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CORE DRILLING AT SHAFT SITES OF PROPOSED MINE-WATER DRAINAGE TUNNEL

ANTHRACITE REGION OF PENNSYLVANIA

By S. H. Ash, R. Emmet Doherty, P. S. Miller
W. M. Romischer, and J. D. Smith

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CORE DRILLING AT SHAFT SITES OF PROPOSED MINE-WATER DRAINAGE TUNNEL

ANTHRACITE REGION OF PENNSYLVANIA [1]

By

S. H. Ash,[2] R. Emmet Doherty,[3] P. S. Miller,[4] W. M. Romischer,[5] and J. D. Smith [6]

Summary

THE information obtained by examining and analyzing the core drillings from 15 diamond-drill holes shows that with the proper equipment little difficulty should be experienced while sinking the shafts at the 15 selected sites. Although a number of holes penetrated formations containing a high percentage of silica, the health hazard from dust can be removed by using proper dust-control equipment.

Methane was detected in small amounts in only one (hole 5) of the boreholes. The methane hazard should present no difficulty if adequate ventilation is employed while sinking the shafts.

Some difficulty in shaft sinking may be encountered at shaft site 5, where an incompetent shale extends 200 feet below the surface. This shale appears to be well-consolidated when it is dry; however, when it is immersed in water it reverts to a mud within a relatively short time. This condition can be handled satisfactorily by suitable construction methods.

No appreciable inflow of water was found while diamond drilling. The largest inflow occurred at hole 10; this was approximately 50 gallons per minute.

The geology of the surface and subsurface between the borehole sites was not investigated; therefore, no definite conclusions were drawn as to the attitude and thickness of the rock formations at the proposed tunnel horizon in these areas. The available Federal and State geological maps covering the route of the proposed tunnel furnish only surface geology and areal extent of the formations and give no data in regard to the attitude, thickness, and other structural features of the formations present.

In determining the extent and places to obtain core borings for the proposed tunnel, it was recognized that the present status of the project did not warrant a too extensive investigation.

It is recognized that before a large tunnel project is actually constructed, a more thorough investigation of the subsurface conditions outside the anthracite measures must be made.

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INTRODUCTION

A comprehensive engineering survey of the mine-water problem is being conducted in the anthracite region of Pennsylvania. The principal factor that threatens to shorten the life of the anthracite industry and seriously affect the welfare of the people and business dependent on anthracite for their livelihood is the inundation of anthracite mines (*2*).[7] Many anthracite mines are now flooded, others will be abandoned because of excessive inflow of water, and the factor of economic damage due to pollution of the receiving bodies of water by acid mine water confronts the industry in the development of the pollution-abatement program of the Commonwealth of Pennsylvania (*3*).

At this stage of the engineering survey it appears that both a short-range and a long-range solution of the anthracite mine-water problem can be best served by a gravity-tunnel system, consisting of a main tunnel and two or more main central pumping plants for emergency use. The main tunnel would convey the water to a point near tidewater outside the anthracite region (*3*). The mine water would be collected at its source and conveyed to the main tunnel by a network of lateral and sublateral tunnels.

ADVANTAGES OF TUNNELING

It is not within the scope of this report to discuss the economics of tunneling; this will be discussed in a later report. However, investigations of a number of first lines of handling mine drainage considered main pumping facilities exclusively, all tunneling and no main pumping facilities, and combinations of these two. Popular opinion among hydraulic engineers and others naturally favors a gravity-tunnel system. Several gravity schemes and pumping schemes for handling mine drainage are being studied.

Many factors affect the economic value of tunnels (*5*). No doubt, the rapid rise of aerial warfare and the bombing of vital utility services, such as pumping plants, canals, conduits, flumes, and power plants, have added an intangible value to deep gravity tunnels in comparison with vulnerable central pumping plants. Moreover, pumping water having a pH of 3.0 presents a problem of pumping acid mine water; this in itself, in a long-range program, favors a gravity-tunnel system that assures optimum protection against inundation and replacements, because of possible corrosion of large pumps and the stability of tunnels compared with pumps.

[7] Italic numbers in parentheses refer to items in the bibliography at the end of this report.

Tunneling consists of a definite cycle of operations, developed from ideas that are crystallized and translated into action programs through various engineering phases that begin with the first preliminary survey and do not end until the job is completed. Once the line of the bore is established and a time is set for the completion of the work, the face must advance according to estimates prepared before work is begun. This schedule must be followed in regular sequence from the moment the drills start against a new face of rock until they are ready again to drill the succeeding face, constituting a round (*1*).

SELECTING THE ROUTE OF THE MAIN TUNNEL

In general, the route of the main tunnel can be fairly well-established because of the hundreds of miles of mine workings comprising the anthracite mines, the altitudes of drainage horizons of the present mine workings and depth of the coal measures, the natural features of topography and convenience of entrance and egress of the tunnel to tidewater, the possibility of obtaining right-of-way or easements under private property, and the effect of mine discharges on the receiving body of water (*3*).

The economy of construction and the convenience of the contractor must be considered. The contractor will require room for shafts, surface plant, and spoil banks.

Considering the above-mentioned factors, the tentative route of the main tunnel being considered begins in the vicinity of Glen Lyon, Pa., and extends south to Conowingo, Md., where the mine water will discharge into the Susquehanna River immediately downstream from the Conowingo Dam; this route follows closely and lies nearly parallel to the 76th meridian (fig.1).

GEOLOGICAL INVESTIGATIONS

The importance of adequate subsurface investigation in planning large engineering projects is so generally accepted that it requires little discussion. The extent of such investigation is, however, a matter of the most-critical judgment and demands an analysis from several points of view. The only way to get a true, undisturbed sample of the bedrock is by core drilling. The cores may be obtained by the diamond drill or the shot drill.

A geological study and a set of borings are important to the engineer for the design and location of a structure; they are even more im-

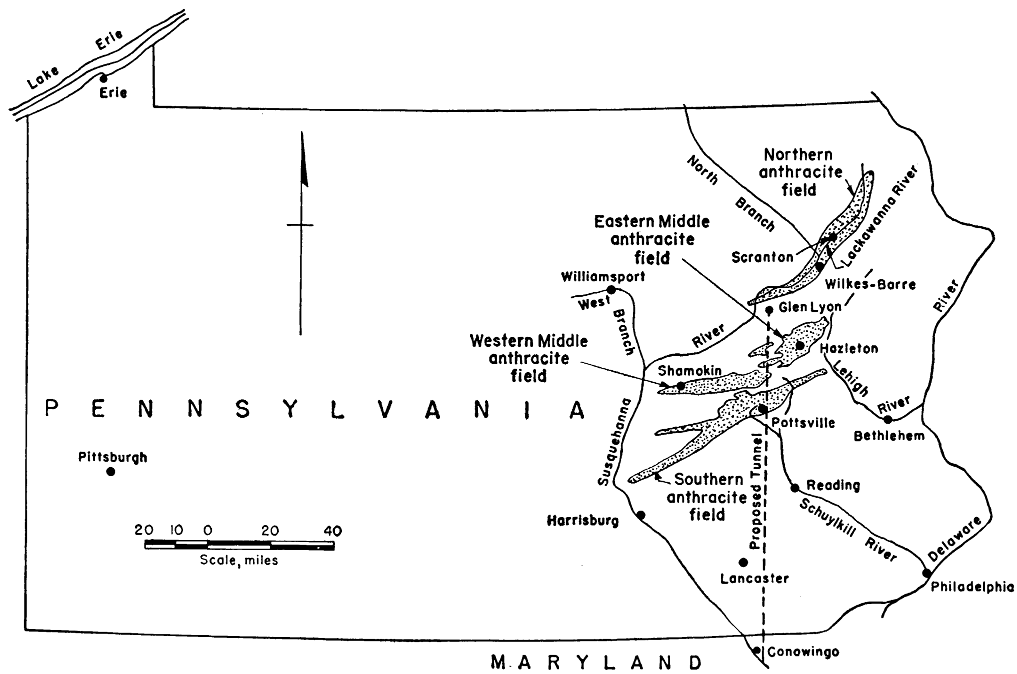

FIGURE 1.—LINE OF PROPOSED MAIN DRAINAGE TUNNEL FROM CONOWINGO, MD., TO GLEN LYON, PA.

portant to the contractor and practical tunnel man. They are like an X-ray plate to the experienced and thoughtful surgeon. They enable them to appraise the hazards and to determine the method of attack, thus permitting the preparation of an intelligent and low estimate. In short, they are the basis for their program of work.

A proper geological study and a good set of borings permit the practical tunnel man to determine his anticipated progress, the quantity of water to be expected, and how to cope with it. They enable him to select the proper equipment to be used, the amount and kind of drill steel and dynamite to be employed, and are the means for narrowing down the elements of risk.

As ground conditions are the great unknown in tunneling, obviously, the more information available, the less the risk entailed and the lower the bid will be.

In the rock formations of the Hudson Highlands through which the Delaware aqueduct tunnel recently was driven 85 miles to supply New York City with water, at least 40 different and readily identified formations were found in the tunnel. More numerous, however, were the structural features of the rock formations that required a complete set of descriptive terms independent of the formational designations. About 6,200 additional formations and structures of individual minerals and species comprise the rock formations.

In general, the alinement of the proposed Conowingo tunnel traverses areas fairly well explored and geologically mapped. Hence, it may be assumed that enough data exist for a preliminary study. However, the history of engineering construction is replete with examples of failure through excessive generalization from previous knowledge and studies. To rely exclusively on adjacent experience or related studies is as harzardous as depending exclusively on test borings alone.

The importance of petrographic examination and identification of the rocks composing the core drillings cannot be overestimated, and no large tunneling project should be attempted without enough core drillings along the tunnel line at tunnel depth. Complete sections and profiles must be drawn to illustrate and record all features in terms that can be evaulated by the contractor and his engineers.

From petrographic data obtained by core drillings, the health and safety hazards, methods of working, time factors, and costs concerning the tunneling project can be evaluated intelligently to formulate specifications, bids, and contracts.

In determining the extent and places to obtain core borings for the proposed tunnel, it was recognized that the present status of the project did not warrant a too extensive investigation. Therefore, it was important that the borings yield a maximum of information. The objectives desired were threefold:

1. To confirm and substantiate the geologic profile developed from existing data and surface observations.
2. To determine the conditions to be encountered in shaft sinking.
3. To establish to a reasonable degree the character of the rock.

A consideration of these limited objectives led to a decision to core drill with diamond drill at each of the 15 shaft sites. This decision proved to be sound and has yielded information well within the scope of this investigation. The diamond-drill holes are situated approximately 8 miles apart and range in depth from 292 to 1,082 feet (fig. 2).

It is recognized that before a project of this magnitude is actually constructed a more thorough investigation of the subsurface conditions outside the anthracite measures must be made. However, it is believed that these borings permit an intelligent appraisal to be made of the available data.

It is further recognized that subsequent inquiry may necessitate changes in alinement as occurred during the construction of the Catskill aqueduct, as well as other comparable projects. Such changes, however, will not greatly affect the over-all picture as presently envisioned.

SCOPE OF REPORT

This report deals with the diamond drilling of 15 holes at the shaft sites of the proposed main drainage tunnel and with the information obtained by a petrographic examination of the core drillings from these boreholes. The type of drilling equipment used, pertinent drilling experience encountered during the course of the normal drilling operations, the character of the geologic formations along the tunnel route, and data obtained by laboratory tests to determine the composition, hardness, and free-silica content of the drill cores are discussed. The topography and surface features at the sites of the proposed shafts along the main tunnel are shown.

ACKNOWLEDGMENTS

The authors acknowledge their indebtedness to Frank W. Earnest, Jr., president of the Anthracite Institute, Wilkes-Barre, Pa., for storing the diamond-drill cores and permission to use their laboratory facilities to analyze the core drillings; Henry Dierks, vice president and general manager, Glen Alden Coal Co., and H. H. Otto, assistant general manager, operating department, the Hudson Coal Co., for engineering service; the property owners who allowed the drilling on their private lands; H. D. Kynor, supervising engineer, who directed the field work; the engineers of the Federal Bureau of Mines who prepared the maps and illustrations; and D. O. Kennedy, assistant chief, Safety Branch, who assisted in preparing the manuscript for publication.

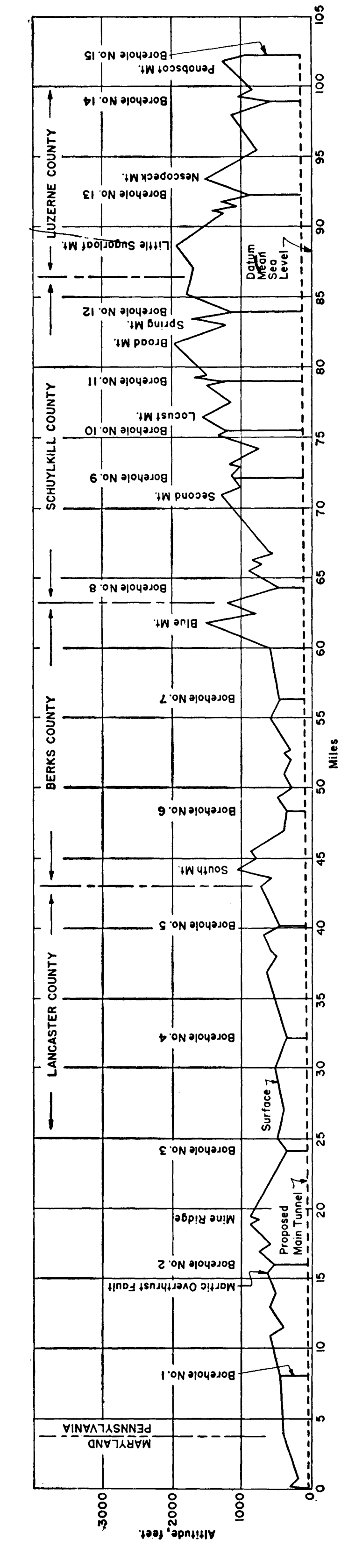

FIGURE 2.—PROFILE ALONG PROPOSED MAIN TUNNEL, SHOWING SPACING AND DEPTH OF BOREHOLES.

Although drilling operations presented no unusual experiences, a description of the drilling equipment indicates to some extent what may be expected of equipment utilized for shaft sinking.

Drilling machine:
- Sullivan 22 HD
- Gas-powered
- 30-hp. Case engine

Feed:
- Hydraulic (twin cylinders)
- 2-foot travel
- 0 to 600 pounds hydraulic (oil) pressure

Drill rod:
- Standard sizes—N, B, and A
- Lengths—5, 10, and 20 feet

Core barrel:
- Series M double-tube barrel
- Lengths—5, 10, 15, and 20 feet
- Sizes—NX, BX, and AX

Bits:
- Diamond (carbon and bortz)
- Fishtail.

Pump:
- Duplex (0 to 250 pounds pressure)
- Gas-powered
- 10-hp. Hercules engine

Drill sizes:	*O. D., inches*	*Core, inches*
NX	$2\frac{15}{16}$	$2\frac{1}{8}$
BX	$2\frac{5}{16}$	$1\frac{5}{8}$
AX	$1\frac{7}{8}$	$1\frac{1}{8}$

SERIES M DOUBLE-TUBE CORE BARREL S. & H.

The series M core barrel is intermediate between the double-tube swivel and the bottom-discharge types. The bit is longer with a box-type coupling instead of the usual pin type (fig. 3). In the ordinary double-tube core barrel an inside taper in the pin of the bit forms the seat for a fluted, split-ring core lifter, and the wash water has to pass between the core lifter and the bit and core. When core drillings are lodged between the bit and core lifter, the latter tends to rotate with the former and may cause grinding and breaking of cores and ultimate blocking of the core barrel. The inner tube of the core barrel has a tapered extension, or shell, that forms the seat for the core lifter and extends close to the face of the bit; this reduces the tendency of the core lifter to rotate with the bit, the length of the core exposed to fast-flowing wash water, the damage from blocking the core barrel, and erosion of the core. In broken and soft rocks much greater recoveries have been obtained than with the ordinary, double-tube, swivel-type core barrel (*4*). The recovery achieved on the project of drilling the 15 drill holes was approximately 97 percent.

Figure 3 shows details of the series M double-tube core barrel.

DIAMOND BITS

Carbon coring bits are operated under relatively high feed pressures and low to moderate bit speeds (250 to 500 r. p. m.), whereas modern bortz coring bits are operated with bit speeds of 800 to 1,200 r. p. m. and occasionally 1,750 to 2,000 r. p. m. in hard rock. These speeds apply primarily to small coring bits (sizes EX and AX), and it can be stated generally that the speed decreases with an increase in the diameter of the bit (*4*).

ROTATION SPEED

The proper rotation speed, or bit speed, varies greatly with the size and type of the core barrel and cutting medium and with the character of the material to be sampled. Drilling machines are capable, because of gear shifts and engine throttles, to vary the rota-

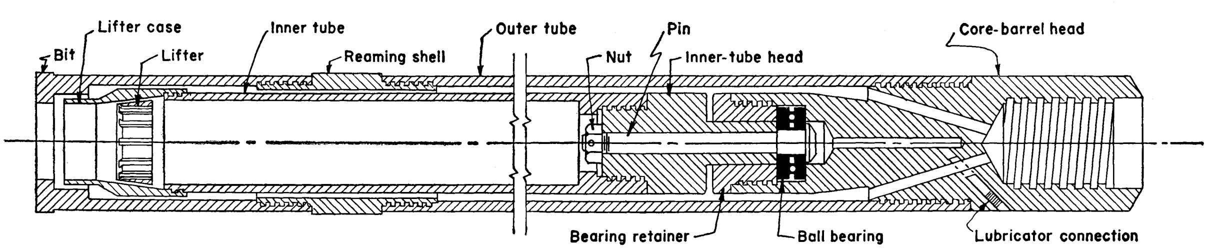

FIGURE 3.—DRAWING OF SERIES M DOUBLE-TUBE CORE BARREL.

tion speed of the bit within very wide limits. With diamond core barrels, the speed may range from 300 to 1,500 r. p. m. The average bit speed for modern, small, diamond core barrels used in hard and uniform rock is about 1,000 r. p. m., but speeds up to 1,750 r. p. m. are occasionally used (*4*).

To avoid whip and vibrations of the drill rod and core barrel, especially at high bit speeds, it is essential that the drill rod be carefully centered in the borehole and chuck of the drill head and that the drill rod in make-up condition is straight. A drill collar or section of drill rod, with increased outside diameter, wall thickness, and weight, is often inserted above large-diameter core barrels and tends to decrease whip, vibration, and danger of breaking the core (*4*).

Excessive bit speed for a particular type of coring bit and subsurface formation causes whip and vibration of the core barrel, chattering, excessive wear of the bit, and breaking of the core. A low bit speed decreases the rate of progress, but it will generally increase the recovery ratio and the length of core obtainable in a single operation, except when the rate of progress becomes so slow that the material in the lower part of the core and below the bit is exposed to erosion by the circulating fluid for an excessively long time.

BIT PRESSURE AND FEED

The pressure of the coring bit and its rate of advance or feed must be carefully adjusted in accordance with the character of the material penetrated and the type of bit and bit speed. Too high a pressure and rate of feed may damage the bit and will cause plugging of the bit and fluid passages and failure of the subsurface material before it enters the core barrel. Too low a bit pressure and slow or intermittent feed may expose the core to excessive erosion and torsional stresses and may be equivalent to the "drilling-off" procedure used in separating the core from the formation.

Hydraulic feed by means of twin hydraulic cylinders permits definite control of the bit pressure and also the rate of feed. The bit pressure can be determined by a gage indicating the oil pressure in the hydraulic cylinders and is, for a given rate of feed and bit speed, indicative of the character of the formation being cored.

DESCRIPTION OF SITES OF HOLES

HOLE 1

Hole 1 is on the south side of a wooded area near the edge of a cultivated field, east of a township road. A brick dwelling, barn, two silos, and smaller farm buildings are on the west side of the road. The nearest source of water is a small stream one-half mile to the east. The ground is comparatively level. A small-stream valley lies to the east. (See figs. 4 and 6.)

HOLE 2

Hole 2 is at the southern end of a field, east of a township road. The Atglen Branch of the Pennsylvania Electric Railroad is approximately 600 feet north. A small creek, 4 feet wide, is 50 feet south of the hole. The ground slopes upward very gently, both to the north and to the south of the hole. (See figs. 5 and 7.)

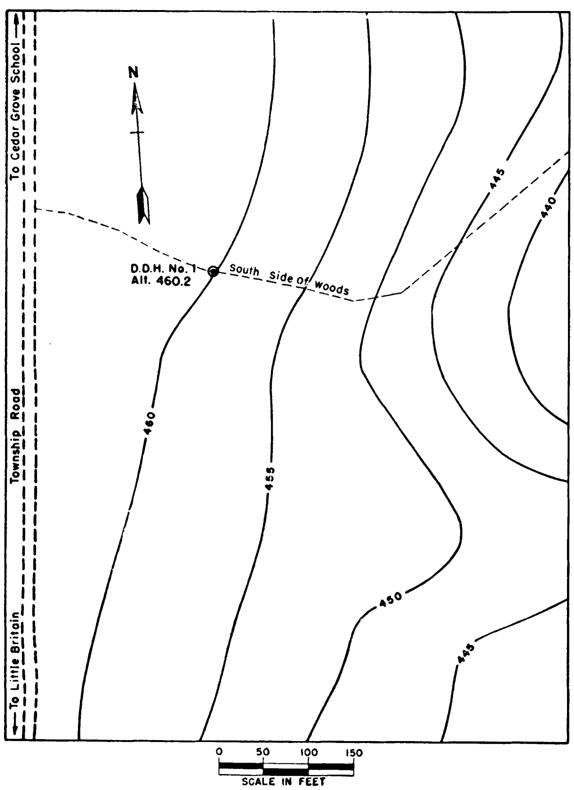

FIGURE 4.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 1.

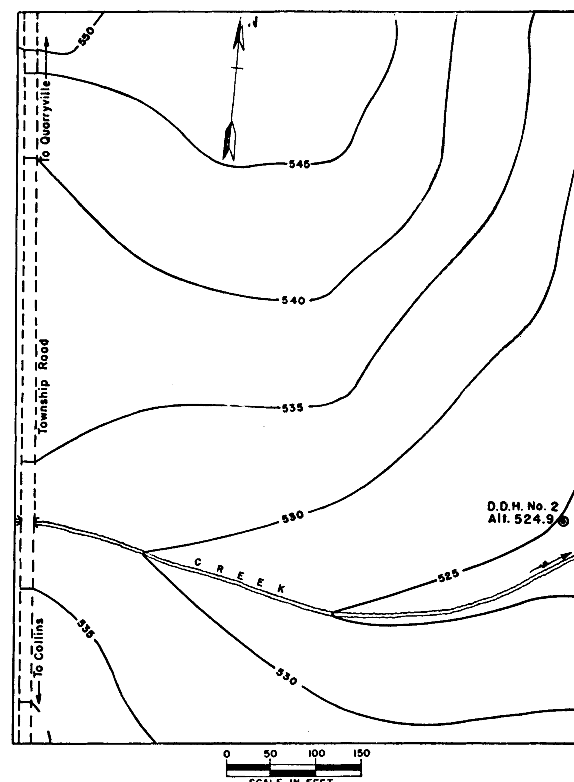

FIGURE 5.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 2.

Figure 6.—VIEW OF SITE AT HOLE 1, NEAR LITTLE BRITAIN, PA.

Figure 7.—VIEW OF SITE AT HOLE 2, NEAR QUARRYVILLE, PA.

HOLE 3

Hole 3 is in a level pasture, approximately 500 feet south of a township road to Gordonville. A farmhouse, barn, and smaller farm buildings are to the north, near the township road. A small creek flows close to the hole. The main line of the Pennsylvania Electric Railroad is one-third mile south of it. (See figs. 8 and 10.)

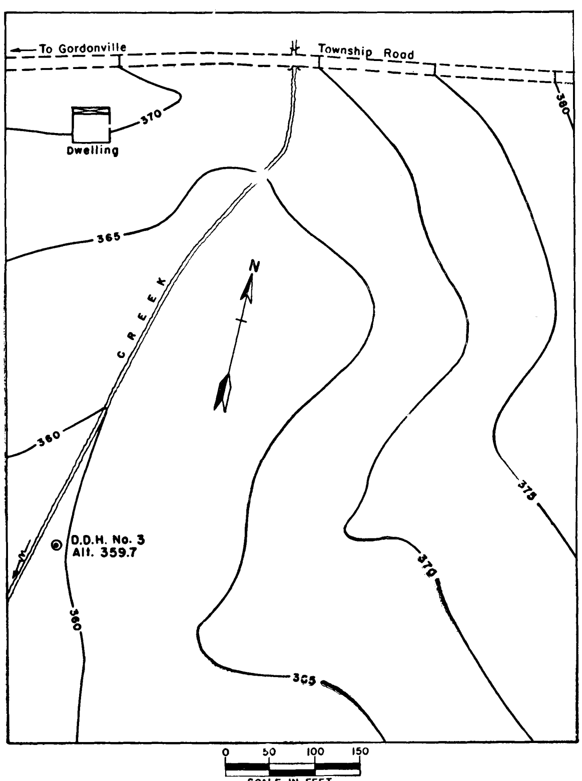

FIGURE 8.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 3.

HOLE 4

Hole 4 is in a cleared area between two cultivated fields west of the State highway between Hinkleton and New Holland. Several hundred feet west of the hole is an abandoned limestone quarry. The nearest source of water is approximately 1 mile away. The ground in this area is gently rolling, with occasional small hills. (See figs. 9 and 11.)

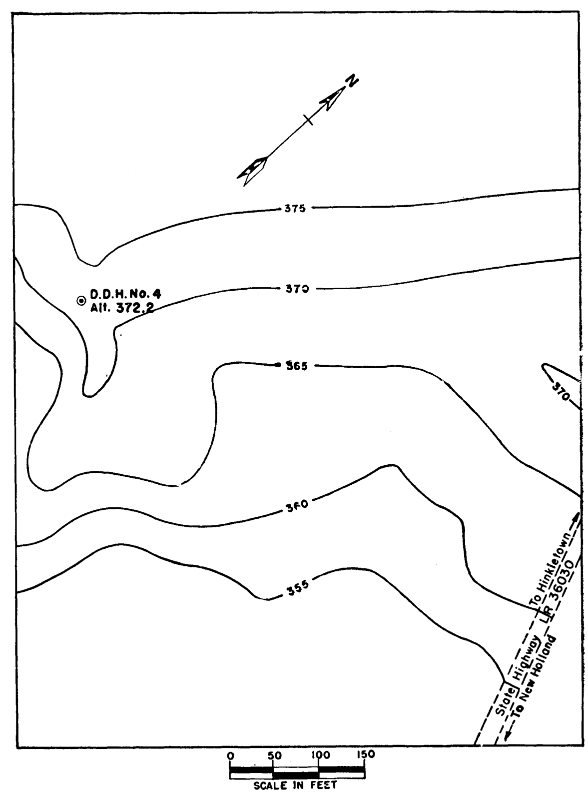

FIGURE 9.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 4.

FIGURE 10.—VIEW OF SITE AT HOLE 3, NEAR GORDONVILLE, PA.

FIGURE 11.—VIEW OF SITE AT HOLE 4, NEAR HINKLETOWN, PA.

HOLE 5

Hole 5 is in a wooded area, 500 feet northeast of a township road. The ground slopes gently to the east. A small stream (a tributary of Little Cocalico Creek) is approximately 200 feet east of the hole. Several buildings are near the township road northwest of the site. A high-tension power line is nearby. (See figs. 12 and 14.)

HOLE 6

Hole 6 is in a meadow, which has some woodland, consisting of light timber. A tributary of Spring Creek flows close to the hole. The nearest power line is approximately 1½ miles west of the hole. A number of small hills surround the site. Several hundred feet to the northwest is a farm dwelling, barn, and several smaller farm buildings. (See figs. 13 and 15.)

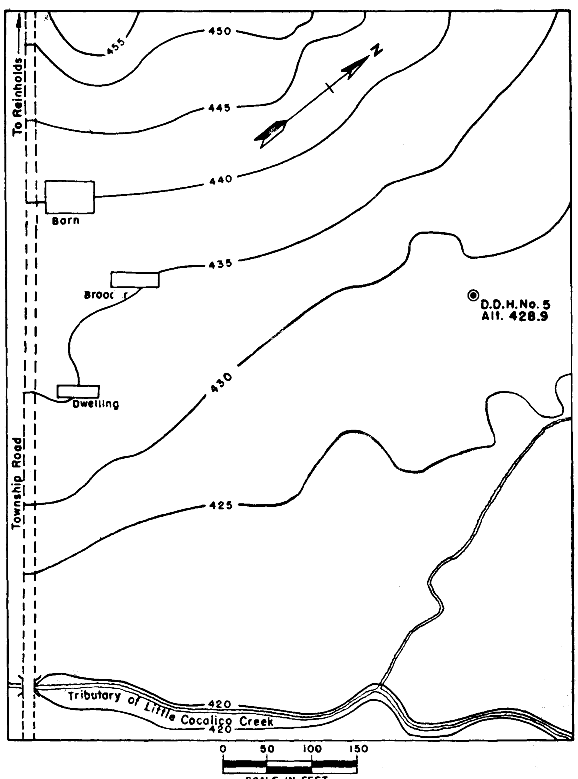

FIGURE 12.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 5.

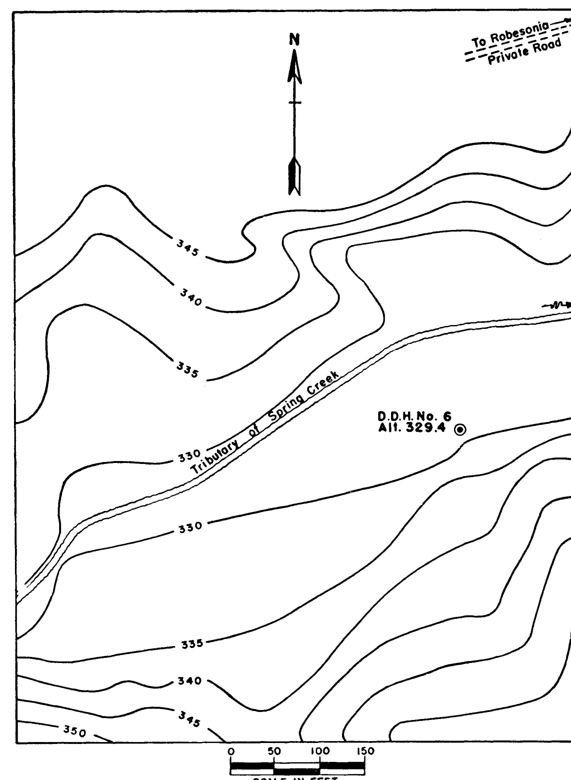

FIGURE 13.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 6.

FIGURE 14.—VIEW OF SITE AT HOLE 5, NEAR REINHOLDS, PA.

FIGURE 15.—VIEW OF SITE AT HOLE 6, NEAR ROBESONIA, PA.

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HOLE 7

Hole 7 is in cultivated farm land in a shallow valley surrounded by low, rolling hills. It is near the north side of a township road. Dwellings, barns, and smaller farm buildings are nearby. The nearest supply of water is 1,500 feet away. (See figs. 16 and 18.)

HOLE 8

Hole 8 is near Pine Creek, which is a fairly large stream in a sparsely wooded area. A small settlement is north of the hole. The Pennsylvania and Reading Railroads and the Schuylkill River are west of this hole. Power lines are available at Auburn. (See figs. 17 and 19.)

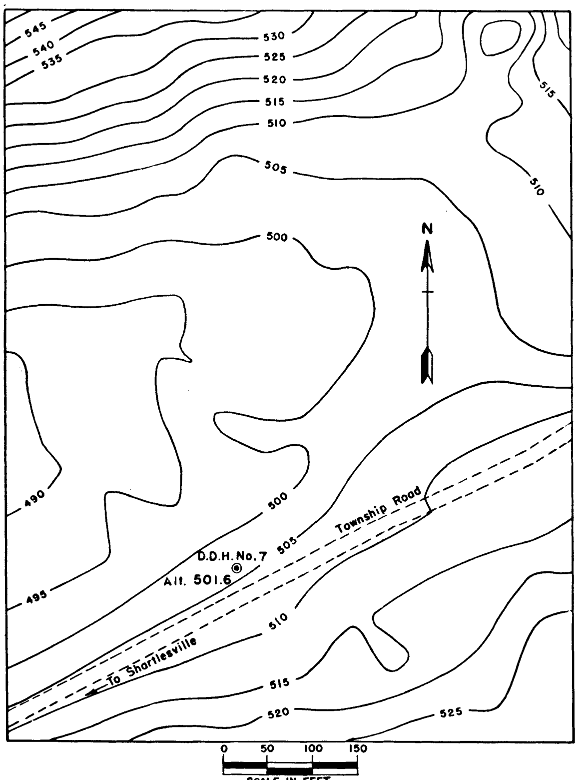

FIGURE 16.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 7.

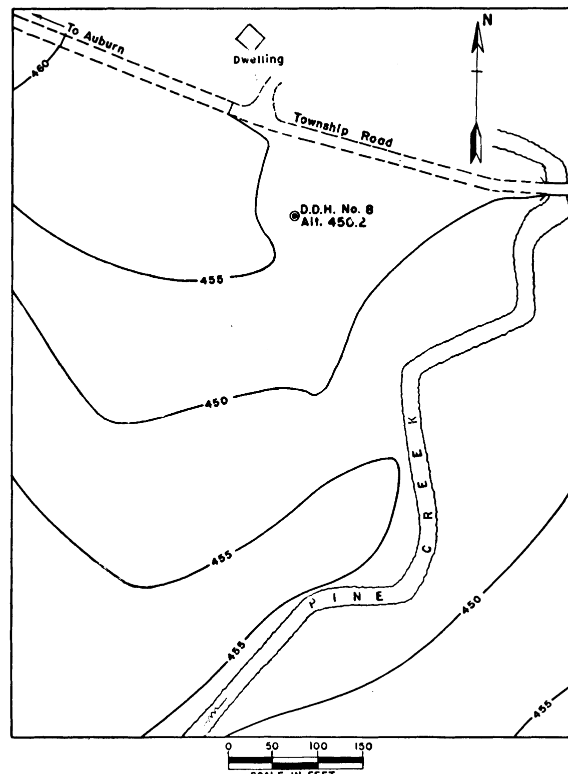

FIGURE 17.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 8.

FIGURE 18.—VIEW OF SITE AT HOLE 7, NEAR SHARTLESVILLE, PA.

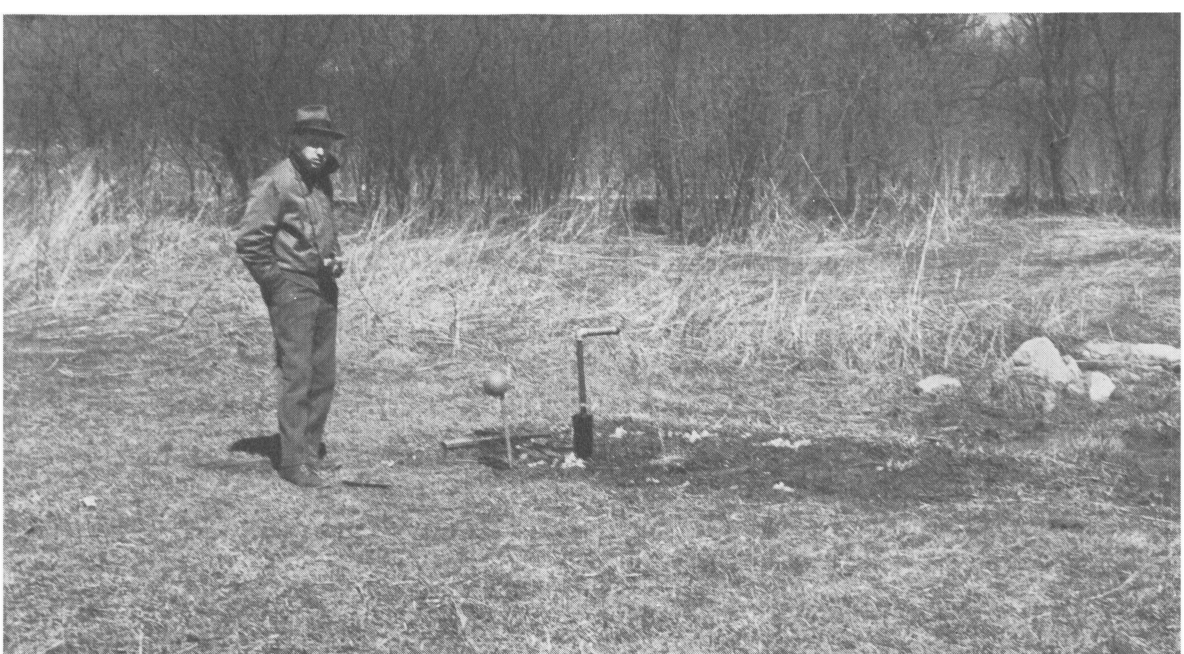

FIGURE 19.—VIEW OF SITE AT HOLE 8, NEAR AUBURN, PA.

HOLE 9

Hole 9 is in a cultivated field on the southern slope of Sharp Mountain and adjoins a wooded area. The nearest surface water is one-half mile southeast of the hole. No power lines are in the vicinity. A State highway is several hundred feet to the northwest. (See figs. 20 and 22.)

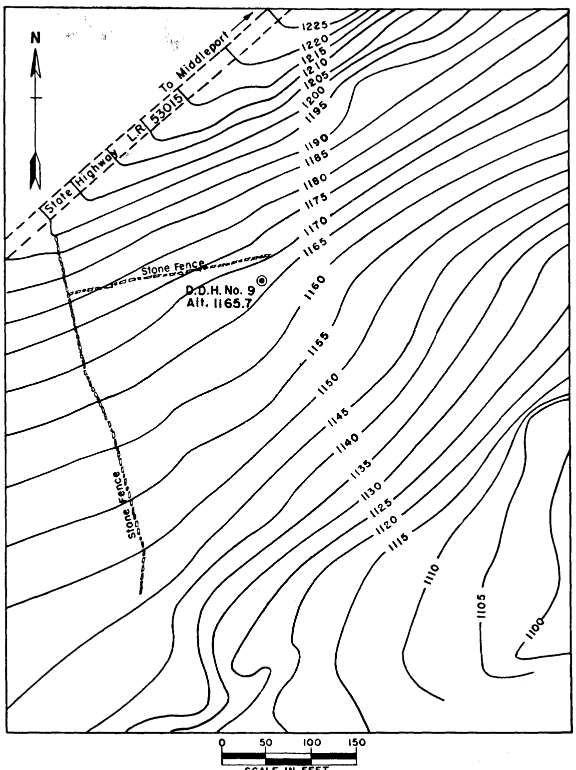

FIGURE 20.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 9.

HOLE 10

Hole 10 is in a wooded area south of Moss Glen Reservoir and west of Big Creek Stream. No power lines are in the immediate vicinity. The hole is reached by a private road serving the reservoir. (See figs. 21 and 23.)

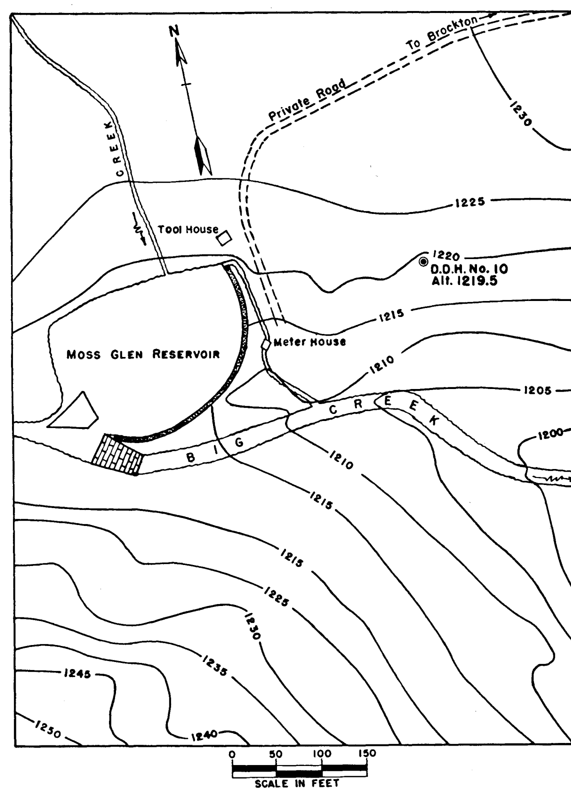

FIGURE 21.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 10.

FIGURE 22.—VIEW OF SITE AT HOLE 9, NEAR MIDDLEPORT, PA.

FIGURE 23.—VIEW OF SITE AT HOLE 10, NEAR BROCKTON, PA.

HOLE 11

Hole 11 is in a wooded area, which is being cleared. Water is available from nearby Hosensock Creek. A power line is approximately one-half mile to the west. State Highway 45 is about 500 feet northwest of the hole. (See figs. 24 and 26.)

HOLE 12

Hole 12 is in a wooded area, one-quarter mile south of Township Road 455 and 3 miles east of Sheppton on State Highway 924. No buildings are in the vicinity. A branch of Catawissa Creek flows 300 feet away and can furnish an ample water supply. An electric power line passes through this area. (See figs. 25 and 27.)

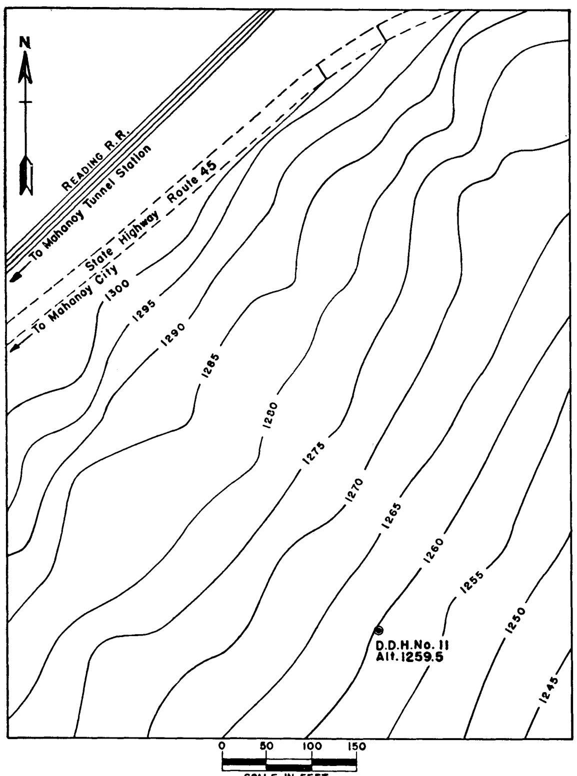

FIGURE 24.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 11.

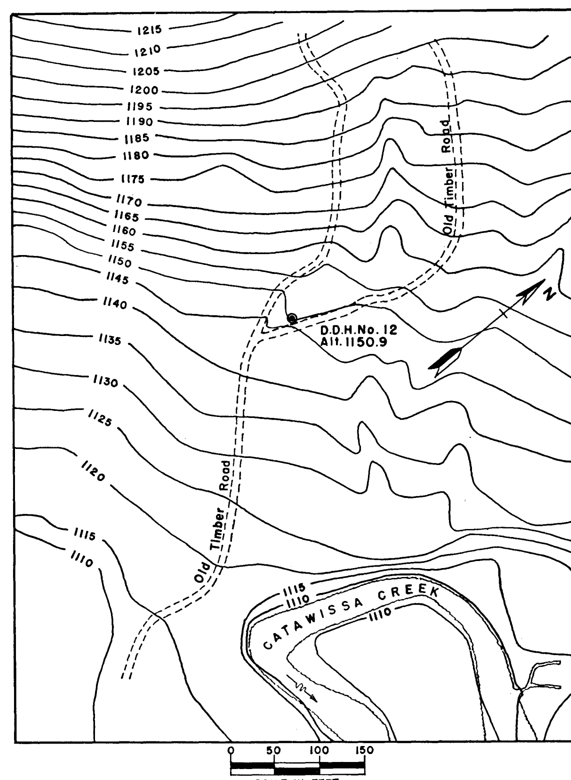

FIGURE 25.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 12.

FIGURE 26.—VIEW OF SITE AT HOLE 11, NEAR MAHANOY TUNNEL STATION, PA.

FIGURE 27.—VIEW OF SITE AT HOLE 12, NEAR SHEPPTON, PA.

HOLE 13

Hole 13 is at the edge of a private road, 50 feet north of a tributary of Nescopeck Creek. No buildings or power lines are in the immediate vicinity. The hole is in a shallow valley formed by the stream. (See figs. 28 and 30.)

HOLE 14

Hole 14 is at the edge of a rolling cultivated field near the top of a wooded hill, which slopes into Little Wapwallopen Creek. A farm dwelling and smaller farm buildings are nearby. No power lines are in the immediate vicinity. (See figs. 29 and 31.)

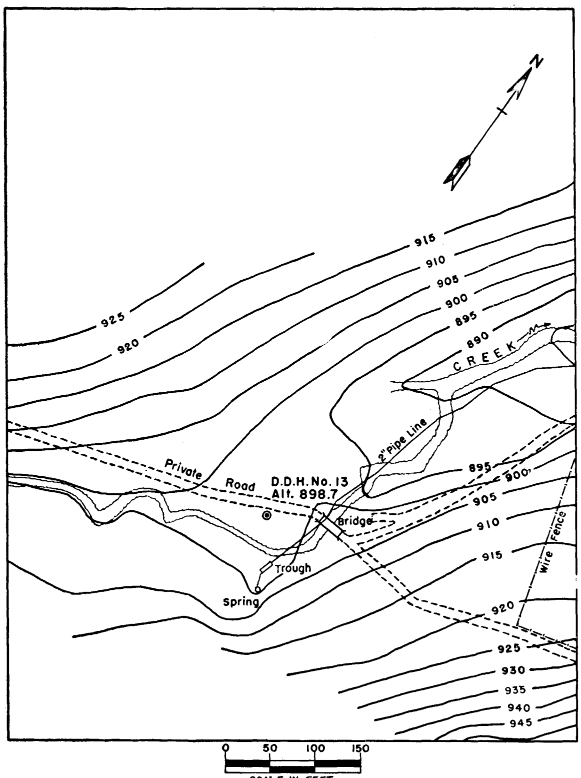

FIGURE 28.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 13.

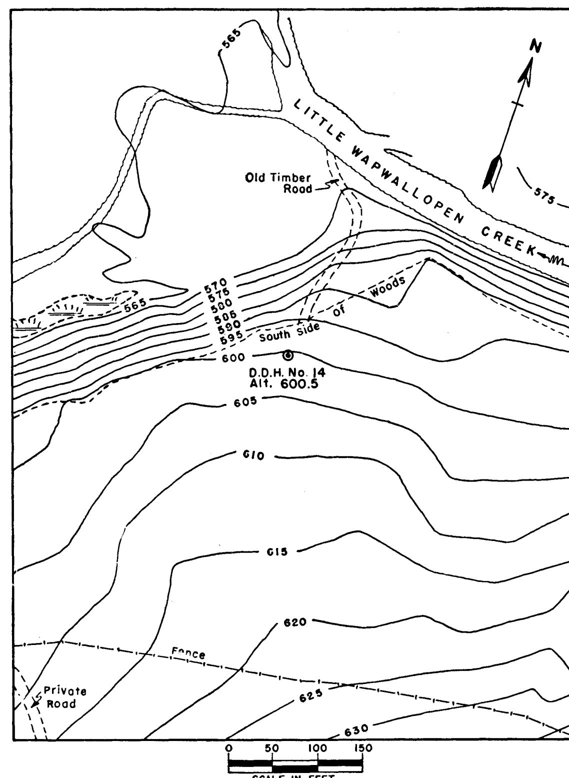

FIGURE 29.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 14.

FIGURE 30.—VIEW OF SITE AT HOLE 13, NEAR SYBERTSVILLE, PA.

FIGURE 31.—VIEW OF SITE AT HOLE 14, NEAR WAPWALLOPEN, PA.

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HOLE 15

Hole 15 is in a fairly heavily wooded area that runs parallel to the highway from Glen Lyon to Mocanaqua. No buildings are in the immediate vicinity. A high-tension power line is adjacent to the site, and a small stream flows between the highway and the mountain, which rises to the south of the hole. (See figs. 32 and 33.)

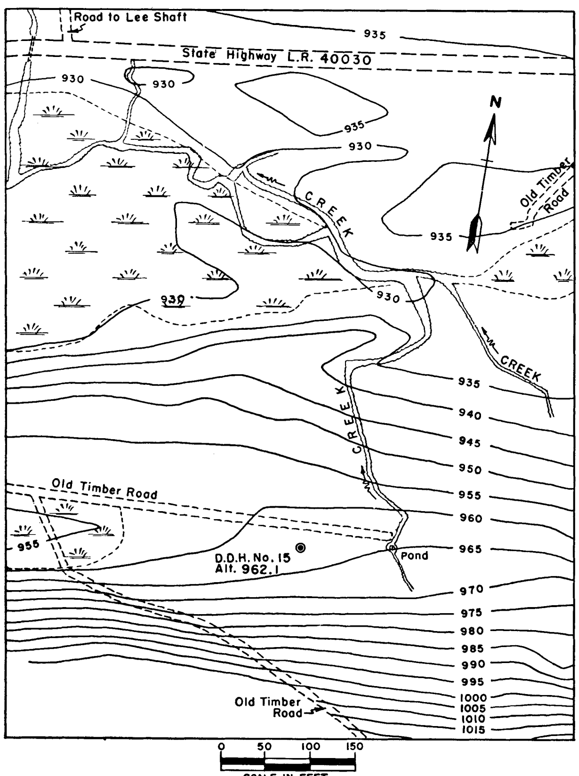

FIGURE 32.—TOPOGRAPHIC MAP OF VICINITY OF HOLE 15.

FIGURE 33.—VIEW OF SITE AT HOLE 15, NEAR GLEN LYON, PA.

DRILLING OPERATIONS

On June 12, 1950, core drilling by diamond drill was begun at hole 15, which is near Glen Lyon, Pa. Drilling holes 14 to 1 along the alinement of the proposed tunnel (see fig. 1) was completed on October 25, 1950, when the core drilling was completed at hole 1, which is 8 miles north of the tunnel portal near Conowingo, Md.

The core drillings are to be used to determine subsurface geological conditions at the 15 proposed shaft sites along the line of the main tunnel.

When core drilling commenced, the contemplated tunnel gradient was 2 feet per mile from the discharge portal to hole 11 near Mahanoy City, Pa., thence it was 1.44 feet per mile to hole 15. Further study has revealed the advantages gained by using a gradient of 1 foot per mile for the entire length of the main tunnel. The depths of holes 15 to 6, inclusive, were controlled by the original gradients of 2 feet and 1.44 feet per mile. The depths of holes 5 to 1, inclusive, were controlled by the gradient of 1 foot per mile (fig. 2).

All altitudes referred to in this report are based on a datum of mean sea level.

While drilling was in progress, the core recovered from each borehole was immediately placed in its respective place in a specially constructed wooden core box. The core boxes, 5 feet long, were made locally and divided into compartments wide enough to accommodate the cores. The NX bit (2 15/16 inches outside diameter) core boxes were divided into four compartments, the BX bit (2 5/16 inches outside diameter) into five compartments, and the AX bit (1 7/8 inches outside diameter) into six compartments. The cores from each run were separated by wooden blocks marked with the appropriate depth and were placed at the bottom and top of each section or run. Each core box was marked on the top and on one end to show the box number, hole number, and depth from which that particular core was extracted. Each hole was visited daily while drilling was in progress, and the core was examined and logged by a Bureau of Mines geologist. After each hole was completed, the core boxes were transported to the Anthracite Institute, Wilkes-Barre, Pa., where the cores were stored and later analyzed.

Detailed logs of cores from all drill holes are given in tables 1 to 15, inclusive.

TABLE 1.—*Log of hole 1*

Site: Little Britain, Pa.
Surface altitude: 460.2 feet
Depth: 414 feet

Started: Oct. 13, 1950
Completed: Oct. 25, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 30.0			Overburden, composed of soil and decomposed schist.		Seated NX bit; casing to 31.0 ft.
30.0 to 78.5	2 1/8	18.0	Schist, light olive-green, soft, muscovite-sericite, very highly weathered.		Occasional thin quartz layers.
78.5 to 99.0	2 1/8	18.5	Schist, light olive-green, muscovite-chlorite, weathered, hard, but highly schistose.		Occasional thin quartz layers. Some jointing. Several small encrusted solution fissures.
99.0 to 136.0	2 1/8	35.5	Schist, light- to dark-green, slightly weathered, muscovite-chlorite, highly schistose.		Occasional thin quartz and sericite layers. Some jointing and a few small pyrite concentrations.
136.0 to 154.0	2 1/8	18.0	Schist, light- to dark-green, slightly weathered, muscovite-chlorite, iron-stained.		Occasional thin quartz and sericite layers. Some small pyrite concentrations. Some movement at 154 ft.
154.0 to 173.0	2 1/8, 1 5/8	18.5	Schist, light- to dark-green, muscovite-chlorite, highly schistose.		Changed to BX bit at 160.0 ft. Numerous magnetite specks. Quartz layer at 164 to 166 ft.
173.0 to 414.0	1 5/8	219.2	do	45	Numerous sericite quartz layers (2 in. to 2 ft. thick). Numerous magnetite specks. Fractured at 348 to 368 ft. Numerous small folds throughout full depth of hole.

TABLE 2.—*Log of hole 2* [1]

Site: Quarryville, Pa.
Surface altitude: 524.9 feet
Depth: 479 feet

Started: Oct. 7, 1950
Completed: Oct. 16, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 14.0			Overburden, composed of small pebbles and sand		Seated NX bit; casing to 14.0 ft.
14.0 to 53.0	2⅛	17.0	Schist, light-gray with black banding, fairly hard, highly calcareous, micaceous.		Very highly weathered at 24, 26, 30, 32, and 49 ft. Sand-filled cavity at 35 to 44 ft. Numerous pyrite crystals and a large amount of minute mica flakes.
53.0 to 88.0	2⅛	17.0	77.0 to 81.0 ft., schist, light-gray, banded, weathered, highly calcareous, some parts carbonaceous and micaceous, and light-gray marble.		Sand-filled cavity at 53 to 70 ft., lined with 3.0 ft. of frosted, massive quartz. Much slickensiding in marble and numerous scattered pyrite crystals.
88.0 to 107.0	2⅛	19.0	88.0 to 92.0 ft., limestone, light-gray, hard, fine-grained, banded, crystalline. 92.0 to 107.0 ft., schist, dark-banded, sericitic, carbonaceous.		Numerous pyrite crystals and slickensides.
107.0 to 151.4	2⅛, 1⅝	43.5	Schist, light-gray, banded, calcareous, moderately hard, micaceous.	35	Changed to BX bit at 112 ft. Light gray when weathered, dark gray to black on fresh fracture. Slickensides and small pyrite concentrations.
151.4 to 229.0	1⅝	77.5	Schist, grayish black (fresh), calcareous, micaceous, hard, but highly schistose.	35	Slickensided, with small pyrite concentrations.
229.0 to 249.0	1⅝	19.5	Limestone, black, fine-grained, splintery, somewhat metamorphosed, crystalline.	35	Do.
249.0 to 268.0	1⅝	19.0	Limestone, black, fine-grained, crystalline, with interbedded white marble, micaceous schist, and graphitic slate.	35	Do.
268.0 to 287.5	1⅝	19.5	Limestone, dark-gray to black, fine-grained, crystalline. Schist, mica-tourmaline.	35	Slickensides and numerous pyrite and other metallic sulfide concentrations.
287.5 to 307.0	1⅝	19.5	Limestone, dark-gray to black, banded, hard, fine-grained, crystalline. Schist, micaceous, with some graphite.	35	Muscovite-sericite schist. Slickensides, occasional solution fissures, numerous metallic sulfide concentrations.
307.0 to 365.0	1⅝	57.5	Marble, dark-gray to black, hard, banded. Schist, micaceous, sericitic, with some graphite.	35	Slickensides, calcite-filled solution cavities, numerous metallic sulfide concentrations.
365.0 to 385.0	1⅝	19.5	Marble, dark-gray to black, hard, banded. Schist, garnetiferous, micaceous, sericitic, with some graphite.	35	Slickensides and numerous metallic sulfide concentrations.
385.0 to 443.0	1⅝	57.2	Marble, dark-gray to black, hard, banded. Schist, micaceous (biotite-sericite).	35	Slickensides and pyrite concentrations.
443.0 to 462.8	1⅝	19.5	Schist, dark-green, sericitic; dark-gray to black, micaceous, highly mineralized.	35	Do.
462.8 to 481.0	1⅝	18.2	Marble, dark-gray to black, hard, banded. Schist, hard, micaceous.	35	Do.

[1] This hole is in the faulted area of the Martic Overthrust.

TABLE 3.—*Log of hole 3*

Site: Gordonville, Pa.
Surface altitude: 359.7 feet
Depth: 306 feet

Started: Sept. 29, 1950
Completed: Oct. 10, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 4.0			Overburden, composed of soil and decomposed dolomite.		Seated NX bit; casing to 25.0 ft.
4.0 to 15.0			Limestone, dolomitic, soft, decomposed		
15.0 to 38.0	2⅛	17.0	Limestone, dolomitic, light-gray, hard, siliceous, impure.	Flat	Numerous weathered fractures. Sand-filled cavity at 18 to 20 ft. Lost water at 18 ft.
38.0 to 90.0	2⅛	52.0	Limestone, dolomitic, light-gray, hard, siliceous, impure, with some white marble.	do	Highly fractured and weathered, with iron-stained fractures. Rock weak in vicinity of fractures at 74 to 90 ft. Large amount of milky quartz and several small solution cavities.
90.0 to 107.0	2⅛, 1⅝	17.0	Limestone, dolomitic. Marble, light-gray to white, hard, impure, banded.	do	Highly fractured and weathered, with iron-stained fractures. Changed to BX bit at 101.6 ft.
107.0 to 132.8	1⅝	23.0	Limestone, dolomitic, light-gray, hard, impure, with white dolomitic marble.	do	Highly fractured and weathered, with iron-stained fractures. Weak in vicinity of fractures, with sand-filled cavity at 110 to 112 ft.
132.8 to 167.0	1⅝ 1⅛	28.0	Limestone, dolomitic, light-gray, hard, impure	do	Highly fractured and weathered, with iron-stained fractures. Sand-filled cavity at 158 to 164 ft. Changed to AX bit at 152 to 167 ft. Full water return after casing to 165 ft.
167.0 to 306.5	1⅝	133.7	Limestone, dolomitic, light blue-gray, hard, impure.		BX bit at 167 to 306.5 ft. Highly fractured and weathered, with iron-stained fractures. Numerous small solution cavities. 1-in. solution quartz vein at 210 ft. Very highly weathered at 278 to 281 ft.

Table 4.—*Log of hole 4*

Site: Hinkletown, Pa.
Surface altitude: 372.2 feet
Depth: 313 feet

Started: Sept. 26, 1950
Completed: Oct. 3, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 9.5	2⅛	3.0	Fractured limestone and clay		Seated NX bit; casing to 8.0 ft.
9.5 to 83.0	2⅛, 1⅝	71.0	Limestone, blue-gray to blue-black, hard	Flat	Numerous calcite seams and small iron-stained solution cavities. Soft red clay seam at 38 ft. Some edgewise conglomerate at 50 ft. A few small siderite seams. Changed to BX bit at 69 ft.
83.0 to 106.1	1⅝	23.0	Limestone, blue-black, hard, impure; arenaceous, interbedded, dark-red, fine-grained.	do	Numerous slickensides, edgewise conglomerate, calcite seams (white and pink calcite) and small iron oxide deposits throughout.
106.1 to 154.5	1⅝	48.3	Limestone, buff to bluish-gray, hard, somewhat brecciated.	do	Numerous small concentrations of siderite, limonite, calcite, and serpentinelike coatings on frequent slickensides. Several ¼- to ½-in. solution passages.
154.5 to 225.7	1⅝	71.2	Limestone, breccia, buff to bluish-gray, hard	do	Small concentrations of siderite, limonite, white and pink calcite and sericite on frequent slickensides.
225.7 to 298.6	1⅝	72.4	Limestone, laminated, gray to bluish-black, hard (some limestone breccia).	do	Slickensides, white and pink calcite, some granular limestone and siderite. A few small solution cavities.
298.6 to 313.0	1⅝	14.4	Limestone, laminated, gray to bluish-black, hard. Marble, buff-colored.	do	Slickensides, some small solution cavities, white and pink calcite, and some siderite.

Table 5.—*Log of hole 5*

Site: Reinholds, Pa.
Surface altitude: 428.9 feet
Depth: 370 feet

Started: Sept. 20, 1950
Completed: Sept. 27, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 30.0			Overburden, very soft, highly weathered red shale.		Seated NX bit; casing to 40.0 ft.
30.0 to 56.0	2⅛	19.0	Shale, reddish-brown, very soft, with some more-competent siltstone members.		Highly weathered.
56.0 to 195.5	2⅛	131.2	Shale, reddish-brown, incompetent, soft		Weathered, with some fracturing; evidence of movement. Few competent siltstone layers, 2- to 3-ft. intervals, at 136.4 to 155.0 ft. 3-ft. layer of moderately hard siltstone at 176.2 to 195.5 ft. Some encrusted quartz present.
195.5 to 216.0	2⅛	19.0	Shale, reddish-brown, fairly soft, with some fairly hard layers of edgwise conglomeratic sandstone (evidence of reworking).		Indication of some movement.
216.0 to 233.0	2⅛	17.0	Shale, reddish-brown, moderately soft, with a 3-ft. layer of fairly hard, red, fine-grained sandstone.		Shale is slickensided and mottled blue-gray in several places.
233.0 to 253.0	2⅛	19.2	Shale, reddish-brown, moderately hard, with a 7-ft. layer of hard, reddish-brown, fine-grained sandstone.		Shale is slickensided.
253.0 to 272.6	2⅛	19.0	Sandstone, gray-red, hard, medium-grained. Siltstone, reddish-brown, fairly soft. Shale, reddish-brown, soft.	35	Shale and siltstone are slickensided.
272.6 to 291.0	2⅛	18.4	Sandstone, red-gray, hard, medium-grained. Conglomerate, pebble, red, hard. Siltstone, reddish-brown, soft.		Siltstone is slickensided.
291.0 to 311.2	2⅛, 1⅝	19.0	291.0 to 308.0 ft., conglomerate, red-gray, hard, pebble to cobble size. 308.0 to 311.2 ft., siltstone, red, fairly hard.		Pebbles in conglomerate are quartz. Changed to BX bit at 308 ft.
311.2 to 331.0	1⅝	19.0	Siltstone, reddish-brown, moderately soft. Sandstone, red, hard, medium-grained.		Some gray-blue mottling.
331.0 to 370.0	1⅝	37.8	Shale, reddish-brown, silty, fairly soft		Numerous slickensides; 1-in. quartz vein at 369 ft.

Table 6.—*Log of hole 6*

Site: Robesonia, Pa.
Surface altitude: 329.4 feet
Depth: 292 feet

Started: Sept. 11, 1950
Completed: Sept. 18, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 3.0			Overburden, soil and decomposed shale		Seated NX bit; casing to 10.0 ft.
3.0 to 37.0	2⅛	19.0	Shale, black, brittle, carbonaceous, fissile		Several 2-in. calcite seams. Frequent fractures.
37.0 to 76.4	2⅛, 1⅝	37.5	Shale, black (white-banded), carbonaceous, brittle, fissile.	40	Changed to BX bit at 64 ft. Rock has appearance of having undergone some strain—numerous slickensides. Frequent fractures.
76.4 to 292.3	1⅝, 1⅛	214.2	Shale, black (white-banded), brittle, highly carbonaceous, fissile.	40	Slickensides throughout and several large calcite seams. Changed to AX bit at 233 ft. Frequent fractures. All exhibit high luster.

TABLE 7.—*Log of hole 7*

Site: Shartlesville, Pa.
Surface altitude: 501.6 feet
Depth: 405 feet

Started: Sept. 9, 1950
Completed: Sept. 20, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 20.0			Overburden, composed of soil and yellow clay		Seated NX bit; casing to 20.0 ft.
20.0 to 39.0	2⅛	15.0	Sandstone, light-brown, fine-grained, poorly consolidated. Shale, brown, fairly soft.		Highly weathered and fractured.
39.0 to 63.0	2⅛	16.0	Sandstone, brownish-gray, medium-grained, poorly consolidated, fairly soft, with some thin, brown shale layers.		Do.
63.0 to 83.0	2⅛	18.0	Sandstone, blue-gray, medium-grained, hard. Shale, black, hard, fissile.	45	Sandstone, jointed and weathered.
83.0 to 103.0	2⅛	19.0	Sandstone, gray, hard, medium-grained. Shale, black, hard, fissile, somewhat carbonaceous.		Lost water at 90 ft.
103.0 to 122.0	2⅛	18.5	Shale, black, fairly hard, fissile, carbonaceous. Sandstone, gray, hard, fine-grained.	45	Parts of shale are very hard and have slatelike appearance.
122.0 to 141.0	2⅛	19.0	Shale, blue-gray, fairly hard. Sandstone, hard, medium-grained.		Some slickensiding and weathering in sandstone.
141.0 to 160.0	2⅛	18.7	Sandstone, blue-gray, hard, medium-grained. Shale, fairly hard, somewhat fissile.		Some slickensiding and calcite seams in shale.
160.0 to 179.7	2⅛	18.0	Sandstone, blue-gray, hard, medium-grained. Shale, fairly hard, blocky.		Some slickensiding in shale.
179.7 to 199.3	2⅛	19.0	Shale, black, fairly hard, carbonaceous, blocky. Sandstone, blue-gray, hard, medium-grained.		Slickensides and carbonate-filled seams.
199.3 to 219.0	2⅛	19.4	Sandstone, blue-gray, hard, medium-grained. Shale, black, hard, blocky.		Some fracturing and weathering. Sandstone has occasional ½-in. calcite seams.
219.0 to 239.0	2⅛	19.0	Sandstone, blue-gray, hard, medium-grained. Shale, black, hard, carbonaceous, blocky.		Some slickensides and a few calcite seams.
239.0 to 259.0	2⅛	19.6	Sandstone, blue-gray, hard, medium-grained, with a few layers of hard, black, blocky shale.		Jointed with some calcite seams and slickensides.
259.0 to 323.0	2⅛, 1⅝	62.8	Sandstone, blue-gray, hard, medium-grained. Shale, black, hard, blocky.	30	Some slickensides and calcite seams. Changed to BX bit at 296 ft.
323.0 to 348.0	1⅝	24.7	Sandstone, blue-gray, hard, medium-grained. Shale, black, hard, carbonaceous, somewhat fissile.		Slickensides and some 1- to 2-in. calcite seams.
348.0 to 397.0	1⅝	48.4	Sandstone, blue-gray, hard, medium-grained. Shale, black, hard, blocky.		Some calcite seams and slickensides.
397.0 to 405.0	1⅝	7.6	Sandstone, blue-gray, hard, medium-grained, with some thin layers of black fissile shale.		Some large calcite seams in sandstone.

TABLE 8.—*Log of hole 8*

Site: Auburn, Pa.
Surface altitude: 450.2 feet
Depth: 410 feet

Started: Aug. 26, 1950
Completed: Sept. 2, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 14.0			Overburden, composed of soil, pebbles, and cobbles.		Seated NX bit; casing to 14.0 ft.
14.0 to 207.0	2⅛	189.4	Shale, fairly soft, silty, black, weathered, jointed, slightly calcareous.		Occasional slickensides. Pyrite concentration in joints at 96 ft. Fossiliferous at 108 to 128 ft.
207.0 to 346.0	2⅛	138.5	Shale, black, fairly soft		A few intermittent calcite stringers.
346.0 to 364.4	2⅛	18.4	346.0 to 356.0 ft., shale, black, silty, fairly soft. 356.0 to 364.4 ft., quartzite, dark-gray, fine-grained, hard.	30	Several calcite stringers in quartzite.
364.4 to 384.3	2⅛	19.5	Quartzite, bluish-gray, fine-grained, very hard		
384.3 to 403.0	2⅛	18.7	Quartzite, dark-gray, fine-grained, very hard. Sandstone, dark-gray- fine-grained, hard.		Encountered artesian water flow at 398 ft. (several gallons per minute).
403.0 to 411.0	2⅛	8.0	Quartzite, black, hard, fine-grained		Slickensides at 405 ft.

TABLE 9.—*Log of hole 9*

Site: Middleport, Pa.
Surface altitude: 1,165.7 feet
Depth: 975 feet

Started: Aug. 23, 1950
Completed: Sept. 8, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 4.0			Overburden, consisting of soil and sand		Seated NX bit; casing to 10.0 ft.
4.0 to 16.0	2⅛	5.0	Sandstone, brown, medium-grained, manganese-stained, weathered, fractured.		0.5 ft. of red shale at 6.0 ft.
16.0 to 23.0	2⅛	6.0	Sandstone, brownish-green, conglomeratic, weathered, fractured.		
23.0 to 29.0	2⅛	6.0	Sandstone, olive-brown, medium-grained, weathered, fractured.		
29.0 to 31.6	2⅛	2.5	Siltstone, olive, soft, fractured, weathered		
31.6 to 49.5	2⅛	17.9	Shale, fairly soft. Sandstone, greenish-brown, fine-grained, fairly soft, highly weathered, fractured.		Iron and manganese staining throughout.
49.5 to 66.5	2⅛	17.0	Shale, brownish-red, fairly hard, highly weathered, fractured.		Manganese stains and large amount of iron staining.
66.5 to 85.3	2⅛	18.7	66.5 to 76.0 ft., shale, dark-red, fairly hard. 76.0 to 85.3 ft., shale, gray-green, fairly hard, serpentinelike appearance.		
85.3 to 142.0	2⅛	56.7	Siltstone, gray-green, hard, massive	70	Slickensides at 98, 122, 132.5 and 137.5 ft.
142.0 to 200.5	2⅛	57.7	Siltstone, gray-green, hard, massive, glauconitic appearance.		Slickensides at 146 and 156 ft.
200.5 to 219.7	2⅛	19.2	Shale, gray-green, fairly hard, serpentinelike appearance, argillaceous.		
219.7 to 278.0	2⅛	57.9	Sandstone, gray-green, hard, fine-grained, glauconitic appearance.		Small black slivers of carbonaceous matter scattered throughout.
278.0 to 297.2	2⅛	19.0	Quartzite, dark-gray, conglomeratic (cobble size), very hard.		¼-in. seam of coal at 284 ft.
297.2 to 336.0	2⅛, 1⅝	38.8	Quartzite, alternating dark-gray, coarse, very hard and medium-grained, conglomeratic.		Changed to BX bit at 317 ft.
336.0 to 360.0	2⅛, 1⅝	24.0	336.0 to 355.0 ft., quartzite, dark-gray, coarse, conglomeratic, very hard. 355.0 to 360.0 ft., shale, black, fairly hard, highly fissile.		
360.0 to 383.4	2⅛, 1⅝	23.4	360.0 to 362.5 ft., shale, black, fairly soft. 362.5 to 383.4 ft., quartzite, light-gray, coarse, conglomeratic, hard.		
383.4 to 408.0	2⅛, 1⅝	24.4	Quartzite, alternating light-gray, coarse, conglomeratic and fine-grained.		Soft, black shale layer at 401 to 403 ft.
408.0 to 431.6	2⅛, 1⅝	23.6	Quartzite, light-gray, coarse, conglomeratic, hard		
431.6 to 452.0	2⅛, 1⅝	20.4	431.6 to 447.0 ft., quartzite, light-gray, coarse, conglomeratic, hard. 447.0 to 452.0 ft., sandstone, black, fine-grained, hard.		
452.0 to 480.5	2⅛, 1⅝	27.9	Quartzite, dark-gray, slightly carbonaceous, coarse, conglomeratic, hard.		
480.5 to 528.8	2⅛, 1⅝	48.3	Quartzite, light-gray, coarse, conglomeratic, slightly carbonaceous, very hard.	65	Hard, light-gray, medium-grained quartzite at 510.0 to 513.0 ft.
528.8 to 602.0	2⅛, 1⅝	73.2	Quartzite, alternating light-gray, hard, coarse, conglomeratic and medium-grained.		
602.0 to 626.8	2⅛, 1⅝	24.8	Quartzite, dark-gray, hard, medium-grained		Slickensides at 624.0 ft.
626.8 to 641.0	1⅝	14.2	Quartzite, alternating light-gray, conglomeratic and hard, medium-grained.		
641.0 to 651.0	1⅝	10.0	Shale, hard, black. Siltstone, carbonaceous		
651.0 to 674.0	1⅝	23.0	651.0 to 663.0 ft., slate, black. 663.0 to 674.0 ft., quartzite, dark-gray, very hard, conglomeratic, slightly carbonaceous.		Slickensides in slate, ½-in. coal seam at 671 ft.
674.0 to 698.3	1⅝	24.0	Quartzite, alternating dark-gray, very hard, coarse, conclomeratic and hard, medium-grained.		½-in. coal seams at 675 and 687 ft.
698.3 to 795.5	1⅝	96.8	Quartzite, alternating dark-gray, very hard, coarse, conglomeratic and hard, fine-grained.		½-in. coal seam at 706 ft. Slickensides at 714.7 and 733 ft. ¼- and ½-in. coal seams at 727, 741.5, and 743.4 ft. Conglomerate, slightly carbonaceous. Weakened by minute coal seams at 788.5, 790, 790.5, 791, 794.5, 795, and 795.5 ft.
795.5 to 820.5	1⅝, 1⅛	24.8	Quartzite, dark-gray, hard, carbonaceous, conglomeratic.		Changed to AX bit at 811 ft. Numerous ½- to 1-in. coal seams scattered throughout.
820.5 to 821.5	1⅝, 1⅛	1.0	Shale, hard, black, carbonaceous		
821.5 to 907.5	1⅝, 1⅛	86.0	Quartzite, alternating dark-gray, hard, medium-grained and dark-gray, hard, carbonaceous, coarse, conglomeratic.		Numerous scattered thin coal seams; some slickensides and joints. 3-in. coal seam at 838.5 ft.; 2-in. coal and pyrite seam at 872 ft.; 1-in. coal seam at 902 ft. Slickensides at 905 ft.
907.5 to 936.1	1⅝, 1⅛	28.6	Quartzite, alternating dark-gray, hard, coarse, conglomeratic and medium-grained, micaceous.		Occasional slickensides and some thin coals.
936.1 to 975.0	1⅝, 1⅛	38.9	Quartzite, alternating dark-gray, hard, carbonaceous, coarse, conglomeratic and medium-grained, carbonaceous, hard.		Frequent joints and slickensides in medium-grained quartzite.

TABLE 10.—*Log of hole 10*

Site: Brockton, Pa.
Surface altitude: 1,219.5 feet
Depth: 1,048 feet

Started: July 24, 1950
Completed: Aug. 18, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 29.0			Overburden, composed of gravel, sand, and clay		Seated NX bit; casing to 26.0 ft.
29.0 to 35.0	2⅛	5.5	Sandstone, light- to dark-gray, banded, highly weathered. Conglomerate, light quartz.		Occasional thin coal seams (½ in.) at 29 to 35 ft.
35.0 to 48.0	2⅛	12.0	35.0 to 36.0 ft., siltstone, dark, poorly consolidated (soft), carbonaceous. 36.0 to 40.5 ft., conglomerate, light-gray, very hard, quartzitic. 40.5 to 48.0 ft., quartzite, dark-gray, hard; conglomerate, light-gray, hard, quartz, with thin coal seams (½ in.).		Thin coal seams (½ to 1 in.) at 36.0 to 40.5 ft. 0.4-ft., soft, carbonaceous shale seam at 43.1 ft.
48.0 to 67.3	2⅛	18.0	Quartzite, light- to dark-gray, very hard, conglomeratic.		Occasional thin coal seams (½ to 1 in.).
67.3 to 85.7	2⅛	18.4	67.3 to 70.0 ft., quartzite, light- to dark-gray, very hard, conglomeratic. 70.0 to 77.4 ft., siltstone, black, fairly hard, carbonaceous; shale, dark, soft, carbonaceous. 77.4 ft. to 85.7 ft., siltstone, black, fairly hard.		Intermittent coal seams (½ to 1½ in.) with occasional pyrite concentrations at 70.0 to 77.4 ft.
85.7 to 104.6	2⅛	17.9	85.7 ft. to 95.2 ft., siltstone, black, fairly hard, carbonaceous; argillite, black, fairly hard. 95.2 to 101.0 ft., anthracite and bony coal. 101.0 to 104.6 ft., argillite, black, fairly hard; shale, black, rather easily broken, fissile.		Coal, highly fractured.
104.6 to 124.4	2⅛	18.9	104.6 to 109.6 ft., siltstone, black, fairly hard, carbonaceous. 109.6 to 119.0 ft., sandstone, light- to dark-gray. 119.6 to 124.4 ft., quartzite, dark-gray, hard, conglomeratic.		Reworked fragments of conglomerate, with occasional thin coals and argillite ¼ to ½ in., at 109.6 to 119.0 ft.
124.4 to 148.6	1⅝	24.0	124.4 to 132.0 ft., quartzite, dark-gray, very hard, conglomeratic, with large amount of carbonaceous matter. 132.0 to 144.0 ft., quartzite, dark-gray, very hard, fine-grained, with occasional thin coals. 144.0 to 148.6 ft., quartzite, dark, hard, carbonaceous, conglomeratic.		Changed to BX bit at 124.4 ft. Intermittent jointing at 132 to 144 ft. Occasional black shale seams (½ to 1 in.) at 132 to 148 ft.
148.6 to 172.0	1⅝	23.0	148.6 to 151.2 ft., quartzite, light-gray, very hard, conglomeratic. 151.2 to 156.7 ft., quartzite, dark-gray, very hard, fine-grained. 156.7 to 161.7 ft., quartzite, dark-gray, hard, carbonaceous, conglomeratic. 161.7 to 163.7 ft., shale, dark, hard, banded, carbonaceous. 163.7 to 172.0 ft., quartzite, dark-gray, hard, some fine-grained and some conglomeratic.		Jointed at 151.2 to 156.7 ft. Jointed and well-fractured, somewhat sealed at 163.7 to 172.0 ft. Occasional thin coal seams (less than ½ in.).
172.0 to 195.5	1⅝	23.5	172.0 to 192.0 ft., quartzite, dark-gray, hard, some fine-grained and some conglomeratic; siltstone, dark, carbonaceous, banded; occur in alternate layers. Siltstone and fine-grained quartzite, both jointed. 192.0 to 195.5 ft., quartzite, light-gray, hard, conglomeratic, made of large quartz pebbles (up to 20+ mm.).	40	Contains scattered thin coal seams (½ to 1 in.) at 172 to 192 ft. Slickensides at 186 ft. Lost water at 195 ft.
195.5 to 219.7	1⅝	24.0	Quartzite, gray, very hard, carbonaceous, conglomeratic. Sandstone, dark-gray, hard, medium-grained.		Slickensides at 199 ft. Scattered thin coal seams throughout. Quartz pebbles in conglomerate up to 40 mm.
219.7 to 244.0	1⅝	24.3	Quartzite, gray, very hard, some conglomeratic and some medium-grained. Sandstone, medium-grained, gray, very hard.		Conglomerate has large-size quartz pebbles and carbonaceous matter. Cavity with solution quartz filling at 240 ft.
244.0 to 267.0	1⅝	23.0	Quartzite, some gray, very hard, conglomeratic, somewhat fractured and some dark-gray, hard, medium-grained, carbonaceous.		Cavity with solution quartz filling at 246 ft. 2-in. coal seam at 256 ft. Pebbles in conglomerate up to 50+ mm.
267.0 to 290.7	1⅝	23.7	Quartzite, dark-gray, very hard, carbonaceous, part conglomeratic and some medium-grained. Siltstone, black, hard, carbonaceous.		Core well-fractured in part.
290.7 to 313.9	1⅝	23.2	Quartzite, dark-gray, very hard, conglomeratic. Sandstone, dark-gray, hard, medium-grained. Occur in alternate layers.		Some carbonaceous sandstone and quartzite.
313.9 to 338.8	1⅝	24.3	Quartzite, dark-gray, very hard, conglomeratic. Sandstone, grayish-black. Some fine-grained micaceous and medium-grained quartzite occurring in alternate layers.		Carbonaceous; two ½-in. coal seams.
338.8 to 363.1	1⅝	24.0	338.8 to 357.0 ft., sandstone, grayish-black, fairly hard, with scattered quartz pebbles; quartzite, dark-gray, very hard, conglomeratic; occur in alternate layers. 357.0 to 359.0 ft., shale, black, carbonaceous, and coal. 359.0 to 362.0 ft., sandstone, grayish-black, fairly hard, with scattered quartz pebbles; quartzite, dark-gray, very hard, conglomeratic; occur in alternate layers. 362.0 to 363.0 ft., siltstone, black, micaceous.		Core about 3 ft., well-fractured.
363.1 to 386.5	1⅝	23.4	Quartzite, dark-gray, hard, conglomeratic. Sandstone, black, fairly hard, medium-grained, micaceous, interbedded with carbonaceous shale and coal.		Some fracturing and jointing. Carbonaceous matter throughout. Coal ½ to 4 in. thick. Slickensides at 1- to 2-ft. intervals.
386.5 to 411.3	1⅝	24.5	Quartzite, dark-gray, very hard, conglomeratic		Large amount of carbonaceous matter.
411.3 to 435.0	1⅝	23.7	Quartzite, black, hard, highly carbonaceous, conglomeratic. Sandstone, black, fairly hard, fine-grained, carbonaceous and micaceous, with interbedded carbonaceous shale layers and coal seams.		Coal ½ to 3 in. thick.

TABLE 10.—*Log of hole 10*—Continued

Site: Brockton, Pa.
Surface altitude: 1,219.5 feet
Depth: 1,048 feet

Started: July 24, 1950
Completed: Aug. 18, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
435.0 to 459.5	1⅝	24.0	435.0 to 454.0 ft., quartzite, dark-gray, hard, conglomeratic and some medium-grained; sandstone, dark-gray, hard, with interbedded thin coal seams. 454.0 to 457.0 ft., shale, dark-gray, fairly hard. 457.0 to 459.5 ft., quartzite, dark-gray, hard, conglomeratic and some medium-grained; sandstone, dark-gray, hard, with interbedded thin coal seams.		Coal ½ to 3 in. thick.
459.5 to 483.8	1⅝	24.3	Quartzite, dark, hard, highly carbonaceous, conglomeratic. Sandstone, dark, fine-grained, quartzitic, with interbedded coal seams.		One seam of coal 3 in. thick.
483.8 to 507.7	1⅝	23.9	483.8 to 492.0 ft., quartzite, dark-gray, hard, carbonaceous, conglomeratic. 492.0 to 507.0 ft., sandstone, dark-gray, fairly hard, carbonaceous, micaceous, fine-grained.		Some thin coals at 483 to 492 ft.
507.7 to 531.0	1⅝	23.3	507.7 to 522.0 ft., quartzite, dark-gray, hard, conglomeratic. 522.0 to 531.0 ft., sandstone, dark-gray, fairly hard, fine-grained, carbonaceous and micaceous.		3-in. coal seam at 528 and 529 ft.; 2-in. carbonaceous shale seam at 529 and 530 ft.
531.0 to 580.0	1⅝	48.3	Siltstone, dark, medium-hard, carbonaceous. Quartzite, dark-gray, hard, carbonaceous, conglomeratic. Sandstone, dark-gray, fairly hard, carbonaceous and micaceous. Occur in intermittent layers.		Scattered thin coals throughout. Some fracturing at 556 to 580 ft.
580.0 to 604.8	1⅝	24.4	Sandstone, dark-gray, fairly hard, carbonaceous, micaceous, fine-grained. Quartzite, dark-gray, hard, conglomeratic.		Very little carbonaceous material in the quartzite.
604.8 to 652.8	1⅝	23.3	Quartzite, dark-gray, very hard, some conglomeratic and some medium-grained. Sandstone, black, fairly hard, fine-grained, carbonaceous and micaceous.		Two ½-in. coal seams at 619 and 620 ft., respectively. Considerable carbonaceous material present throughout. Occasional thin coal seams at 628.1 to 652.8 ft.
652.8 to 677.4	1⅝	24.6	Sandstone, dark-gray, fairly hard, fine-grained, carbonaceous and micaceous. Quartzite, dark-gray, hard, carbonaceous, some conglomeratic and some medium-grained.		Several 1- to 2-in. coal seams and 1- to 2-in. carbonaceous shale seams.
677.4 to 702.0	1⅝	24.6	Quartzite, dark-gray, hard, some carbonaceous, some conglomeratic and some medium-grained. Sandstone, dark-gray, fairly hard, fine-grained, carbonaceous and micaceous.		Occasional small coal and carbonaceous shale seams.
702.0 to 727.0	1⅝	24.6	Quartzite, dark-gray, very hard, conglomeratic		¼-in. coal seam at 703 ft.
727.0 to 751.0	1⅝	24.0	Quartzite, dark-gray, very hard, conglomeratic. Shale, black, fairly hard, carbonaceous. Siltstone, black, fairly hard, highly carbonaceous. Sandstone, dark-gray, fairly hard, carbonaceous and micaceous. Occur in intermittent layers.		Coal seam 0.2 ft. thick at 727.5 ft. Occasional thin coal seams throughout.
751.0 to 799.1	1⅝, 1⅛	47.8	Quartzite, dark-gray, hard, conglomeratic. Sandstone, dark-gray, fairly hard, fine-grained, carbonaceous and micaceous. Occur in alternate layers.		Occasional very thin coal seams in quartzite. Changed to AX bit at 795.6 ft.
799.1 to 829.3	1⅛	29.3	Quartzite, dark-gray, hard, conglomeratic and some medium-grained. Sandstone, dark-gray, fairly hard, fine-grained, carbonaceous and micaceous. Occur in alternate layers.		Occasional very thin coal seams.
829.3 to 888.3	1⅛	58.8	Quartzite, dark-gray, hard, conglomeratic. Sandstone, dark-gray, fairly hard, fine-grained, carbonaceous and micaceous. Shale, black, medium-hard, highly carbonaceous.		Large inflow of artesian water at 870 ft. Occasional thin coal seams. Slickensides at 881.6 and 882.6 ft. Some fracturing of core at 858.3 to 888.3 ft.
888.3 to 917.6	1⅛	29.3	Quartzite, dark-gray, hard, conglomeratic. Sandstone, dark-gray, fairly hard, fine-grained, quartzitic, with interbedded shale, black, fairly hard, carbonaceous. Occur in alternate layers.		Some fracturing of core.
917.6 to 947.3	1⅛	29.7	Shale, dark-gray, fairly hard, carbonaceous. Sandstone, dark-gray, fairly hard, fine-grained, carbonaceous. Quartzite, dark-gray, hard, conglomeratic. Occur in intermittent layers.		Occasional thin coal seams. Numerous small cavities filled with solution quartz crystals at 917 to 934 ft. Core is well-fractured.
947.3 to 976.7	1⅛	29.4	Sandstone, dark-gray, fairly hard, fine-grained, carbonaceous. Quartzite, dark-gray, hard, conglomeratic, carbonaceous. Sandstone, dark-gray, fairly hard, conglomeratic. Occur in intermittent layers.		Fine-grained sandstone is jointed and slickensided at about 1-ft. intervals at 947 to 959 ft. Solution quartz-filled cavities are frequent at 947 to 965 ft.
976.7 to 1,009.2	1⅛	30.2	Quartzite, dark-gray, hard, conglomeratic. Sandstone, dark-gray, fairly hard, medium-grained, carbonaceous. Shale, black, medium-hard, carbonaceous. Occur in intermittent layers.		Frequent solution quartz-filled cavities. Occasional thin coal seams and slickensides.
1,009.2 to 1,039.3	1⅛	30.0	Sandstone, dark-gray, fairly hard, medium-grained, carbonaceous. Quartzite, dark-gray, hard, conglomeratic, carbonaceous. Occur in alternate layers.		Numerous quartz seams in sandstone. Frequent thin coal seams and slickensides.
1,039.3 to 1,050.1	1⅛	10.7	Sandstone, dark-gray, fairly hard, medium-grained, carbonaceous and quartzitic.		Slickensides and occasional quartz seams.

979425°—52——5

TABLE 11.—*Log of hole 11*

Site: Mahanoy Tunnel Station, Pa.
Surface altitude: 1,259.5 feet
Depth: 1,082 feet

Started: Aug. 3, 1950
Completed: Aug. 24, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 45.0					Seated NX bit; casing to 61 ft.
45.0 to 64.0	2⅛	18.0	Shale, red, soft, silty. Sandstone, brownish-gray, fairly hard, fine-grained, micaceous.	30	Core weathered and fractured, with manganese stains in fractures. With mica and chlorite present, the rock has a schistose nature.
64.0 to 90.8	2⅛	18.5	Sandstone, gray, fairly hard, fine-grained, with 2 ft. of reddish-gray conglomeratic siltstone; light- to dark-brown, poorly consolidated, highly weathered.		Core is badly fractured and weathered, with iron and manganese staining.
90.8 to 110.5	2⅛	19.0	Arkose, gray-red, hard, quartzitic, with interbedded red shale and arkosic breccia.		Some weathering, iron and manganese staining at 90.8 to 100.0 ft.
110.5 to 149.5	2⅛	37.8	110.5 to 115.0 ft., quartzite, gray, hard, medium-grained, arkosic, with occasional quartz banding. 115.0 to 149.5 ft., shale, red, somewhat fissile and somewhat weathered and pitted.		Some of core is highly fractured at 129.7 to 149.5 ft.
149.5 to 168.5	2⅛	18.7	Sandstone, red, fairly hard, fine-grained, micaceous. Shale, red, fairly soft, slightly fissile.		Some fracturing and weathering of core, with chlorite and mica present. 1-in. seam of large quartz and calcite crystals at 167 ft.
168.5 to 188.4	2⅛	18.9	Sandstone, red, fairly hard, fine-grained. Shale, red, soft, fissile.		Sandstone and shale, both fractured and weathered. Some sandstone is very soft. 1-in. seam of quartz and calcite crystals at 170 ft. Quartz-encrusted solution cavities at 173.5, 176, and 188 ft.
188.4 to 304.0	2⅛, 1⅝	114.2	Siltstone, red, hard. Shale, red, fairly hard, slightly fissile. Occur in alternate layers.	40	Dip of bedding at 284 ft. is 40°. Some green siltstone mottling at 265 to 284 ft. Changed to BX bit at 294 ft.
304.0 to 377.5	1⅝	73.0	Shale, red, fairly hard, slightly fissile. Siltstone, red, fairly hard.		
377.5 to 402.0	1⅝	24.5	Sandstone, red, hard, fine-grained. Siltstone, red, fairly hard, with some red fissile shale.		Marcasite-encrusted fracture in sandstone at 399 ft. Calcite-filled slickensides at 379 and 390 ft.
402.0 to 425.8	1⅝	23.8	Sandstone, red, hard, fine-grained, with a small amount of mica and chlorite throughout.		Slickensides at 405, 410, and 415 ft. Solution quartz and calcite at 412 and 417 ft. Quartz and calcite deposit 1 in. thick, very porous, at 424 ft.
425.8 to 450.0	1⅝	24.2	Siltstone, red, hard, red shale particles imbedded at 432 and 440 ft. Shale, red, fairly hard.		3-in. seams of calcite and quartz at 429 and 439 ft.
450.0 to 474.5	1⅝	24.5	Shale, red, fairly hard. Siltstone, red, hard, with some interbedded shale.		Marcasite- and calcite-encrusted fractures at 453 and 456 ft.
474.5 to 524.0	1⅝	49.0	Sandstone, red, hard, fine-grained, micaceous. Siltstone, red, hard, with some thin layers or large particles of red shale.		Slickensides in sandstone at 502.8 ft.
524.0 to 547.0	1⅝	23.0	Sandstone, red, hard, fine-grained, micaceous. Siltstone, red, hard. Shale, red, fairly hard. Occur in intermittent layers.	30	Cross bedding at 525 to 529 ft.
547.0 to 598.5	1⅝	49.5	Sandstone, red, hard, fine-grained, with interbedded shale, red, soft, fissile.		1-in. calcite seam at 565 ft. Some fracturing at 547 to 572 ft.
598.5 to 621.5	1⅝	23.0	Sandstone, red, hard, fine-grained, micaceous. Siltstone, red, fairly hard. Shale, red, soft. Occur in intermittent layers.		Shale weak, with 1-in. calcite seam at 600 ft. Some fracturing.
621.5 to 645.0	1⅝	23.5	Sandstone, red, hard, fine-grained, micaceous. Siltstone, red, soft. Occur in alternate layers.		Slickensides at 631.5 ft. 1-in. calcite seam at 631.5 ft. Some fracturing.
645.0 to 669.0	1⅝	24.0	Siltstone, red, fairly hard. Shale, red, fairly hard, slightly fissile.		Some fracturing.
669.0 to 718.0	1⅝	43.8	Sandstone, red, hard, fine-grained, micaceous, with interbedded shale, red, fairly hard.		693 to 718 ft., shale, green-mottled. Slickensides at 695.5 ft.
718.0 to 742.0	1⅝	24.0	Shale, red, fairly hard. Siltstone, red, fairly hard. Occur in alternate layers.		Jointed at 740 and 741 ft.
742.0 to 767.0	1⅝	24.6	Sandstone, red, hard, fine-grained, micaceous. Siltstone, red, fairly hard. Shale, red, fairly hard. Occur in intermittent layers.		
767.0 to 790.0	1⅝, 1⅛	23.0	Sandstone, red, hard, fine-grained, micaceous. Shale, red, fairly soft, slightly weathered.		Changed to AX bit at 789 ft. ½ in. calcite seam at 768.5 ft. Numerous calcite stringers at 782 and 789 ft., some highly weathered.
790.0 to 878.0	1⅛	87.5	Sandstone, red, hard, fine-grained, micaceous. Siltstone, red, fairly hard. Shale, red, fairly hard. Occur in intermittent layers.		Several quartz and calcite seams ½ to 1 in. at 790 to 819 ft. Slickensides at 814 and 819 to 848 ft., a few calcite stringers and green mottling. Joints at 864 and 878 ft.
878.0 to 907.2	1⅛	29.2	Sandstone, red, hard, fine-grained, micaceous. Shale, red, fairly hard.	30	Some green mottling in the sandstone, with angular fragments of shale edgewise.
907.2 to 1,083.6	1⅛	175.3	Sandstone, red, hard, fine-grained. Siltstone, red, fairly hard. Shale, red, fairly hard. Occur in intermittent layers.		Very good recovery of core. Some green mottling in the sandstone, with angular fragments of shale edgewise. Slickensides at 991, 1,063, and 1,072.5 ft.

TABLE 12.—*Log of hole 12*

Site: Sheppton, Pa.
Surface altitude: 1,150.9 feet
Depth: 966 feet

Started: July 5, 1950
Completed: July 29, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 30.0	2⅛		Overburden, composed of boulders, gravel, and sand.		Seated NX bit; casing to 135 ft.
30.0 to 46.0	2⅛	3.0	Conglomerate, light-gray and brown quartz	Flat	Fractured and weathered.
46.0 to 71.3	2⅛	15.0	Siltstone, dark-red, fairly hard, arenaceous and micaceous.	do	Fractured and weathered. Manganese stains.
71.3 to 92.7	2⅛	19.0	Shale, red, soft, fissile. Siltstone, red, fairly hard, arenaceous and micaceous.	do	Highly weathered at 82.2 to 85.0 ft.
92.7 to 112.7	2⅛	19.8	Siltstone, red, hard, arenaceous. Sandstone, red, hard, fine-grained, interbedded with red shale. Some weathering at 95 to 96 ft.	do	
112.7 to 116.0	2⅛	3.3	Sandstone, red, hard, fine-grained	do	
116.0 to 131.1	2⅛	15.1	Shale, red, fairly hard, fissile, with some slightly silty, pitted shale.	do	Mottled by streaks and blotches of green shale.
131.1 to 150.0	2⅛, 1⅝	18.9	Shale, red, hard, slightly silty, some green mottling.	do	Changed to BX bit at 135 ft.
150.0 to 156.0	1⅝	6.0	Shale, red, hard	do	
156.0 to 170.0	1⅝	14.0	Siltstone, red, hard. Sandstone, red, hard, fine-grained, conglomeratic.	do	Edgewise conglomerate at 164 to 170 ft.
170.0 to 194.0	1⅝	23.8	Shale, red. Siltstone, red, shaly. Sandstone, red, fine-grained. Some green mottling.	do	
194.0 to 217.0	1⅝	22.9	Shale, red, hard. Siltstone, red, hard, micaceous. Occur in alternate layers.	do	Seams at 204 and 214 ft. filled with white crystalline carbonates.
217.0 to 290.4	1⅝	72.7	Shale, red, hard. Siltstone, red, hard, micaceous at 217 to 224 ft. Occur in alternate layers.	do	Green mottling.
290.4 to 461.0	1⅝	168.8	Shale, red, fairly hard, fissile. Siltstone, red, hard, in some places micaceous.	do	Aragonite vein filling at 305 ft. Rock gives varied appearance (laminae). Green mottling at 364 to 388 ft. Carbonate seam at 409 ft. Green mottling at 437 to 461 ft.
461.0 to 510.0	1⅝	48.2	Shale, red, somewhat fissile. Siltstone, red, fairly hard, micaceous. Sandstone, red, hard, fine-grained, micaceous. Occur in intermittent layers.	do	Some green mottling. Shale well-fractured at 492 and 497 ft.
510.0 to 607.6	1⅝	96.0	Shale, red, hard and fairly hard, some fissile. Siltstone, red, fairly hard, micaceous, arenaceous. Some green sandstone at 584 to 607 ft.	do	Some green mottling, at 534 to 583 ft.
607.6 to 632.0	1⅝	23.6	Shale, red, fairly hard. Siltstone, red, fairly hard, micaceous. Sandstone, red, hard, fine-grained, arenaceous, brecciated and conglomeratic.	do	Some green sandstone and evidence as shown by particles of breccia being edgewise.
632.0 to 730.4	1⅝	98.0	Sandstone, red, hard, fine-grained. Shale, red, fairly hard. Occur in alternate layers.	do	Thin calcite seam, weak at 671.6 ft. Slickensides at 707.5 ft.
730.4 to 755.0	1⅝	24.4	Sandstone, red, hard, fine-grained. Siltstone, red, fairly hard. Shale, red, easily fractured, somewhat fissile. Occur in intermittent layers.	do	
755.0 to 834.0	1⅝, 1⅛	78.4	Siltstone, red, hard, and fairly hard, some micaceous. Shale, red, fairly hard. Occur in alternate layers.	do	Red shale has large amount of green shale interbedded. Changed to AX bit at 782 ft.
834.0 to 863.0	1⅛	29.0	Siltstone, red, hard, micaceous. Sandstone, red, hard, banded, fine-grained. Shale, red.	do	Slickensides at 854 ft. Shale, mottled-green.
863.0 to 966.0	1⅛	101.4	Siltstone, red, fairly hard, micaceous. Shale red. Occur in alternate layers.	do	Conglomerate composed of siltstone and shale particles at 885 to 887 ft. Green-mottled slickensides in shale at 903 ft. Slickensides in siltstone at 920.8 ft.

TABLE 13.—*Log of hole 13*

Site: Sybertsville, Pa.
Surface altitude: 898.7 feet
Depth: 702 feet

Started: July 3, 1950
Completed: July 18, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 9.0			Overburden, composed of small boulders and clay.		Fishtailed to 12.0 ft.
9.0 to 12.0		0.0	Shale, red, soft, weathered		Seated NX bit; casing to 12.0 ft.
12.0 to 29.0	2⅛	15.5	Siltstone, red, poorly consolidated. Shale, red, poorly consolidated.	Flat	Rock highly weathered. Limonite and manganese staining in fractures.
29.0 to 48.0	2⅛	18.0	Siltstone, red, loosely consolidated, arenaceous. Shale, red, highly weathered.	do	Fractures filled with quartz in siltstone. Cross bedding at 33.0 to 34.0 ft. Manganese staining in fractures.
48.0 to 61.0	2⅛	12.4	Sandstone, gray and red, fine-grained, loosely consolidated.	do	Fractures with manganese staining. Some pieces of core highly fractured.
61.0 to 64.0	2⅛	2.6	Shale, red, soft, fissile	do	
64.0 to 68.0	2⅛	4.0	Sandstone, reddish-gray, fairly hard, fine-grained, quartzitic.	do	
68.0 to 75.0	2⅛	7.0	Quartzite, gray and red, hard, fine-grained	do	
75.0 to 78.0	2⅛	2.8	Sandstone, very light red, loosely consolidated, medium-grained, quartzitic.	do	
78.0 to 86.0	2⅛	7.7	Shale, light-brown, muddy, soft, incompetent	do	
86.0 to 97.5	2⅛	11.5	Sandstone, red, fairly well consolidated, fine-grained.	do	
97.5 to 106.0	2⅛	8.3	Shale, red, fairly hard, silty	do	Mottled green shale, very soft, pitted (weathered), at 103.0 ft.

TABLE 13.—*Log of hole 13*—Continued

Site: Sybertsville, Pa.
Surface altitude: 898.7 feet
Depth: 702 feet

Started: July 3, 1950
Completed: July 18, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
106.0 to 124.0	2⅛	17.8	Sandstone, dark-gray, well-consolidated, quartzitic, medium-grained. Sandstone, dark-gray, poorly consolidated, shaly and quartzitic, medium-grained. Occur in alternate layers.	Low	Shale particles appear as pebbles and form irregular pattern.
124.0 to 129.0	2⅛	5.0	Quartzite, hard, gray and red, conglomeratic	do	
129.0 to 143.0	2⅛	14.0	Siltstone, red, hard, fine-grained, arenaceous	do	
143.0 to 156.2	2⅛	13.2	Sandstone, red, hard, fine-grained, micaceous and quartzitic.	do	Muscovite variety of mica.
156.2 to 162.0	2⅛	5.8	Shale, red, hard	do	Shale, somewhat conglomeratic and fractured.
162.0 to 182.0	2⅛	19.9	Shale, red, hard, silty	do	Mottled by streaks or layers of green shale.
182.0 to 200.9	2⅛	18.8	Shale, red, hard. Siltstone, red, hard, interbedded.	do	Mottled by green shale; weathered fractures present.
200.9 to 220.0	2⅛	19.0	Shale, red, moderately soft	do	Mottled by interbedded green shale.
220.0 to 237.0	2⅛	17.0	Shale, red, fairly hard	do	Mottled by green shale.
237.0 to 239.0	2⅛	2.0	Siltstone, red, fairly hard	do	
239.0 to 251.0	2⅛	11.8	Shale, blue-gray, hard	do	Rock changes color from red to blue-gray at 240.0 ft.
251.0 to 253.0	2⅛	1.9	Shale, light-brown, soft	do	
253.0 to 270.0	2⅛	17.0	Sandstone, dark-gray, hard, medium-grained, micaceous and quartzitic.	do	Some scattered pyrite crystals at 260 to 270 ft.
270.0 to 273.0	2⅛	2.5	Shale, dark-gray, soft and friable, micaceous, weathered.	do	
273.0 to 277.0	2⅛	4.0	Sandstone, dark-gray, hard, medium-grained, micaceous.	do	
277.0 to 290.0	2⅛	12.4	Sandstone, dark-gray, hard, fine-grained	do	Jointed at 285 to 286 ft. Pyrite crystals. Crustings of black, vitreous, carbonaceous material.
290.0 to 296.8	2⅛	6.0	Quartzite, light-gray, hard, medium-grained, conglomeratic.	do	
296.8 to 334.8	2⅛, 1⅝	37.9	Quartzite, gray, very hard, medium-grained, conglomeratic.	do	Encountered inflow of water at 300 ft. Changed to BX bit at 314 ft. Loosely consolidated at 326 to 329 ft.
334.8 to 337.2	1⅝	2.1	Shale (argillite), black, hard	do	
337.2 to 360.8	1⅝	22.5	Shale (argillite), hard, blue-gray	do	Very hard, chertlike material. Can be scratched with knife.
360.8 to 407.8	1⅝	47.0	Quartzite, dark-gray, very hard, medium-grained, micaceous.	do	Muscovite mica present.
407.8 to 414.0	1⅝	6.1	Shale (argillite), black, hard, arenaceous	do	
414.0 to 442.4	1⅝	28.4	Quartzite, gray and dark-gray, hard, micaceous	do	1-in. pyrite and coal seam at 426.1 ft.
442.4 to 455.0	1⅝	12.5	Shale (argillite), black, very hard	do	Shale contains large amounts of mica particles and some minute coal seams.
455.0 to 503.6	1⅝	48.4	Sandstone, dark-gray, fine-grained, micaceous. Quartzite, light-gray, hard, medium-grained. Occur in alternate layers.	do	Interbedded thin black shale and pyrite seams in the quartzite.
503.6 to 537.0	1⅝	33.0	Quartzite, bands of light- and dark-gray, micaceous.	do	Bands, thin black shale, coal, and pyrite. Solution quartz and sphalerite crystals at 527 and 528 ft.
537.0 to 551.6	1⅝	13.9	Quartzite, light-gray, hard	do	Black shale fragments and pyrite scattered in the quartzite.
551.6 to 575.6	1⅝	24.4	Quartzite, light-gray, hard, medium-grained, with thin black shale seams. Sandstone, dark-gray, hard, fine-grained. Occur in alternate layers.	do	Occasional small concentrations of pyrite crystals. 1-in. anthracite seam at 571 ft.
575.6 to 599.9	1⅝	24.3	Sandstone, dark-gray, hard, fine-grained, micaceous. Quartzite, light-gray, very hard.	do	Occasional seam of coal ¼ in. thick. Pyrite concentrations and coal seams slickensided. Lost water at 590 ft. 1-in. soft carbonaceous shale layer at 596 ft.
599.9 to 623.5	1⅝	23.5	Sandstone, dark-gray, fine-grained, micaceous. Quartzite, light- to dark-gray, hard, medium-grained, with some conglomeratic members. Occur in alternate layers.	do	Occasional ½- to 1-in. coal and black shale seams.
623.5 to 633.5	1⅝	10.0	Quartzite, dark, hard, medium-grained. Sandstone, light-gray, fine-grained, micaceous.	do	Occasional thin coal seams.
633.5 to 647.0	1⅝	13.5	Quartzite, very hard, conglomeratic, with some black shale seams.	do	Quartz pebbles in conglomeratic members up to 20+ mm.
647.0 to 671.5	1⅝	24.5	Sandstone, dark-gray, hard, fine-grained, micaceous. Quartzite, light- to dark-gray, hard, medium-grained, conglomeratic. Occur in alternate layers.	do	Interbedded black shale and coal seams.
671.5 to 680.0	1⅝	8.5	Quartzite, light- to dark-gray, very hard, medium-grained, conglomeratic.	do	Intermittent ½-in. coal seams.
680.0 to 694.0	1⅝	14.0	Quartzite, light- to dark-gray, hard, medium-grained, conglomeratic.	do	Numerous anthracite seams ½ to 1 in. thick; concentrations of pyrite. Rock weak in vicinity of coal seams.
694.0 to 703.6	1⅝	9.6	Quartzite, light- to dark-gray, hard, medium-grained, conglomeratic. Shale, black, fairly hard. Sandstone, dark-gray, fairly hard. Occur in intermittent layers.	do	Several ½-in. coal seams. Water encountered again near bottom of hole; when drilling ceased, water stood within 10 in. of collar of hole.

Table 14.—*Log of hole 14*

Site: Wapwallopen, Pa.
Surface altitude: 600.5 feet
Depth: 397 feet

Started: June 19, 1950
Completed: June 28, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 54.0			Overburden, composed of boulders, cobble, and gravel.		Seated NX bit; casing to 54.0 ft.
54.0 to 64.0	2⅛	7.3	Shale, black, hard, carbonaceous	Flat	Weathered rock, iron oxide staining, at 54 to 58 ft.
64.0 to 67.5	2⅛	3.5	Siltstone, grayish-black, hard	do	
67.5 to 72.0	2⅛	4.2	Shale, black, hard, carbonaceous	do	
72.0 to 91.1	2⅛	19.0	Shale, balck, hard, carbonaceous. Siltstone, grayish-black, hard, arenaceous. Occur in alternate layers.	do	
91.1 to 202.0	2⅛	109.9	Shale, black, hard, carbonaceous	do	Marcasite seam ½ in. wide at 98 ft. Pyrite- and carbonate-filled seam at 168 ft. Lost water at 188 ft. Core slightly weathered at 190 and 195 ft. Large cluster of carbonate crystals ½ in. thick at 196.5 ft.
202.0 to 397.0	2⅛	194.3	Shale, black, hard, carbonaceous	do	Fossiliferous at 287 to 332 ft. Filled seam of aragonite and pyrite crystals at 332 ft.

Table 15.—*Log of hole 15*

Site: Glen Lyon, Pa.
Surface altitude: 962.1 feet
Depth: 752 feet

Started: June 12, 1950
Completed: July 1, 1950

Interval, feet	Core size, inches	Recovery, feet	Lithology	Dip of bedding, degrees	Remarks
0.0 to 1.5			Mantle		
1.5 to 7.0	2⅛	4.9	Siltstone, red, massive	90	Seated NX bit; casing to 4.5 ft.
7.0 to 16.1	2⅛	8.0	Sandstone, red, fine-grained, manganese-stained at 7.5 ft.		
16.1 to 160.0	2⅛	142.4	Shale, red, fairly hard, slightly silty, occasional carbonate seams, some interbedded green siltstone.	90	Lost water at 20.6 ft. Calcite-filled slickensides at 82.0 ft.
160.0 to 189.5	2⅛	28.8	Shale, hard, red, fissile, slightly silty, some interbedded green siltstone.	85	Carbonate-filled fractures at 173 ft.
189.5 to 230.0	2⅛	40.1	Sandstone, hard, red, fine-grained, iron-stained joints at 196.5 and 204.5 ft., some green sandstone.		Jointed at 0.2- to 0.7-ft. intervals at 208 to 215 ft. Calcite-filled slickensides at 230 ft.
230.0 to 300.1	2⅛	69.8	Shale, hard, fissile, red, with interbedded red siltstone, some thin green siltstone layers. Considerable jointing at irregular intervals in siltstone.	85	Small pyrite crystals in joint at 264 ft. Frequent occurrences of calcite-filled slickensides.
300.1 to 409.7	2⅛	109.4	Sandstone, hard, red, fine-grained, with carbonate-encrusted joints at irregular intervals. Frequent thin, white carbonate seams occasionally associated with pyrite.	80	Calcite-filled slickensides at 310, 320 and 352 ft. Small mudstone seams at 408 to 409.7 ft.
409.7 to 434.0	2⅛	24.3	Sandstone, hard, red, medium-grained, with small visible quartz grains.	80	Thin mudstone seams at 411 and 412 ft. Pyrite-encrusted slickensides at 419 and 421 ft.
434.0 to 515.0	2⅛	79.8	Shale, fairly hard, fissile, red, arenaceous, with interbedded siltstone.	75	Slickensides at 492 ft. Slickensides and jointing at 485 to 486 ft.
515.0 to 554.4	2⅛	39.4	Sandstone, hard, red, fine-grained		Highly polished slickensides with calcite fillings at 532 and 545 ft.
554.4 to 634.3	2⅛	78.7	Shale, fairly hard, red, silty, with interbedded red siltstone, mottled by frequent seams of green siltstone.	70	Friable shale at 560 to 561 ft. and at 572 to 576 ft. Carbonate-filled slickensides at 592, 602, and 624 ft.
634.3 to 649.3	2⅛	15.0	Sandstone, hard, red, medium-grained, laminated, with red, arenaceous siltstone and red, fissile shale.	70	
649.3 to 752.0	1⅝	101.5	Siltstone, hard, red, laminated, with silty, somewhat fissile shale, mottled by thin seams of green siltstone.	65	Changed to BX bit at 649.3 ft. Dip of bedding, 55° at 752 ft.

DIAMOND-DRILL CORE ANALYSIS

A comprehensive study was made of the cores recovered from each of the 15 holes so that contracting firms would have a better understanding of the geologic and petrographic qualities of the subsurface strata.

Mineral hardness was determined by the standard Mohs' scale of hardness; this information enables a contractor to compute approximate drilling speeds and mucking time. Determinations of free silica were made so that an average percentage of silica is known for each type of rock; a contractor can therefore remove the dust hazard and prevent occupational disease from harmful dust.

The cores, totaling 8,907 feet in length, are stored at the Anthracite Institute, Wilkes-Barre, Pa.

PROCEDURE USED FOR EXAMINING CORES

The following procedure was employed for determining the physical and other pertinent qualities of the cores:

1. The core was removed from the box and examined megascopically with a hand lens, a constant check being made against the original borehole log.
2. A representative sample 2 to 3 inches long was selected for each type of rock or formation recovered from the drill hole.
3. The samples from each drill hole were taken to the laboratory and tested for hardness by using Mohs' hardness-test minerals.
4. If any of the cores appeared to contain calcitic minerals, as revealed either by color or by hardness, they were then tested with dilute hydrochloric acid.
5. A representative sample was tested for silica content by cutting some material from the core with a diamond scriber. The cuttings were deposited on a MSA cell. This cutting method of removing material is similar to channel sampling and gave a representative sample of the material tested. The material ranged from 10 to 20 microns in size. It is then immersed in oil of cloves, which has a refractive index of 1.53, very close to that of quartz (silica). Microscopic examination at a magnification of 200 diameters is then employed in conjunction with a polarizing attachment. The quartz (silica) content of each of several fields is determined, from which an average percentage of silica is estimated.

Figures 34 to 48 give a condensed graphic and verbal description of the rock encountered in each borehole, the percentage of silica, and the degree of hardness.

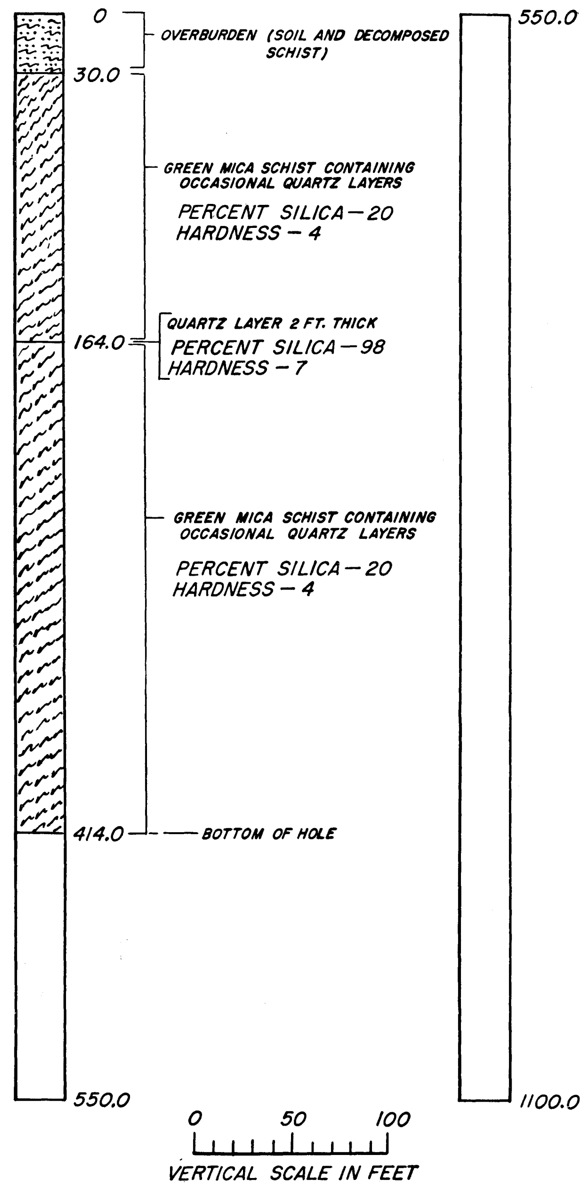

FIGURE 34.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 1.

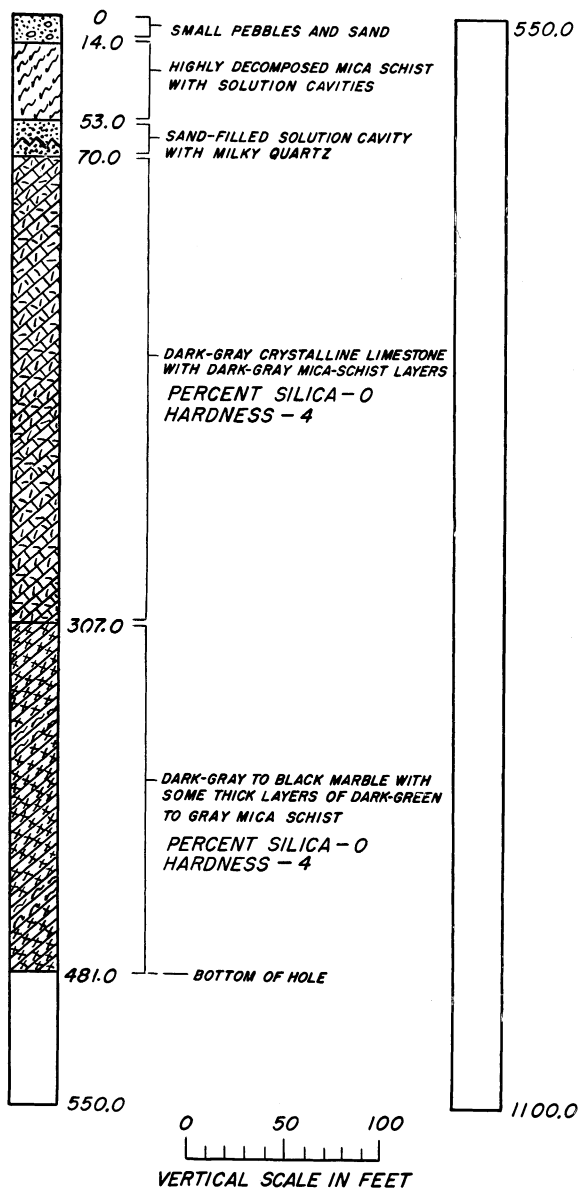

FIGURE 35.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 2.

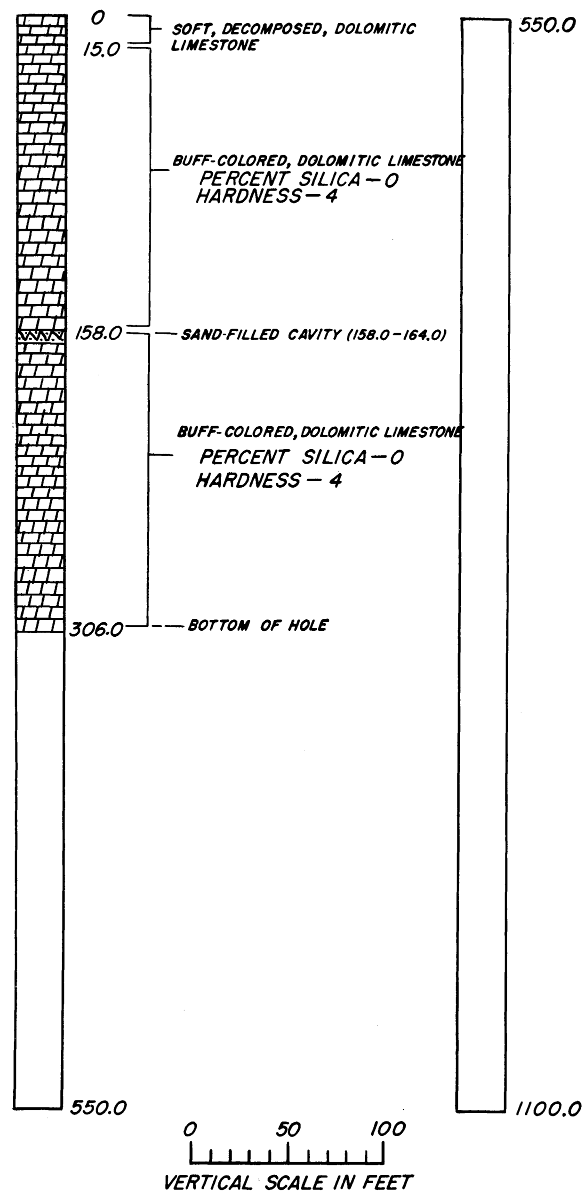

FIGURE 36.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 3.

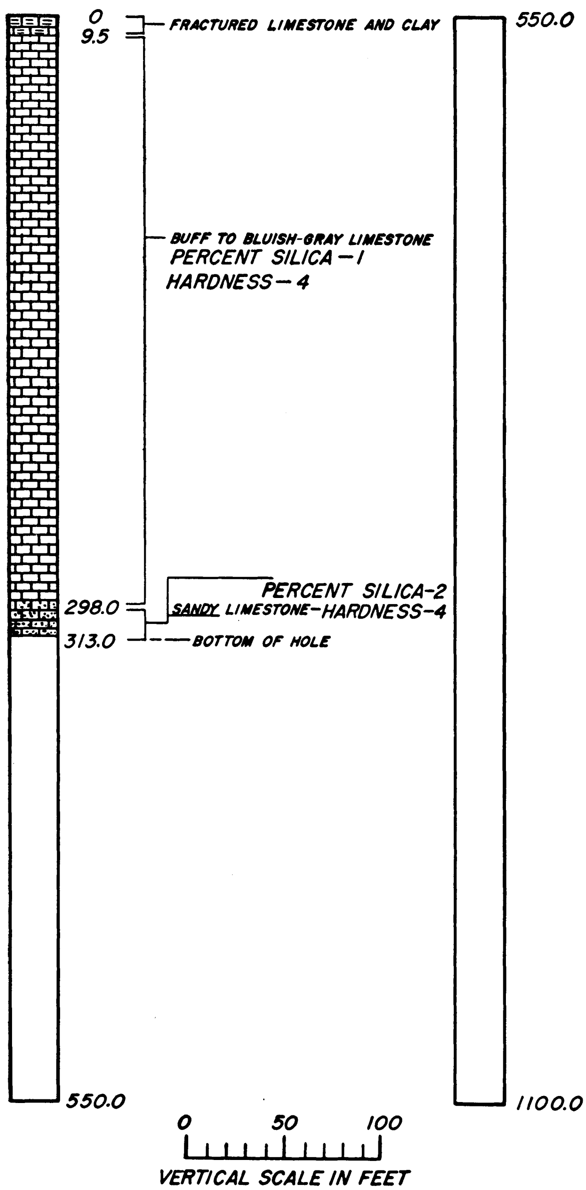

FIGURE 37.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 4.

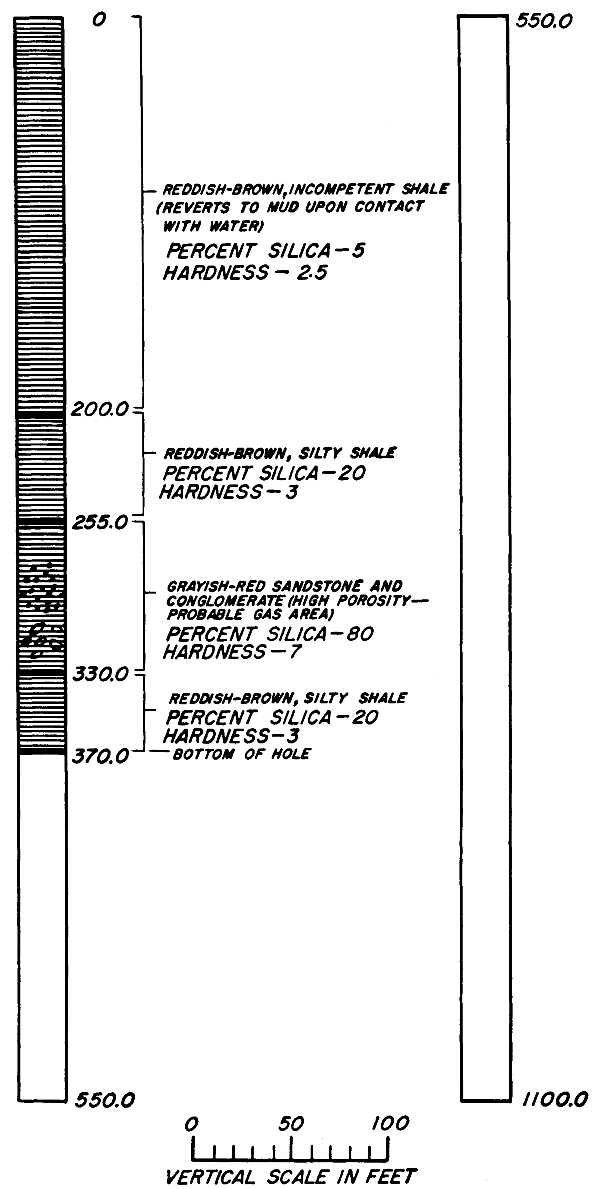

FIGURE 38.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 5.

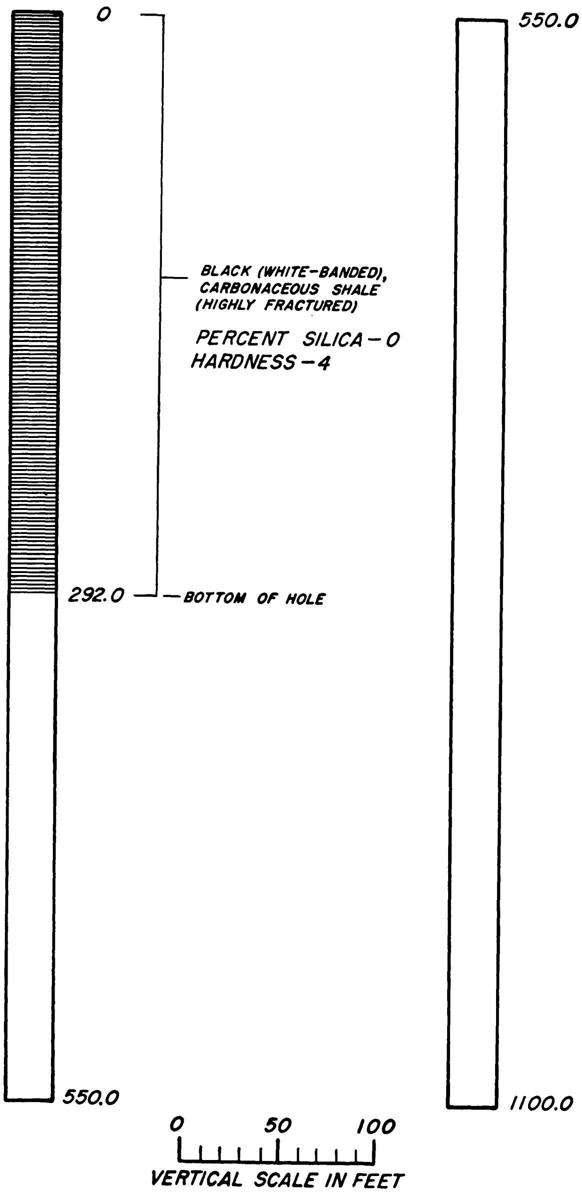

FIGURE 39.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 6.

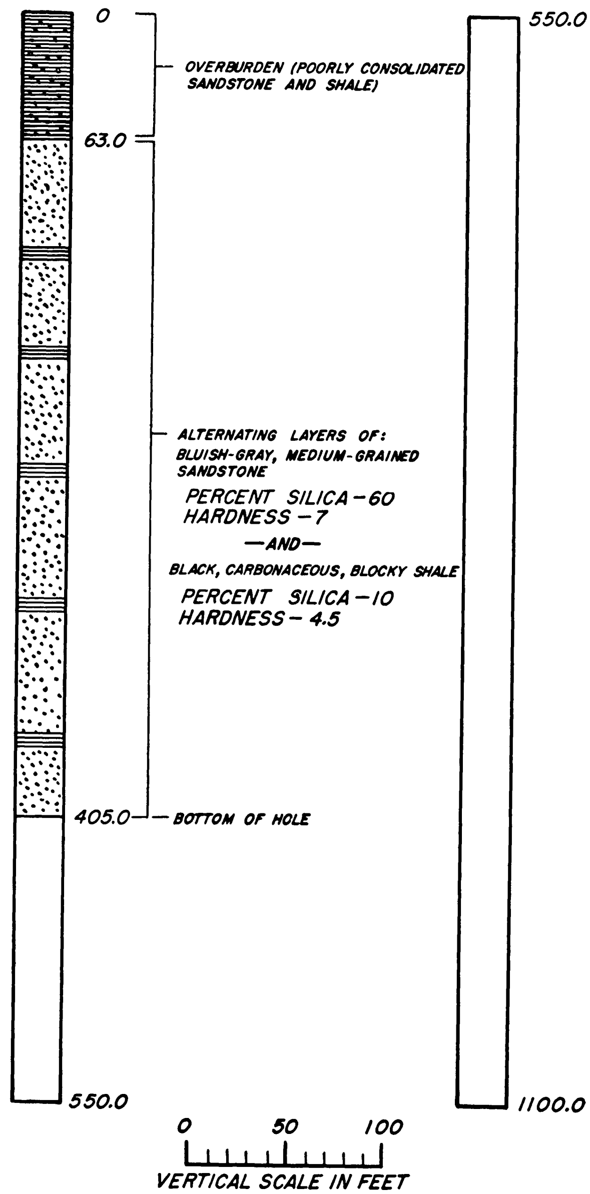

FIGURE 40.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 7.

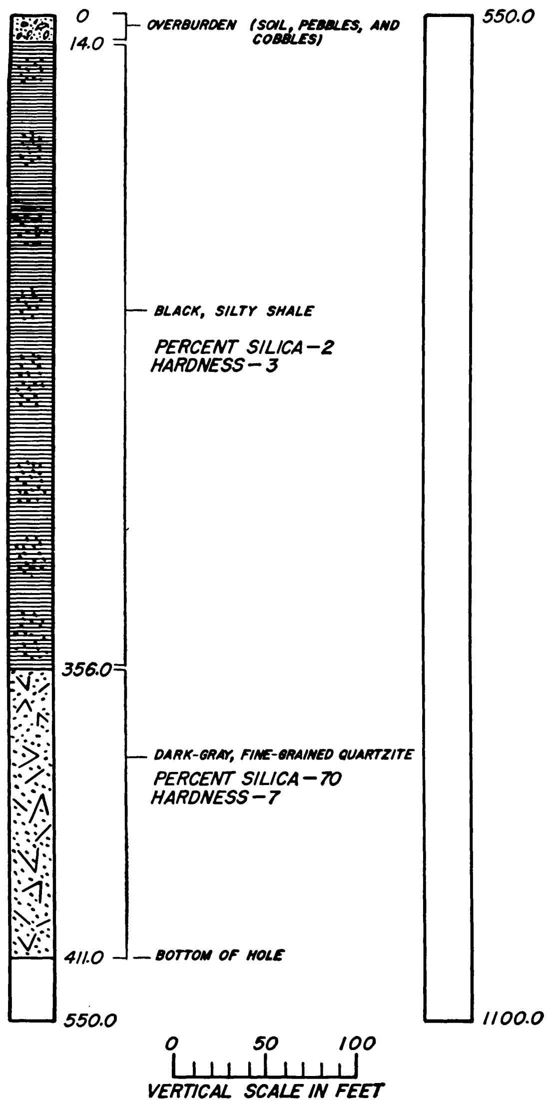

FIGURE 41.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 8.

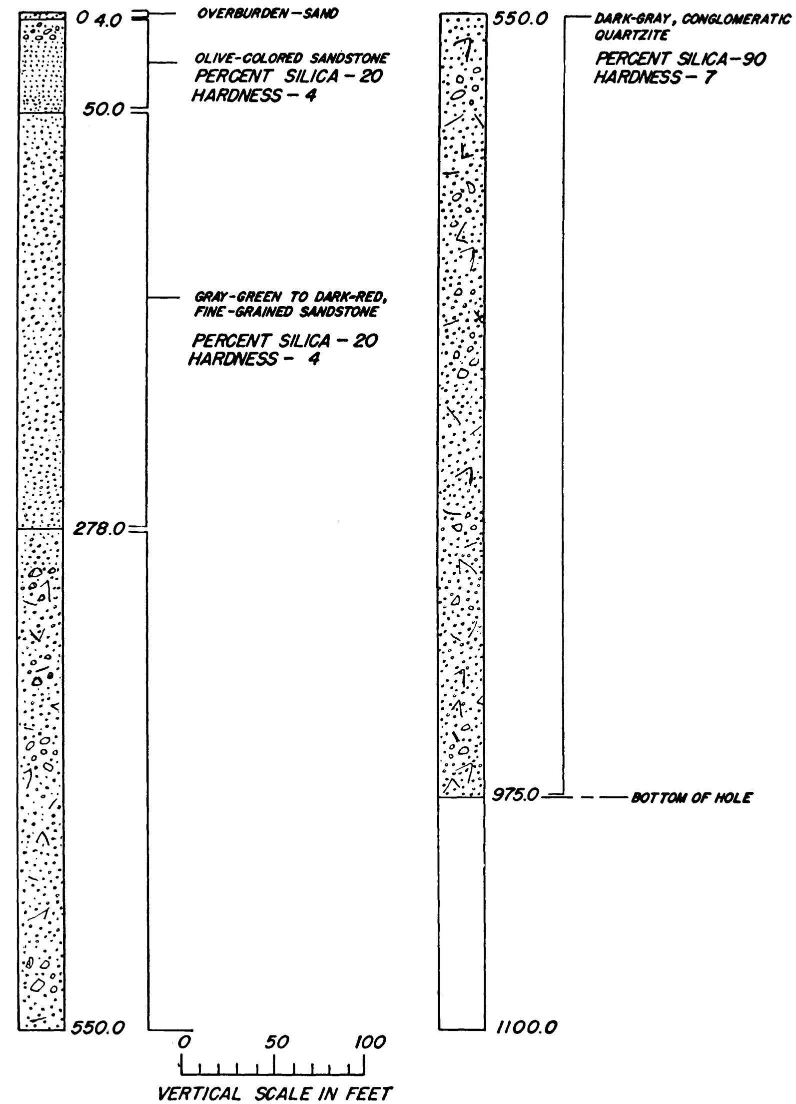

FIGURE 42.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 9.

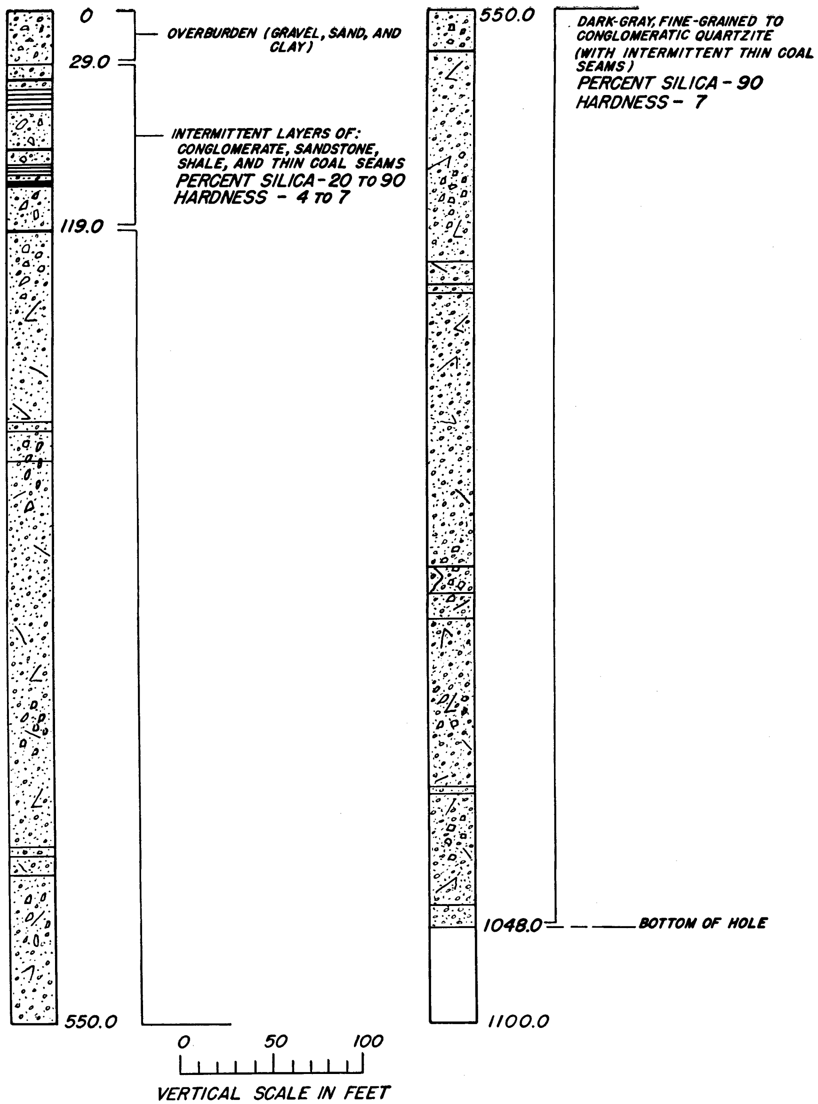

FIGURE 43.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 10.

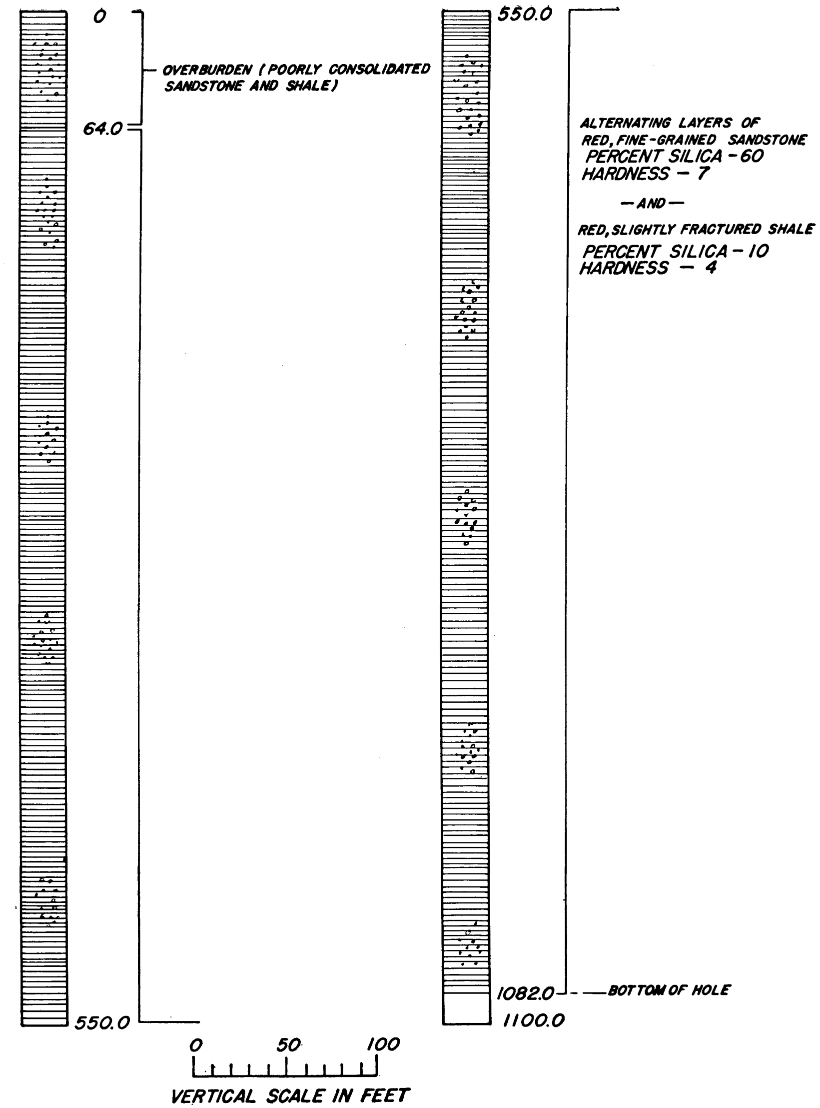

FIGURE 44.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 11.

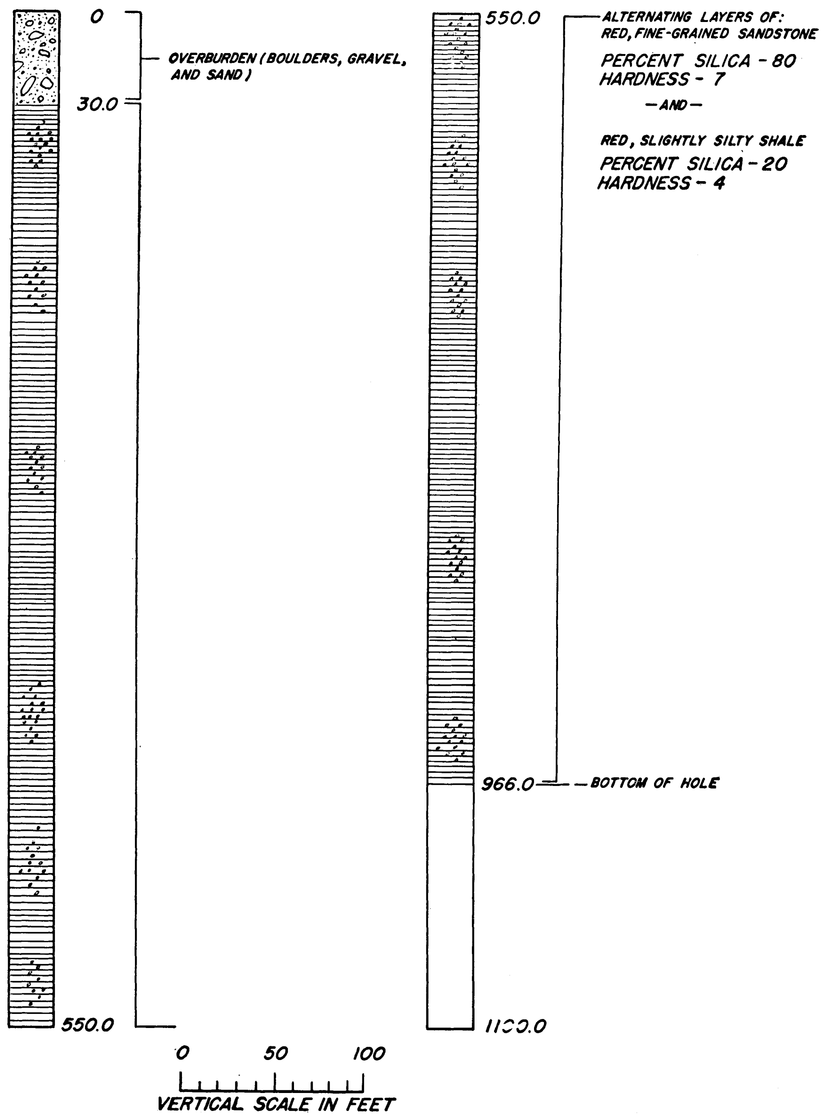

FIGURE 45.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 12.

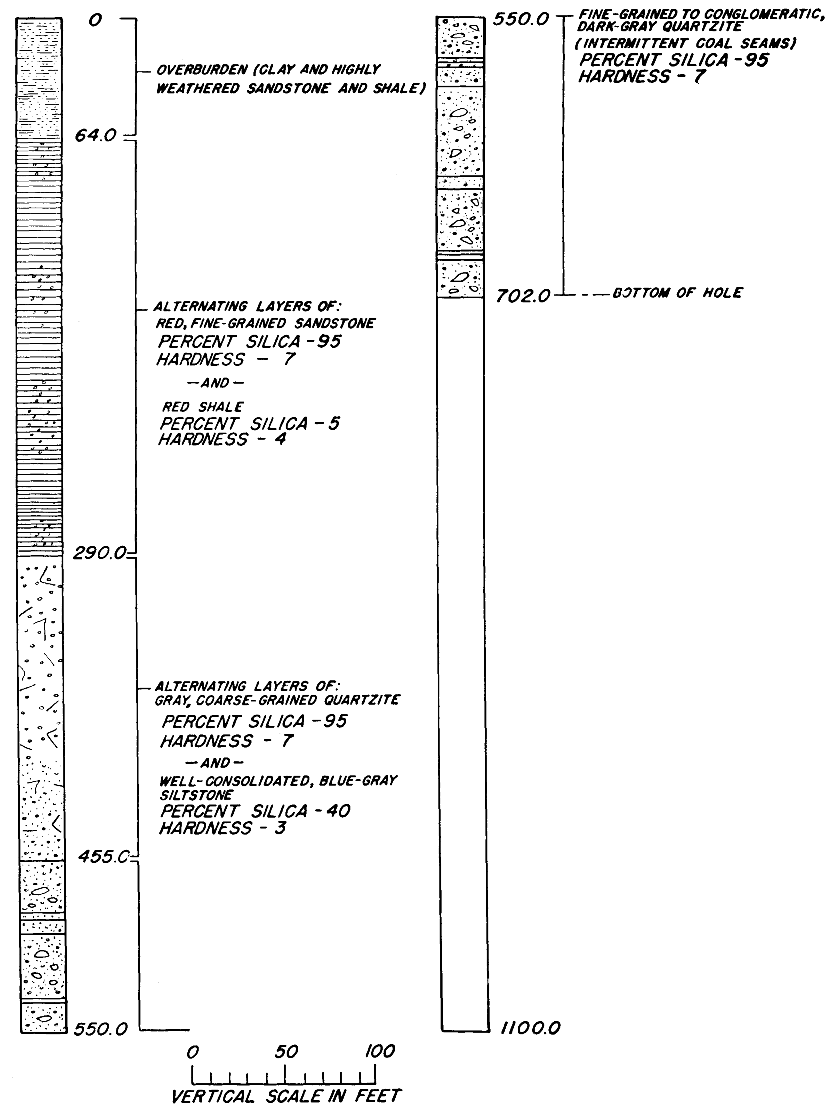

FIGURE 46.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 13.

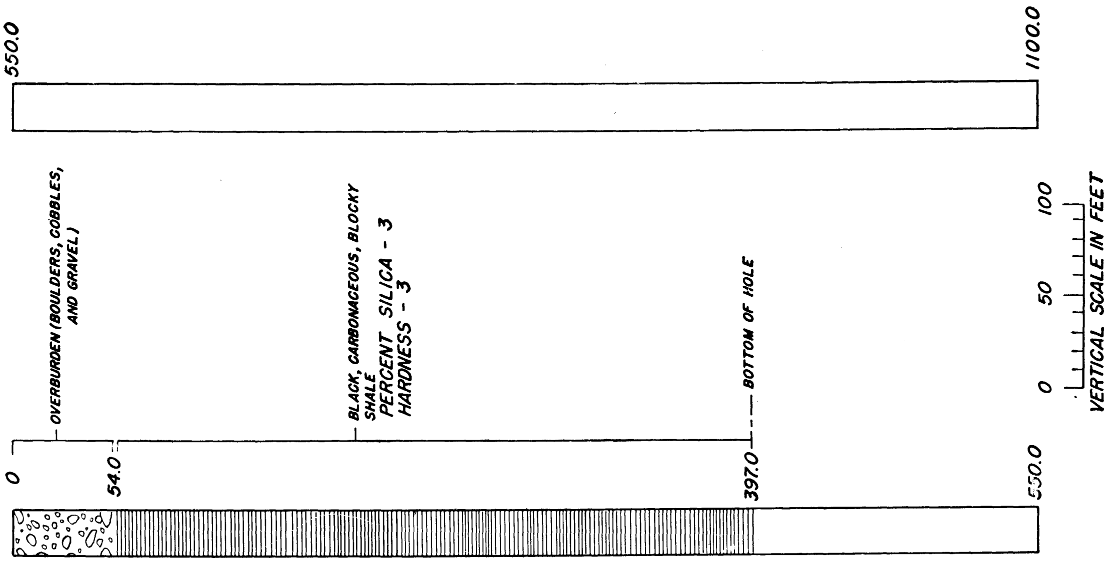

FIGURE 47.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 14.

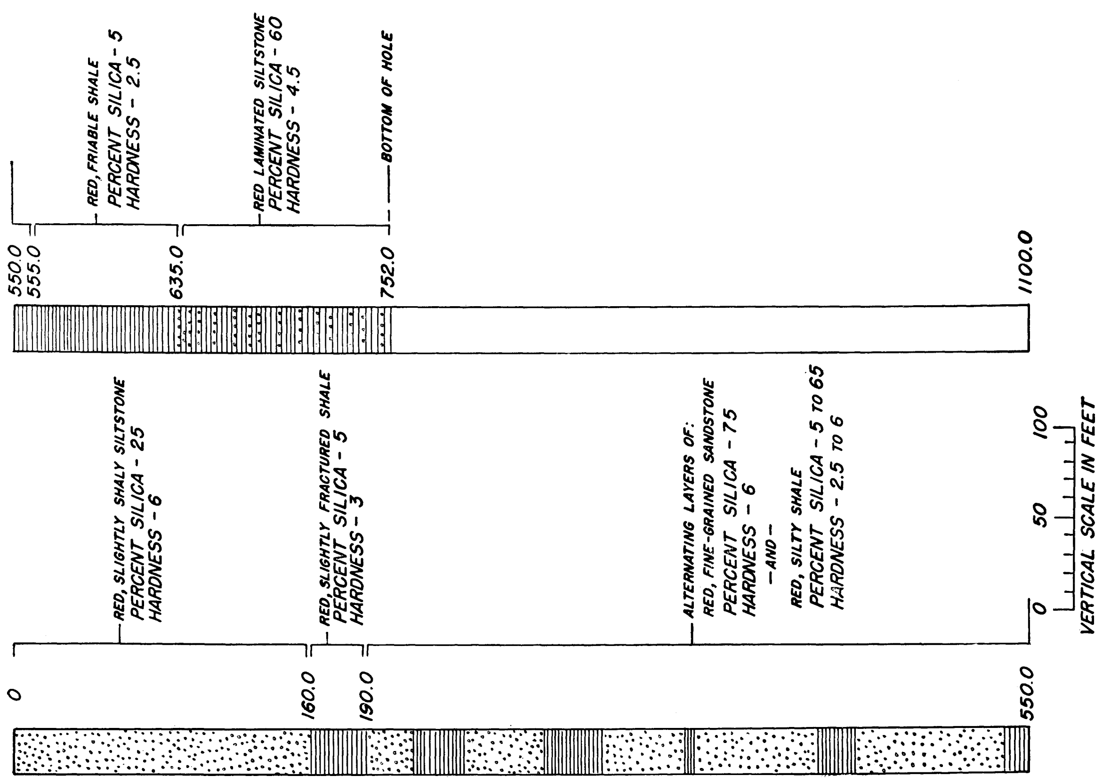

FIGURE 48.—GRAPHIC LOG SHOWING HARDNESS AND SILICA CONTENT, HOLE 15.

ARTESIAN WATER FLOWS

The largest artesian water flow was found in hole 10, which is located 1½ miles from Brockton, Pa., on the land of the Blythe Township Water Authority.

Most of the drilling in this hole was through hard conglomeratic quartzite; this required frequent replacement of the diamond-drill bits. There was an artesian flow of water of 40 to 50 gallons per minute when the drilling reached 870 feet. A check valve was installed in the rod above the core barrel to prevent water spouting when pulling the rods.

The reservoir of the Blythe Township Water Authority is 200 feet from hole 10, the collar of which is several feet higher than the normal water level of the reservoir. While hole 10 was being drilled, the water level of the reservoir was below normal because of dry weather. Upon completion of the hole, the engineers of the water authority piped the water overflowing from the borehole to the reservoir, thus increasing the water supply. The water from hole 10 was tested by the water-authority engineers and found to have a pH of 6.2.

An artesian flow of water was encountered in hole 8, which is located one-half mile east of Auburn, Pa. The water flow was 10 to 15 gallons per minute when it was first detected at a depth of 398 feet in a hard, fine-grained sandstone. This sandstone is overlain almost entirely by a black, silty shale. The water was fit for drinking and was being used by the local rural inhabitants as a supplementary water supply.

WATER FOR DRILLING

Water was readily available for drilling purposes in small and large streams 25 to 1,500 feet from the drilling sites for all holes except holes 1 and 4. Drilling water had to be hauled by truck to these holes.

Ten oil drums (capacity, 55 gallons) were hauled by a truck that made two round trips from the drill to a stream situated more than a mile away during each 8-hour drilling shift. The water was pumped from the stream into the drums by a small gasoline-powered pump. After being transported to the drill site, the water was stored for use in a sump 6 feet square and 4 feet deep, 20 feet from the drill. A small amount of cement was applied to the sides of the sump to prevent leakage. When the holes were completed, the storage sumps were filled with dirt.

HOLE PLUGGING FOR WATER RETURN

As the drilling operations at hole 13 neared completion, a shortage of water was noted at a spring near the hole. This spring was used for watering cattle and ceased flowing shortly after the hole was completed.

It was noted during the drilling of hole 13 that the water flow at the 300-foot depth was lost when the hole was 590 feet deep.

To cause the water to flow at the spring, a tapered wooden wedge was inserted in the hole at a point 314 feet from the collar (at this depth the drill size was reduced from bit NX to bit BX). A 350-foot length of wire rope having a 5-foot section of BX drill rod fastened to its end was mounted on a reel and used to tamp the wooden plug in place. Four 30-inch cement cartridges (2 inches in diameter) were then placed above the wooden plug and tamped with the BX drill rod. After tamping, the cement column extended 6 feet above the wooden plug. Approximately 30 seconds after the wooden plug was in place, water began overflowing from the drivepipe. The drivepipe was then capped, and within a relatively short time the spring began to flow.

After leaving the drivepipe capped overnight, the water flow of the spring returned to normal. The cap was removed from the drivepipe, and the water again overflowed as it had immediately after the plugging operation. One 12-inch and two 24-inch cement cartridges were then dropped into the hole and tamped as a safety measure to insure proper sealing of the hole and to prevent further leakage.

DRILLING COSTS

The contract for drilling was based on bids submitted by the contractor before work was begun. These bids provided for a sliding scale based on size of bit used and a fixed price per foot of casing placed in each hole.

As shown in table 16, three sizes of bits were used, and 275.5 feet of casing was placed in the drilling of 8,907 feet of holes. The total cost of drilling was $34,062.15, based on the following contract prices:

	Drilling cost
3,750 feet NX size at $3. 95 per foot	$14, 812. 50
4,179 feet BX size at $3. 70 per foot	15, 462. 30
978 feet AX size at $3. 45 per foot	3, 374. 10
275. 5 feet casing at $1. 50 per foot	413. 25
Total	34, 062. 15

TABLE 16.—*Footage drilled in each hole by sizes and length of casing placed in each hole*

Hole	Footage drilled				Casing placed, feet
	NX bit	BX bit	AX bit	Total	
1	160	254		414	31. 0
2	112	367		479	14. 0
3	101	190	15	306	25. 0
4	69	242		311	8. 0
5	308	62		370	40. 0
6	64	169	59	292	10. 0
7	296	107		403	20. 0
8	410			410	14. 0
9	317	484	174	975	10. 0
10	124	671	253	1, 048	26. 0
11	294	495	293	1, 082	61. 0
12	135	647	184	966	
13	314	388		702	12. 0
14	397			397	
15	649	103		752	4. 5
Total	3, 750	4, 179	978	8, 907	275. 5

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