the ice by subglacial streams heavily laden with abrasive materials was also considered. In some instances information concerning the attitude and the character of the rock strata in relation to its resistance to erosion was considered. Dashed lines are used to indicate the contours whenever insufficient information was available to provide a reasonable degree of accuracy.

The depth of the mantle of alluvium and glacial deposits over the surface of the rock is indicated by a color scheme. (See legend, figs. 7 to 13 (box).)

The information utilized to determine the vertical distance from the surface of the ground to the top of solid rock was obtained chiefly from (a) borehole records, maps, and other engineering data of the mining companies having properties under the buried valley; (b) excavations made in the surface deposits for various purposes; and (c) field work to determine rock outcrops and other pertinent surface features.

The depth of alluvium and glacial deposits at any place is the difference between the altitude of the top of the rock and the altitude of the surface of the ground. Interpolation between the depths of alluvium at points where
this information is known is used to determine the boundary between colors. In areas where
the altitude of the surface of the ground
changes, the limits of the colors may indicate
little relationship between the contours of the
rock surface and the depth of the overburden;
however, where the surface of the ground is
level, the contours of the rock surface and the
color limits between the various depths of over-
burden bear close relationship.

In the areas where the contours of the rock
surface are represented by dashed lines because
of insufficient information, the depths of the
alluvium, as indicated by the colors, are only
approximate.

Twenty-two transverse cross sections across
the buried valley are given; these are spaced at
intervals of 1 mile and are approximately at
right angles to the trend of the buried valley.
An exaggerated vertical scale is used to show
greater detail concerning the nature of the val-
ey-fill deposits. (See figs. 14 to 35 (box).)

The cross sections show the profile of the sur-
face of the ground, the Susquehanna River,
other pertinent surface features, the profile of
the rock surface of the bottom of the buried
valley, the boreholes drilled on or near the sec-
tions, the thickness and character of the valley-
fill deposits as revealed by the records of the
boreholes, and the position of anthracite beds
that the boreholes may have encountered.

GENERAL DESCRIPTION

CONTOUR MAPS

Figure 7 (box) is a map of the western part
of the buried valley and covers the area between
Newport Creek, Newport Township, Glen
Lyon, and Wanamie. This includes the buried
channel beneath Newport Creek and the South
Branch of Newport Creek. The depressions
shown are relatively narrow, with steep walls.
The rock surface of the buried valley rises
toward the west in the direction of the head-
waters of Newport Creek. A series of local
depressions with intervening saddles shows a
rise of the rock surface in the valley bottom
from 443 feet altitude to 620 feet altitude under
the main stream. The overburden ranges from
a thin mantle to 165 feet in thickness.

The buried channel beneath the South Branch
has conditions similar to those of the main
channel, but the overburden is more shallow.
(See figs. 6 (p. 19), and 14, 15, and 16 (box).)

Figure 8 (box) is a map of the buried valley
covering the area between Wanamie and east
Nanticoke, including parts of Newport, Ply-
mouth, and Hanover Townships, and Nanti-
coke. Figure 8 covers parts of the drainage
areas of the lower part and headwaters of
Nanticoke Creek and its tributaries. (See
fig. 6, p. 19.)

The major portion of the buried valley ends
north of Nanticoke; however, a portion of the
depression continues in the same general trend
beneath Newport Creek. The lowest altitude
of the rock surface of the buried valley in this
area is 344 feet and is situated where the main
portion joins that beneath Newport Creek. At
this point the buried valley becomes narrower
and maintains its depth for 2 miles, after which
the bottom trends upward.

The valley-fill deposits beneath the South
Branch of Newport Creek and Nanticoke Creek
are shallower and at a higher altitude than
those beneath Newport Creek or beneath the
Susquehanna River in this area. (See figs. 6
(p. 19), and 17, 18, 19, and 20 (box).)

Figure 9 (box) is a map of the buried valley
covering the area between east Nanticoke and
Plymouth; this area lies in Hanover and
Plymouth Townships and the boroughs of
Plymouth, Warrior Run, Sugar Notch, and
Ashley. The main deep channel in this part
of the buried valley has marked depressions,
which extend prominently below the general
rock surface. One of these, south of Plymouth
and west of the Breslaw bridge, has the lowest
altitude (201 feet) of rock surface in the buried
valley.

The mantle of alluvium and glacial deposits
extends over a wide area, as shown on this map.
The ramifications south of the main channel in-
clude Warrior Creek, Nanticoke Creek, the
lower reaches of Solomon’s Creek (Buttonwood
Creek), and their tributaries. Small creeks
enter the valley from the north. (See figs. 6
(p. 19), and 21, 22, and 23 (box).)

Figure 10 (box) is a map of the buried valley
covering the area between Plymouth and north
Wilkes-Barre. Toby Creek, parts of Mill
Creek, Solomon Creek, Hanover and Wilkes-
Barre Townships, Wilkes-Barre, and the bor-
oughs of Ashley, Plymouth, Kingston, Lark-
sville, Edwardsville, and Pringle are in this area.

The main channel of the buried valley is
broad and deep in this area and contains a
number of depressions, the bottoms of which
approach 300 feet altitude. The north wall of
the buried valley has a steep slope, whereas the
slope of the south wall is moderate. North
and west of Edwardsville a wide depression is
separated from the main buried valley by a
rocky ridge; this was a side channel of the river
at one time and is now filled with a thick de-
posit of sand and gravel (13).

The confluence of the filled former channel of
Mill Creek with the main channel of the buried
valley is near the central part of Wilkes-Barre.
(See figs. 6 (p. 19), and 24, 25, and 26 (box).)
Figure 11 (box) is a map of the buried valley covering the area between north Wilkes-Barre and east Plains lying mainly in Wilkes-Barre, Plains, and Kingston Townships. Wilkes-Barre and the boroughs of Kingston, Luzerne, Pringle, Forty Fort, Swoyerville, Wyoming, and West Wyoming are in this area.

The main deep channel in this part of the buried valley has relatively few marked depressions that extend prominently below the general rock surface of the bottom of the buried valley. One of these, near the boundary between Luzerne and Swoyerville Boroughs, has a minimum altitude of the rock surface of 300 feet. The mantle of alluvium and glacial deposits extends over a wide area.

The ramifications south of the main channel of the buried valley contain the wide valley of Mill Creek. Ramifications north of the main channel contain part of the channel of Toby Creek and the confluence of Abraham Creek with the Susquehanna River.

The channel of the present river lies south of the deepest part of the buried valley.

The north wall of the buried valley is relatively steep and regular in contrast to the south wall, which varies in slope and is more irregular. (See figs. 6 (p. 19), and 27, 28, and 29 (box).)

Figure 12 (box) is a map of the buried valley covering the area between east Plains and Pittston, lying mainly in Jenkins Township, Pittston, and the boroughs of Exeter, West Pittston, Wyoming, and West Wyoming. The deeper portions of the main channel in this part of the buried valley become relatively narrow in the western and eastern portions of this area. In the central portion, the main channel becomes much broader because of confluence with the portion of the buried channel underlying Abraham Creek and that of a tributary of the main buried channel. The main buried channel is not as deep as in some of the other areas. Only a few depressions in the buried valley in this area have altitudes lower than 400 feet.

The present channel of the Susquehanna River is generally south of the deep portion of the buried valley. Some deep terrace deposits are present in the southern and northern portions of this area, especially and in the vicinity of Pittston and West Pittston. (See figs. 6 p. 19), and 30, 31, and 32 (box).)

Figure 13 (box) is a map of the buried valley covering the area between Pittston and the Luzerne-Lackawanna County line. Some of Pittston and the boroughs of Dunyee, West Pittston, and Exeter are in this area. The confluence of the portion of the buried valley underlying the Lackawanna River with the main channel of the buried valley is in this area. The buried valley of the Susquehanna River continues upstream under or near the present river channel beyond the area covered in this report. The Susquehanna River enters the Wyoming Valley at Coxton, passes over the above-mentioned confluence, and does not reach the deep buried channel until near the west edge of figure 13. The present Lackawanna River is south of the deep channel of the portion of the buried valley underlying this river. (See figs. 6 (p. 19), and 33, 34, and 35 (box).)

CROSS SECTIONS

The valley-fill deposits shown in figure 14 (box) or cross section 1 range from 10 to 105 feet in thickness, and the rock surface of the bottom of the buried valley has a minimum altitude of 583 feet. These deposits occur as alternating pervious layers of sand, gravel, quicksand, and mixtures of sand and gravel. (See figs. 6 (p. 19) and 7 (box).)

Figure 15 (box) or cross section 2 shows the main channel and a tributary channel of Newport Creek. In the former, the valley-fill deposits are composed of layers and mixtures of sand, gravel, and boulders ranging from a thin mantle to 30 feet in thickness. The minimum altitude of the rock surface of the bottom of the buried valley is 607 feet. The valley-fill deposits in the tributary channel consists of layers and mixtures of sand, clay, and gravel ranging from a thin mantle to 110 feet in thickness. The minimum altitude of the rock surface is 530 feet. The valley wall contains a notched channel. (See figs. 6 (p. 19) and 7 (box).

Figure 16 (box) or cross section 3 shows the main channel of Newport Creek, the alluvium and rock surface for some distance north of this channel, and the south branch of Newport Creek. The main-channel deposits are composed of layers and mixtures of clay, sand, gravel, and quicksand, which is present in the lowest part of the depression. The deposits range from a thin mantle to 167 feet in thickness. The rock surface has a minimum altitude of 503 feet. (See figs. 6 (p. 19) and 7 (box).)

In the area adjacent Newport Creek on the north, the mantle overlying the rock surface of the buried valley is composed of clay, sand, gravel, and boulders, coal wash being identified in one place.

The deposits beneath the south fork of Newport Creek consist of layers and mixtures of clay, sand, and gravel. The coarser materials are present in the deep part of the depression. The deposits range from a thin mantle to 65 feet in thickness. The lowest altitude of the rock surface is 608 feet. (See figs. 6 (p. 19) and 7 (box).)

Figure 17 (box) or cross section 4 covers a section of the buried valley underlying New-
port Creek and its south branch. The valley-fill deposits beneath the main stream are relatively deep and narrow and have a notched channel in the south wall of the valley. The deposits consist primarily of layers and mixtures of clay, sand, and gravel; however, quicksand predominates in the deeper part of the channel. The deposits range from a thin mantle to 203 feet in thickness. The lowest altitude of the rock surface is 389 feet.

The valley-fill deposits beneath the south branch of Newport Creek in this area are relatively shallow and contain deposits of clay, sand, and gravel having a maximum depth of 42 feet. The lowest altitude of the rock surface is 563 feet. (See figs. 6 (p. 19) and 8 (box).)

Figure 18 (box) or cross section 5 is a section across Newport Creek and its south branch from their confluence southward. Here the buried valley is relatively wide and deep and has a notched channel on its north wall. The valley-fill deposits consist of clay, sand, boulders, and unclassified materials. The coarser constituents lie in the bottom of the depression. The valley-fill deposits range from a thin mantle on the north wall to 163 feet in thickness in the bottom of the depression. The lowest altitude of the rock surface is 393 feet.

Southward from the main channel, the valley-fill deposits range from 15 to 32 feet in thickness and consist of clay, sand, gravel, boulders, and unclassified material. A local depression 5,500 feet from the north end of the section is filled with clay, sand, gravel, and boulders. The coarser constituents occur in the bottom of the depression, and a clay bed extends along the south wall of the valley. The valley-fill deposits in the depression range from 12 to 83 feet in thickness. The lowest altitude of the rock surface is 497 feet.

From the foregoing point southward along the section, the rock surface of the bottom of the buried valley is covered by a thin layer of clay and sand in most places, except for one local depression, which occurs 1,400 feet from the south end of the section. This depression is filled with deposits of hardpan, clay, sand, gravel, and boulders; the coarser constituents are found in the bottom of the depression. These deposits reach a thickness of 73 feet. The bottom of the buried valley is at 587 feet altitude. (See figs. 6 (p. 19) and 8 (box).)

Figure 19 (box) or cross section 6 is a section through the buried valley from near the confluence of Newport Creek and the Susquehanna River, southward through Nanticoke. It covers a section beneath the branch channel of the headwaters of Nanticoke Creek. The surface of the rock of the main channel of this section is very irregular. The deepest place is in a depression along the trend of Newport Creek, where the valley-fill materials reach a depth of 170 feet and the altitude of the rock surface of the bottom of the buried valley is 365 feet. The valley-fill deposits are composed of layers and mixtures of clay, sand, gravel, ashes, and fill. Quicksand is present in one horizon, and coal wash is found in the deep part of the depression. North of the lowest depression, the section ends under the Susquehanna River where it leaves the valley. The valley-fill deposits in this area consist of clay, sand, gravel, and boulders having a maximum depth of 65 feet. The rock surface is at 420 feet altitude in the north end of the section.

Southward from the main deep channel the rock surface is covered with a thin mantle, except for a local depression in which the clay, sand, and gravel range from 40 to 65 feet in thickness until the section reaches the branch valley of a tributary to Nanticoke Creek near the south end of the section. At this place the valley is filled with clay, sand, gravel, and ashes ranging from a few feet to 63 feet in thickness. The lowest altitude of the rock surface in this tributary valley is 532 feet. (See figs. 6 (p. 19) and 8 (box).)

Figure 20 (box) or cross section 7 is a section through the main portion of the buried valley that extends southward to a point where the altitude of the surface of the rock of the buried valley is 690 feet.

In the main deep channel the present river is near the north bank. The buried valley on this section is broad and irregular in depth, and the data show three depressions. The first is along the north wall of the valley, the second and deepest is south of the present river, and the third is notched in the south valley wall. The valley-fill deposits consist of layers and mixtures of clay, sand, gravel, and boulders. Along the north wall the material is listed as unclassified. Quicksand and coarser materials fill the bottom of the major depression. Clay and sand are near the surface of the ground; these materials range from a thin mantle to 164 feet in thickness. The surface reaches a minimum altitude of 358 feet.

South of the main channel, the overburden is relatively shallow and consists of clay, sand, and gravel. (See figs. 6 (p. 19) and 8 (box).)

Figure 21 (box) or cross section 8 is a section through the buried valley under and adjacent the Susquehanna River and the broad extent of the mantle south of the main channel. The valley-fill deposits in the main channel consist of layers and mixtures of loam, clay, sand, gravel, boulders, and quicksand. In this part,
boulders, quicksand, and gravel are in the bottom of the depression. The valley-fill deposits range from a shallow mantle to 166 feet in thickness, and the minimum altitude of the rock surface is 353 feet.

A shallow channel lies south of the main channel; it is filled with gravel and unclassified materials to a maximum depth of 59 feet. The altitude of the lowest rock surface is 473 feet. The remainder of the cross section indicates a relatively thin mantle of unconsolidated material. Loam, clay, sand, gravel, and boulders were encountered where boreholes have penetrated these deposits. (See figs. 6 (p. 19) and 9 (box).)

Figure 22 (box) or cross section 9 extends across the buried valley and southward across the tributary channels of Warrior Creek. The main channel of the buried valley along this section is broad and deep. The surface of the rock at its bottom is relatively regular in outline and shows two depressions. The first is next to the north valley wall, and the second (the deeper) is near the south valley wall. The present river cuts against the south valley wall. The deposits in these depressions consist of layers of clay, sand, gravel, boulders, and mixtures of these. Quicksand is present in one place. The coarser constituents occur in the bottom of the depressions and the clay deposits near the surface of the ground. These deposits reach a maximum thickness of 215 feet near the center of the deepest depression, and the altitude of the rock surface at this point is 305 feet.

South of the main channel the rock surface is covered by a thin mantle of overburden, except where the section crosses Warrior Creek. Here the buried valley has a relatively smooth, broad bottom, covered by comparatively shallow deposits of clay, sand, gravel, and boulders to a maximum depth of 50 feet. The coarser materials are near the bottom of the buried valley or next to its rock surface. The lowest altitude of the rock surface is 525 feet. (See figs. 6 (p. 19) and 9 (box).)

Figure 23 (box) or cross section 10 crosses the main buried valley at Plymouth, passing near the deepest known depression in its bottom. The rock surface along this section has a gradual slope on the north bank, a flat area on the bottom, and a steep slope to a buried ledge at 450 feet altitude, whence it rises steeply to the south wall of the buried valley. The present channel of the Susquehanna River is north of the deepest part of the buried valley. The valley-fill deposits consist of layers of loam, clay, sand, gravel, and boulders and mixtures of these materials. Quicksand occurs near the north wall of the buried valley. The bottom of the depression is filled with coarser materials.

The lowest altitude of the rock surface in the depression is 216 feet.

The surface material revealed by boreholes north of the river on or near this section is clay. South of the river the surface materials consist of loam, clay, and sand, except in the area over the buried ledge, where they are sand and gravel. Quicksand, sand, and gravel are present beneath the surface material north of the river, whereas a layer of gravel occurs under the surface material south of the river. A prominent bed of clay extends across the valley to the buried ledge at a horizon between the limits of 395 and 510 feet altitudes. This clay bed ranges in thickness from 5 feet on the north end of the section to 90 feet over the deepest part of the depression. The bottom of this depression is covered with the coarser constituents. The lowest altitude of the rock surface in this depression is 216 feet, and the thickness of the valley-fill deposits ranges from 20 feet at the north end of the section to 30 feet over the deepest part of the depression. (See figs. 6 (p. 19) and 9 (box).)

Figure 24 (box) or cross section 11 extends, from its north end, across the confluence of the old channel (west of Edwardsville) with the main channel of the buried valley, southward across the main channel, and up the south slope of the buried valley for a short distance. The north channel of the present river crosses this section near the north wall of the buried valley, and its south channel crosses over the deepest part of the buried valley.

The depression of the confluence of the old channel west of Edwardsville with the main channel is filled with coarse sediment and a small amount of clay. Sand, gravel, and boulders predominate.

The valley-fill deposits in the main channel range from a relatively shallow thickness to a maximum of 179 feet. The rock surface of the bottom of the buried valley has a minimum altitude of 333 feet. These deposits occur mostly as alternating layers of sand, gravel, boulders and mixtures of all three, with clay predominating in the southerly portion of the section. With the exception of clay, the deposits are extremely pervious, and the coarser material has, to a large extent, been deposited in the numerous basins or depressions that occur in the rock surface of the bottom of the buried valley. The shape and permeability of the valley-fill deposits in these basins make them ideal for collecting ground water. (See figs. 6 (p. 19) and 10 (box).)

Figure 25 (box) or cross section 12 partly crosses the depression of the old channel west of Edwardsville at its north end. It extends southward across the north wall of the buried
valley, crosses the main channel of the buried valley, and ends at a deep buried channel underlying a tributary of Solomon Creek. The channel of the present Susquehanna River crosses this section near its center. The trend of this cross section parallels the river for a short distance before the river bends and flows southwestward.

The depression at the north end of the section is filled with mixtures of clay, sand, gravel, and coal wash. The thin mantle of glacial till that covers the rock surface of the rocky ridge between the depression mentioned and the main depression of the buried valley is composed of clay, sand, gravel, and boulders, with some hardpan. The buried valley, where this section crosses it, is broad and has two large, deep channels in its bottom, separated by a prominent rocky ridge. The valley-fill deposits in the north channel range in depth from 35 to 160 feet, and the rock surface of the bottom has a minimum altitude of 360 feet. The valley-fill deposits in the south channel range in depth from 15 to 155 feet. The rock surface of the bottom has a minimum altitude of 382 feet.

The valley-fill deposits in the main depression of the buried valley are mostly alternating layers of clay, sand, gravel, boulders, and mixtures of these. Nearly all the surface material is sand and clay underlain with some gravel. A thick layer of clay extends nearly the entire distance across the basin. This layer or bed of clay ranges in thickness from 15 to 95 feet under the levee along the south bank of the Susquehanna River. Quicksand lies next to the rock surface of the buried valley, except in the southern part of the south channel, where clay predominates. A mantle of unconsolidated materials overlies the rock surface of the rocky ridge separating the main channel of the buried valley and a portion under a tributary of Solomon Creek. This portion of the buried valley is filled with clay, sand, and gravel. (See figs. 6 (p. 19) and 10 (box).)

Figure 26 (box) or cross section 13 begins at the north wall of the buried valley and extends southward. It crosses a broad depression of the buried valley and ends at the filled depression of an old former channel of Mill Creek. The present Susquehanna River channel is in the middle of the section but considerably south of the deep part of the buried valley.

The wide buried valley is divided into two major depressions by a rock ridge; local ridges and minor depressions occur in these.

The valley-fill deposits consist of layers and mixtures of clay, sand, gravel, and boulders. The deposits are relatively heterogeneous in nature, except in local areas. Generally the coarser materials are found in the bottom of the depression, and quicksand deposits are local. In the north channel the deposits reach a thickness of 148 feet. The lowest altitude of the rock surface is 388 feet.

In the south channel the deposits range from 35 to 117 feet in thickness. The lowest altitude of the rock surface is 416 feet. The deposits in the former channel of Mill Creek are composed of clay, sand, gravel, and boulders. In this section these deposits range from a thin mantle to 45 feet in thickness. The lowest altitude of the rock surface is 491 feet. (See figs. 6 (p. 19) and 10 (box).)

Figure 27 (box) or cross section 14 crosses the main channel of the buried valley near the western end of the boroughs of Swoyersville and Forty Fort; this main channel is broad and deep along this section. The rock surface has a gradual slope on the north wall. From where the rock surface of the bottom of the buried valley has a minimum altitude, the rock surface becomes a series of alternating ridges and depressions. The present channel of the Susquehanna River is south of the deepest part of the buried valley and is entrenched near a rock ridge, which projects prominently above the flood plain of the river.

The valley-fill deposits consist of clay, sand, gravel, boulders, and mixtures of these. These deposits are usually local lenses instead of alternating layers across the entire width of the channel. An exception to this is a persistent layer of clay in the south part of the main channel. Quicksand is present in a number of places in the channel; the coarser materials are in the numerous depressions along the rock surface of the valley bottom. (See figs. 6 (p. 19) and 11 (box).)

Figure 28 (box) or cross section 15 extends, from its north end, southward across the broad channel of the buried valley, crosses a rocky ridge between the main channel of the Susquehanna River and the portion of the buried valley underlying Mill Creek, and ends after crossing this portion of the buried valley. The present channel of the Susquehanna River lies south of the deepest part of this portion of the main channel of the buried valley.

The valley-fill deposits in the main channel of the buried valley along this section range from 0 to 179 feet in thickness. The rock surface of the bottom of the buried valley has a minimum altitude of 363 feet. The valley-fill deposits consist mostly of discontinuous layers of clay, sand, gravel, and mixtures of these. Some quicksand and the coarser materials are deposited at the bottom of the depression. A thin mantle of overburden covers the rock surface of the broad rocky ridge between the main channel
of the buried valley and the portion underlying Mill Creek.

The valley-fill deposits underlying Mill Creek are composed of clay, sand, gravel, boulders, and mixtures of some of these materials, with some fire clay at one place. (See figs. 6 (p. 19) and 11 (box).)

Figure 29 (box) or cross section 16 extends from its north end southward across the main channel of the buried valley and ends at the valley's south wall. Two deep channels (north and south) are separated by a prominent rocky ridge in the rock surface of the valley bottom.

The valley-fill deposits in the north channel have a maximum thickness of 145 feet, and the lowest altitude of the rock surface is 391 feet. In the south channel the valley-fill deposits have a maximum thickness of 162 feet, and the lowest altitude of the rock surface is 374 feet.

The present channel of the Susquehanna River is south of the two main channels of the buried valley.

The valley-fill deposits are composed of clay, sand, gravel, boulders, mixtures of these, and some quicksand. These materials are deposited locally and not as layers across the buried valley. The coarser materials are immediately above the rock surface of the buried valley. (See figs. 6 (p. 19) and 11 (box).)

Figure 30 (box) or cross section 17, extends from its north end southward across a deep depression in the buried valley made by confluence of the portion underlying Abraham Creek with the main channel of the buried valley, across the main deep depression and the south wall of the valley, and ends at a point having an altitude of 650 feet. The present channel of the Susquehanna River overlie the southern edge of the deep portion of the buried valley. The main channel of the buried valley has three depressions formed by broad rocky ridges between them. The lowest altitude (395 feet) of the rock surface along this section is in the depression underlying the north bank of the present river channel.

The valley-fill deposits range from a relatively thin mantle to 140 feet in thickness. These deposits are mostly layers of clay, sand, gravel, boulders, and mixtures of these; however, quicksand lies next to the rock surface of the valley bottom, except in the vicinity beneath the channel of the Susquehanna River, where sand, gravel, and clay replace it. (See figs. 6 (p. 19) and 12 (box).)

Figure 31 (box) or cross section 18 extends, from its north end, southward across a portion of the buried valley underlying a tributary of Abraham Creek, the main deep channel, and the broad channel of the buried valley to the southward. In this section the present channel of the Susquehanna River is next to the south wall of the main depression in the buried valley. This main depression has a relatively smooth bottom, and only a few shallow basins and low ridges are present in the rock surface.

The valley-fill deposits range from a comparatively shallow mantle to 145 feet in thickness. The lowest altitude of the rock surface of the bottom of the buried valley is 415 feet. A number of the boreholes near this section fail to classify the nature of the deposits; however, those that have been classified show layers and mixtures of clay, sand, gravel, and boulders. These materials are more in the nature of lenses than extensive deposits. Quick sand is shown in only one borehole, but at two horizons. The coarser materials have been deposited near the bottom of the depression. (See figs. 6 (p. 19) and 12 (box).)

Figure 32 (box) or cross section 19 extends from the north end southward. It crosses a buried rock spur, continues southward through the relatively narrow depression in the main channel, crosses a rock ridge, and ends at a portion of the buried valley underlying a small tributary to the present Susquehanna River. The valley-fill deposits in the depression at the north end of this section are composed of clay, sand, gravel, boulders, coal wash, and mixtures of some of these. The relatively thin mantle over the rock spur is composed of clay, sand, gravel, and boulders.

The bottom of the main channel of the buried valley contains two shallow depressions separated by a low ridge. The valley-fill deposits comprise clay, sand, gravel, boulders, and mixtures of some of these. The deposits are irregular lenses at different horizons. Sand and boulders are near the bottom of the depression. The valley-fill deposits range from a thin mantle to 135 feet in thickness. The minimum altitude of the rock surface is 435 feet. (See figs. 6 (p. 19) and 12 (box).)

Figure 33 (box) or cross section 20 extends, from its north end, southward across the southern part of the depression caused by the confluence of the main channel of the buried valley and the portion underlying the Lackawanna River. The section continues southward across a buried rock ridge, the main depression of the buried valley, and through the thick terrace deposits south of Pittston. The valley-fill deposits in the northern channel are layers and mixtures of loam, clay, sand, and gravel; they range from a thin mantle to 78 feet in thickness. The rock surface of the bottom of the buried valley slopes gently to the bottom of the south or main channel and rises more steeply to the south.
The channel of the present Susquehanna River crosses the section near the south wall of the deep depression, which is filled with layers and mixtures of clay, sand, gravel, boulders, and some quicksand. Coarser material is deposited in the bottom of the depression. The maximum thickness of these deposits is 112 feet, and the altitude of the lowest rock surface is 406 feet. The terrace deposits near the south end of the section consist of sand, gravel, and coal wash, as revealed by two boreholes. These deposits range from 0 to 106 feet in thickness. (See figs. 6 (p. 19) and 13 (box).)

Figure 34 (box) or cross section 21 extends, from its north end, southward, crosses the portion of the buried valley underlying the Lackawanna River near its confluence with the buried channel of the main stream, and extends southward through the high terrace deposits east of Pittston. The Lackawanna River crosses this section south of the main channel of the buried valley. The valley-fill deposits in the main depression range from a relatively thin mantle to 142 feet in thickness. The lowest altitude of the rock surface is 407 feet. (See figs. 6 (p. 19) and 13 (box).)