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TABLE SUMMARIZING GEOLOGIC, HYDROLOGIC, AND ENGINEERING CONDITIONS

The Northeast Corridor is the highly urbanized area between Washington, D. C., and Boston, Massachusetts. The geologic conditions of part of the Northeast Corridor are summarized in a three-part report (Map I-514) of which this part, Bedrock Geology, consists of a map of the bedrock geology with geologic cross sections (sheets 1 through 5), a table of geologic descriptions and engineering characteristics of each geologic map unit (sheet 6), a map showing sources of data (sheet 7), and a list of additional references. Map I-514-B contains similar information on the Coastal Plain and surficial deposits, and Map I-514-C contains data on earthquake epicenters, geothermal gradients, and major excavations within the Northeast Corridor.

Purpose of Study

The Office of High Speed Ground Transportation, U.S. Department of Transportation (formerly part of the Department of Commerce), asked the U.S. Geological Survey to summarize available information on the geology as it would affect construction of a proposed high-speed ground transportation facility between major cities of the Northeast Corridor. Building such a facility could involve surface construction methods, cut-and-cover, tunnels, or some combination of these. Because of the varied construction methods possible, economic solutions must be found and evaluated for a wide variety of problems, many of which are related to geologic and hydrologic conditions.

Accordingly, this report was prepared to provide a regional summary of the geology as required by planners, geologists, and engineers for early feasibility studies, and for subsequent planning of detailed investigations. It may, in addition, have wide application in planning other engineering projects, and it may have broad educational uses. The report is not intended for use in selecting actual alinements, or for supervision during construction. For these and similar purposes detailed information at considerably larger scales is necessary.

Method of Study

Each map and its accompanying cross sections and table were compiled from existing published and unpublished data. These data consist primarily of geologic maps, reports, and other information from governmental and private sources, principally the U.S. Geological Survey, the geological survey organizations of the several States, and various municipal agencies, universities, industrial concerns, and private consultants. Because the study was completed in a short period of time it was not possible to investigate and synthesize all sources rigorously. No original mapping or other investigations were made expressly for this report. Sources used range from detailed, accurate maps complete with explanatory texts to small-scale obsolescent reports of marginal utility to this report. Only a very few of the source reports evaluate engineering characteristics of the mapped earth and rock materials. Most reports had to be interpreted with the aid of data from other sources.

The standard geological classifications of bedrock and surficial deposits used in source reports were broadly regrouped into map units having similar engineering characteristics. Because of disparate source data, and uncertainties in interpreting and correlating them, some of the regrouping, especially of bedrock units, was arbitrary, and perhaps was not always consistent between different parts of the map area. Although the engineering characteristics of the Coastal Plain deposits are broadly similar, local variation has made retention of the geologic classification desirable. The map scale of 1:250,000 was chosen because this scale permits comprehensive viewing of regional conditions, and because adequate base maps at this scale were available. The base map used here was adapted to the shape of the area from standard topographic 1:250,000 series maps published by the U.S. Geological Survey.

Cross sections through the bedrock were constructed along straight lines connecting major cities between Washington and Boston; additional cross sections are included to better illustrate significant geologic relations. The data on which the cross sections of bedrock are based are restricted largely to near-surface observations; deep subsurface portrayals are therefore highly interpretive, and in most cases, speculative. Cross sections through the Coastal Plain and surficial deposits are based largely on subsurface data and were selected to show situations regarded as typical of more general geologic conditions. The accompanying tables summarize appropriate physical properties and selected engineering characteristics, including those of hydrologic nature.

The maps, cross sections, and descriptive parts of the tables were compiled and prepared by Rachel M. Barker, Kathryn V. Dieterich, Jack B. Epstein, James P. Owens, Henry R. Schmoll, Howard E. Simpson, and David L. Southwick. Harold E. Gill compiled the hydrologic data, and prepared the contours on the surface of the bedrock beneath the Coastal Plain deposits. The engineering data map, source data maps, and the engineering properties shown in the tables were prepared by Maxwell E. Gardner. Randolph W. Bromery supplied the geophysical data.

The authors appreciate the very generous support of their colleagues, both within and outside the Geological Survey, who provided many unpublished data printed here for the first time. It is not possible to credit those individuals here, but those not employed by the U.S. Geological Survey are named on Sheet 7, Index to data sources. The following State organizations cooperated in every way possible: Connecticut Geological and Natural History Survey, Delaware Geological Survey, Maryland Geological Survey, New Jersey Bureau of Geology, New York State Museum and Science Service: Geological Survey, Pennsylvania Bureau of Topographic and Geologic Surveys, and Virginia Division of Mineral Resources. Moreover, many reports published by and credited to the U.S. Geological Survey in the Index to data sources were financed in part by State funds.

Geologic Setting

The mapped part of the Northeast Corridor may be broadly divided into three geologically distinct regions according to general types of geologic material present. (1) Bedrock, which underlies the entire mapped area, is commonly found at or near the ground surface northwest of the Fall Line, a geographic line which extends through Washington, Baltimore, Philadelphia, and New York; information about this region is largely confined to the bedrock geology map. (2) Glacial deposits thinly mantle the region north and east of New York, but the bedrock beneath crops out at many places, and its nature is well known. Thus both bedrock and surficial deposits are mapped in this region. (3) Coastal Plain deposits, a thick wedge of nonindurated sediments dominantly of marine origin, completely cover the bedrock in the region southeast of the Fall Line. This wedge thickens seaward to a maximum thickness of 3,500 feet in the map area. The surface of the bedrock beneath this wedge is portrayed on the bedrock map by contours.

Little is known concerning the precise nature of the deeply buried bedrock. Samples have been recovered at only a few places where drills penetrated the nonindurated deposits. The separate table below—"Description of bedrock samples from beneath Coastal Plain deposits"—summarizes selected sample data. Considerable indirect information has been obtained by geophysical methods. Available information indicates that the bedrock is similar in type and structure to rock exposed northwest of the Fall Line. It is not yet possible, however, either to delineate areas of specific bedrock types, or to project structural conditions beneath the Coastal Plain deposits with any degree of certainty.

Lithology and structure of the bedrock formations are fairly well known in the rest of the Northeast Corridor. The rocks are broadly divisible into: (1) thick continental sedimentary rocks and subordinate volcanic rocks (map units 14 and 16 in part, 17, and 19 to 24), and (2) older, mostly metamorphic and plutonic rocks.

The continental sedimentary rocks underlie nearly half the bedrock area in the Northeast Corridor. These rocks occupy five areas, each a distinct topographic lowland and a structural trough or basin, from southwest to northeast as follows: the Deep River Basin in Virginia and Maryland, the Newark Basin in Pennsylvania, New Jersey, and New York, the Connecticut Valley Basin in Connecticut and Massachusetts, the Narragansett Basin in Rhode Island and Massachusetts, and the Boston Basin in Massachusetts.

The sedimentary rocks in these basins range from shale, slate, and argillite to very coarse conglomerate. The original sediments were deposited mostly by streams or in lakes, as alluvial fans, channel fills, and lake bottom deposits.

In three of the basins basaltic lava erupted as flows while the sediments were accumulating, and also was intruded into the sediments as dikes and sills. The flows and sills are confined to the basins, but dikes as much as 100 feet wide extend sporadically for miles through the adjacent metamorphic terrane. These dikes follow faults as well as joints.

The strike of beds in the Deep River and Connecticut Valley Basins is essentially parallel to the axes of the basins; in the Newark Basin, the trend of beds is arcuate. Beds in the Deep River and Newark Basins dip westward and northwestward, respectively; beds in the Connecticut Valley Basin dip eastward. The Deep River and Connecticut Valley Basins are bounded by faults on both flanks; Newark Basin is faulted only on the northwest flank.

In the Narragansett Basin, the sedimentary rocks occupy a gently inclined downfold—or a downfaulted block—whose axis extends northerly for many miles, then turns northeast. Two small, related basins, probably separated by erosion, lie to the west. On the major downfold are several lesser corrugations, each bringing conglomerate to the surface in the center of a gentle downfold. The rocks are generally similar to those in the other basins, but are somewhat more indurated. Toward southern Rhode Island they are increasingly metamorphosed, even to a schist in places. Volcanic rocks, mostly rhyolitic ash and welded tuff, occur near the base. Some beds of meta-anthracite coal are present also.

The Boston Basin is a downfaulted trough. Erosion has cut more deeply into the sedimentary fill here than in the other basins. Volcanic rocks—basalt, rhyolite, felsite, and andesite—are more abundant and exhibit greater lithologic variety than in the other basins; many volcanic rocks crop out also in the neighboring upland. Structurally, the sedimentary rocks in the basin trend generally east in broad, open folds that are much cross faulted. The rocks are mostly coarse conglomerate and hard argillite. Sandstone and volcanic tuff are interbedded with the argillite, and some sandstone also occurs in the conglomerate.

The metamorphic and plutonic rocks in the uplands between the basins are structurally much more varied than the rocks within the basins. Attitudes and structural trends are diverse and complex, and the rocks are heterogeneous in composition.

In the southernmost upland area—between the Deep River Basin and the Newark Basin—gneiss occurs near Baltimore in the center of roughly circular, elongate, or arcuate domed uplifts, enveloped by shells of other metamorphic rocks. All are involved in a huge refolded anticline many miles long that plunges to both the northeast and southwest. Bodies of various intrusive rocks complicate the major structure. To the northwest, folded and faulted coarse-grained schist grades into fine-grained schist with a common trend that wraps around the anticline. Farther north similar, though smaller, major upfolds and downfolds occur west of Philadelphia. Most of these folds are broken by long faults of various kinds, along which great displacement has juxtaposed markedly different rocks.

Another upland separates the Newark and the Connecticut Valley Basins. Here, too, the geologic structure is complicated. Several domes with gneissic centers, major folds, and scattered igneous intrusions are present. A northeast structural trend in the belts of metamorphic rocks is more evident in this upland than in the south.

In the upland east of the Connecticut Valley Basin, rock types and structural features are more similar to those of the southern uplands. At least one major eastward overthrust and several long strike-slip faults displace rocks over great distances. Granitic rocks occupy much of the eastern part of this upland, with only local infolds of metamorphic rocks.

The intricacies of occurrence of rocks that result from structure and lithology are as complex at depth as at the surface, and rock types shown on the geologic map change markedly at depth on the underside of a thrust fault, within a fold or dome, or beneath the floor of a basin. The change from one lithology to another may be abrupt or by gradation. The geologic cross sections illustrate some probable relationships and point up some of the structural complexities. In detail the intermingling of rock types is extremely complicated, and the nature of such intermingling cannot be predicted accurately at depth.

Faults affect every rock unit within the Northeast Corridor to some extent, although few, if any, faults are presently active. In addition to the large regional faults shown on the map, there are multitudes of smaller ones which are commonly indicated by offset lithology or by topographic expression. Small faults, like those joints caused by faulting, are generally subparallel to larger faults nearby.

The size or regional importance of a fault does not necessarily determine the extent to which it may be troublesome during construction. Some major faults along which movement may have aggregated tens of miles comprise broad zones of soft broken rock, yet others are marked by only a few feet of shattered material. Some zones of fault-shattered rock are now completely rehealed and consist of tight rock, even stronger than before rupture. Thus one fault may be troublesome, another healed, and conditions may vary even along the length of the same fault.

During glaciation the northern part of the Northeast Corridor was differentially depressed by the load of glacier ice, and isostatic rebound has occurred since the ice melted. Evidence in the Boston area suggests that rebound has ceased there; if so, rebound may also have ceased elsewhere in the Northeast Corridor. Were additional rebound to occur, its areal and vertical extent could not be predicted. Stress in the rocks caused by loading by glacier ice was probably very low; there is no evidence that residual stress in the rocks at the present time has resulted from glacier loading. As stress in the rock at least locally exceeds that which could have resulted from glacier loading, such stresses are probably tectonic.

In the southern unglaciated part of the Northeast Corridor weathering of the bedrock is deep and thorough. Residual soil is as deep as 75 feet on one quartz diorite body in Maryland, and thicknesses of 5 to 50 feet are prevalent over much of the area. The weathered zone may extend considerably deeper along planes of weakness such as joints, faults, foliation, and bedding planes.

In the glaciated area most rocks are weathered only slightly, even at the surface. Locally, however, weathering has penetrated as much as 50 feet along planes of weakness. In some places, mostly on granitic terrane, there are small, scattered areas of deeply weathered, decomposed whole rock; the thickness of the decomposed rock is not known.

Hydrologic Notes

The depth to the zone of saturation in the Northeast Corridor, where the annual precipitation averages between 40 and 45 inches, is generally within 30 feet of the surface in the valley or lowland areas.

The zone of saturation consists of two subzones: the subzone of unconfined ground water, below, and the subzone of continuous saturation, above. The two are separated by the water table, that surface within the zone of saturation where water occurs at atmospheric pressure; this is the position at which water in an unconfined water body will stand in a well. The subzone of continuous saturation contains water under negative atmospheric pressure (capillary rise). The water table, and consequently the position of the subzone of continuous saturation, fluctuate with seasonal conditions. The thickness of this subzone is controlled by the size of capillary openings, or, for practical considerations, the average particle size of the sediments; it is thickest in fine-textured, nonindurated sediments, where it may be as much as 10 to 15 feet thick. In rocks with low primary permeability, the water table occurs near the top of the zone of saturation, and the subzone of continuous saturation is very thin.

For excavations within the zone of saturation, this zone must be locally dewatered; therefore cut-and-cover construction in nonindurated deposits in the Northeast Corridor will generally require high-capacity dewatering equipment.

GEOLOGIC DESCRIPTION

MAP UNIT	EQUIVALENT GEOLOGIC UNIT[1]	LITHOLOGY	STRUCTURE	WEATHERING	TOPOGRAPHY
1. Biotite-quartz-feldspar gneiss	Baltimore Gneiss (part) Blackstone Series (part) Fordham Gneiss Unnamed units	Medium-grained biotite-quartz-feldspar gneiss, with some hornblende locally. Commonly interlayered with epidote-bearing gneiss, amphibolite, and numerous intricately injected, pinching and swelling sheets of granite, aplite, and pegmatite.	Structure extremely complicated; trends differ from area to area. Foliation plane dominant: dips steep to moderate, locally horizontal. Joints strong, in sets, widely to closely spaced. Large and small faults widespread; rocks sheared to mica schist or mylonite.	Weathers to micaceous clayey or sandy residual soil; mica schist breaks down readily upon weathering.	Rolling to hilly upland.
2. Amphibolite, epidote amphibolite, and metamorphosed gabbro.	Baltimore Gneiss (part) Brimfield Formation (part) Glastonbury Gneiss (part) Maltby Lakes Volcanics (part) Marlboro Formation (part) Middletown Formation (part) Putnam Gneiss (part) Tatnic Hill Formation (part) Unnamed units	Massive to banded, tough, strong amphibolite, amphibolite schist, amphibolite gneiss, hornblende gneiss; in part metagabbroic. Forms extensive thick layers, lenses, and pods. Commonly epidote-bearing; much epidote-rich amphibolite gneiss, and pods of epidote; includes extensive thick light-red to pink garnet-rich, layers. In places schistose toward margins; locally intruded by quartz diorite dikes.	Structure variable; rock ranges from massive, to gneissic. Large massive bodies rarely show folds, whereas smaller or layered bodies commonly are complexly folded. Joints commonly persistent, but vary greatly in spacing.	Weathers to sticky red clay southwest of glaciated area; almost unweathered in glaciated area.	Hills to low mountains; rugged in places, especially near rivers.
3. Layered gneiss	Baltimore Gneiss (part) Brimfield Formation (part) Clinton Granite Gneiss (part) Hartland Formation (part) Mamacoke Gneiss Middletown Gneiss (part) Monson Gneiss New London Gneiss Putnam Gneiss (part) Quinebaug Formation (part) Tatnic Hill Formation (part) Waterbury Gneiss Wilmington Complex (part)	Strongly banded gneiss; layers differ sharply in composition. In Pennsylvania and Maryland consists of either interlayered quartz amphibolite, granulite, and light-colored biotite-quartz-plagioclase gneiss where grade of metamorphis high, or greenstone and schistose felsite where grade of metamorphism low. In Connecticut, less regularly banded; layers consist of biotite-quartz-feldspar gneiss, mica schist, granulite, amphibolite, and hornblende gneiss. Layers ½ in. to at least 100 ft. thick. Cut by quartz veins, pegmatite, and granitic dikes and sills.	Strong foliation generally parallels layering. Joints numerous, commonly closely spaced. Small faults common. Tension joints locally filled with epidote and chlorite.	In the south weathering generally ranges from 0 to 86 ft deep and averages 35 ft. In the glaciated area weathers yellowish brown to a depth of 1–3 ft, in part yielding slabby fragments; locally along foliation planes and fractures weathers to 50 feet or more.	Moderately rolling terrain of low relief.
4. Gabbro	Baltimore Gabbro Cortlandt Complex Lebanon Gabbro Nahant Gabbro Preston Gabbro Unnamed bodies	Generally massive, dense, tough, medium- to coarse-grained, dark green to purple or black gabbro; composition varies internally, commonly by layers; in part biotite rich, in part quartz bearing. Locally includes other rock types: norite, diorite, pyroxenite, peridotite, and amphibolite.	In part foliated; locally contains many shear zones, some with mylonite. Joints common; spacing variable, in places less than 5 ft. Locally cut by numerous basalt dikes of several sets each with characteristic strike and dip.	Southwest of New York weathers to sticky red clay with numerous boulders; locally soil may be cellular and resistant to compaction. Northeast of New York only slightly weathered but somewhat oxidized.	Moderately rolling to hilly terrain of low relief.
5. Diorite and quartz gabbro	Belchertown Tonalite Hardwick Granite Salem Gabbro Diorite Straw Hollow Diorite Quartz-bearing facies of the Baltimore Gabbro Other unnamed bodies	Mixed zone of quartz-bearing gabbroic rocks, hornblende-rich quartz diorite and hornblende diorite. Mostly fine to medium grained, strongly foliated in places. Includes many dikes and sills of granite and aplite, and contains many xenoliths.	Similar to map units 4 and 6.	North of Baltimore weathers to deep residual clayey soil containing residual boulders. In New England weathering slight.	Underlies hilly terrain.
6. Granitic rocks	Acton Granite Andover Granite Ansonia Gneiss (= Ansonia Granite) Arden Granite Assabet Quartz Diorite Ayer Granite Blue Hills Granite Porphyry Bristol Gneiss Brookfield Plutonic Series Bulgarmarsh Granite Canterbury Gneiss Cowesett Granite Dedham Granodiorite Ellicott City Granodiorite Esmond Granite Glastonbury Gneiss (Continued at bottom of table)	Medium- to coarse-grained, equigranular to porphyritic granitic bodies, both gneissic and unfoliated. Rock ranges in composition from hornblende quartz diorite to muscovite granite. In general individual bodies markedly homogeneous in composition and texture despite local variations. Aplites, pegmatites, mafic dikes, segregations, xenoliths, and quartz veins occur locally, in great abundance in some places.	Massive to foliated. May extend without change to depths greater than 5,000 ft or may be relatively thin and tabular and folded in with enclosing metamorphic rocks. Joints prominent, normally widely spaced; joint pattern differs from body to body; most have a prominent strong joint set subparallel to ground surface and other sets inclined at high angles to the surface. In places broken by large and small faults. Shear zones commonly sites of weak rock, many faults and brecciated zones healed and hard.	South of glaciated area commonly weathers to deep residual soil; weathers deeper than any other unit in the Northeast Corridor area. In glaciated area, weathering slight except in local areas of Rhode Island and southeastern Massachusetts, where a rottenstone gravel overlies sound rock.	Upland terrain of strong and ridged character but commonly low local relief.
7. Serpentinite, steatite, and related ultramafic rocks	No names applied	Serpentinite, massive or schistose; steatite, schistose or massive; talc, talc-, actinolite-, and chlorite-containing schists and talc-carbonate-quartz rock. Massive serpentinite generally occurs in thick lenticular bodies; steatite and associated schists occur in thin sheets and lenses, and as rims around and along shear zones within massive serpentinite bodies. Unaltered dunite, peridotite, and pyroxenite occur locally. Rock is generally a mixture of tough hard fragments as much as 5 ft in diameter embedded in a very soft, weak, and highly sheared matrix. Color light green, greenish gray to greenish brown.	Thoroughly sheared and broken by innumerable intersecting zones of weak, friable and slippery material of low strength. Joints common and closely spaced, generally of random orientation and little structural significance. Bodies generally concordant with structure of enclosing rocks (map units 11, 12, and 13).	Massive serpentinite and steatites commonly weather to soils less than 2 ft thick; schistose rocks yield deeper soils.	Generally low rolling topography; locally massive bodies may be prominent.
8. Anorthosite	Anorthosite at Honeybrook	Medium- to coarse-grained, massive, exceedingly tough andesine anorthosite; blue-gray color very characteristic. Cut by a few basic dikes and pegmatites, otherwise markedly homogeneous.	Homogeneous and massive; nonfoliated; joints widely spaced. Body bounded on south by fault; contacts gradational with map unit 6 to east, north, and west.	Weathers to moderately thick clayey soil containing large smooth-surfaced boulders.	Rounded irregular low hills.
9. Quartzite with interbedded conglomerate, schist, and gneiss.	Cardiff Conglomerate Chickies Formation Clough Formation Hardyston Quartzite Harvard Conglomerate Lentil of the Worcester Formation Oakdale Quartzite Plainfield Formation Setters Formation Sugarloaf Mountain Quartzite Vaughn Hills Member of the Worcester Formation Westboro Quartzite Weverton Formation Conglomerate unit in the Wissachickon Schist Quartzite units in the Blackstone Series Quartzite unit in the Marlboro Formation	Fine- to medium-grained, vitreous to granular, generally pure but locally micaceous or feldspathic quartzite, interbedded with quartz schist, quartz-pebble conglomerate (occurs especially at base of unit), mica schist, conglomerate, and feldspar-quartz-biotite gneiss. Thin bedded or flaggy to thick bedded; bedding distinct to lacking. In many areas, quartz grains in the rock scarcely recrystallized; elsewhere the quartzite is wholly crystalline. Where crystalline, rock is very tough and hard; where scarcely recrystallized, similar to sandstone. Pegmatites and quartz veins irregularly spaced through the rock.	Dip of bedding and foliation mostly moderate to steep. Prominent joints commonly spaced one to several feet apart, but locally so closely spaced that the rock breaks into small rectangular blocks. Quartzite broken and shattered locally by faults.	Rocks notably fresh. Weathering generally slight; thicker sandy soils more common in New Jersey and south.	Resistant to weathering and erosion; forms long ridges.
10. Marble, crystalline limestone, and dolomite.	Allentown Dolomite Beekmantown Group Cockeysville Marble Conestoga Formation Conococheague Group Elbrook Formation Inwood Marble Kittatinny Limestone Ledger Dolomite Leithsville Formation Stockbridge Group Vintage Dolomite Unnamed body in Blackstone Series	In areas of medium to high metamorphic grade, generally associated with map unit 11: calcite marble, dolomite marble, and calc-silicate schist and gneiss; some interbedded thin layers of mica schist and graphitic schist. Other areas, generally along northwest border of map area: limestone and dolomite, commonly recrystallized, in places interbedded; thin-to thick-bedded, locally finely laminated or massive; in places interbedded with phyllite, shale, and thin argillaceous partings; locally sandy. Generally fine- to medium-grained, light to dark gray; locally white, bluish, or blue-black.	Commonly complexly and tightly folded; foliation well developed locally; schistose where mica content exceeds a few percent. Folds strongly overturned and overthrust in northwest border area.	South of glaciated area, solution weathering with very uneven and pitted upper surface, generally mantled by red clayey residual soil. In areas north of Baltimore weathers to carbonate sand. May be porous and cavernous to considerable depth. In New York and Connecticut generally fresh where exposed.	Commonly underlies valleys.
11. Coarse mica schist and mica gneiss	Absalona Formation Brimfield Schist Bolton Schist Collins Hill Formation Derby Hill Schist Glastonbury Gneiss (part) Hartland Formation Hebron Formation Littleton Formation Maltby Lakes Volcanics (part) Manhattan Formation Marlboro Formation (part) Nashoba Formation (Continued at bottom of table)	Medium to coarsely crystalline, well-foliated schist and gneiss: biotite schist predominant; biotite gneiss, muscovite-biotite-schist, hornblende gneiss, muscovite schist, amphibolite schist, and granitized gneiss important; quartzite, amphibolite, and granulite common. Medium to high grade of metamorphism. Rock generally tough and strong. South of New England unit consists mostly of muscovite-biotite-quartz-plagioclase schist and minor mica gneiss, with some amphibolite; in New England, assemblage more varied. Large and small pegmatites and quartz veins, crosscutting and concordant, pervade the rock in New England; important but less abundant to the south.	Metamorphic foliation the dominant planar element; main foliation generally parallel to bedding; dips steep to moderate. Multiple directions of foliation common. Many small-scale folds. Jointing irregular; main breakage usually parallel to schistosity, and additional joint sets facilitate breakage into polygonal blocks. Many large and small faults and fault zones, commonly parallel to foliation; many faults filled and healed, others soft and clayey or brecciated. Pegmatites and quartz veins commonly considerably harder than surrounding schist or gneiss.	In south, irregularly deep miceous clayey to sandy residual soils; depth of weathering highly variable. In glaciated north, weathering slight except for extensive, though patchy, deep oxidized zones along foliation planes and joints in some schist.	Rolling to hilly uplands.
12. Fine-grained mica schist, chlorite schist, and phyllite with interbedded quartzose rocks.	Blackstone Series (part) Ijamsville Phyllite Peters Creek Formation Urbana Phyllite Wissahickon Formation Worcester Formation (part) Other unnamed units	Fine-grained schist and phyllite composed chiefly of muscovite, chlorite, quartz, and sodic plagioclase; micaceous quartzite and metagraywacke rhythmically interbedded. In places, beds of pure quartzite, greenstone, and tuffaceous schist common. Rock generally competent and coherent, though less resistant and softer than map unit 11.	Metamorphic foliation dominant planar element; strongest schistosity generally parallel to bedding; dips generally steep. Small-scale folds, tight to open, abundant. Jointing irregular, strongest parallel to schistosity. Shear zones and small faults usually parallel to schistosity; faults of large displacement common.	South of glaciated area forms clayey to sandy mica-rich residual soil containing abundant small rock chips. Depth of weathering 5–50 ft. In glaciated area weathering slight.	Similar to map unit 11.
13. Gneiss and schist, typically massive and granitic in appearance.	Sykesville Formation	Heterogeneous pebble- and boulder-bearing metamorphic rocks of diverse appearance. Typically resemble medium-grained, weakly foliated granitic gneiss, but more strongly foliated locally; elsewhere massive, fine-grained, quartzitic. Contains rounded quartz pebbles and boulders, chips and fragments of mica schist, and blocks and slabs of metamorphic rock. Rock mineralogically uniform; quartz, plagioclase, and muscovite, 85–90 percent; and accessory biotite, chlorite, epidote, magnetite and garnet. Tough and hard. Interpreted to be enormous, metamorphosed, folded submarine landslide deposit.	Characteristically massive or thick-bedded; interbedded with sequences of rhythmically bedded metagraywacke and schist near Susquehanna River. Gradational contact with adjacent schist. Joints prominent, widely spaced in massive rock.	Forms deep clayey to silty residual soils.	Forms rolling upland with steep-sided stream valleys.
14. Argillite, siliceous shale, slaty shale, slate, phyllite, and fine-grained schist.	Antietam Formation Braintree Slate Cambridge Argillite Harpers Formation Hoppin Slate Jacksonburg Formation Martinsburg Formation Normanskill Shale Peach Bottom Slate Weymouth Formation	Argillaceous rocks, variously metamorphosed. Include dense, dark argillite, siliceous shale, thin-bedded, locally carbonaceous, slaty shale, dark slate, phyllite, fine-grained quartz-mica schist and medium-grained quartz-albite schist. Most sequences incorporate sandstone and graywacke; locally limestone, and, in Boston, volcanic tuff.	Argillite, siliceous shale and some slaty shale well-bedded; dips generally steep. Strong slaty cleavage in slate. Phyllite and schist strongly and finely foliated: bedding obscured. Rock splits readily along bedding, slaty cleavage, or foliation, depending on degree of metamorphism. Cross joints vary in spacing and development, commonly closely spaced. Extensive large and small faults.	South of glaciated area, clayey to sandy soil containing many slaty chips; weathering may be as deep as 75 ft along shear zones. In north, rock generally sound and unweathered. In and near Boston patches of argillite deeply altered to soft white clay.	Commonly forms lower ground in uplands.
15. Greenstone and greenschist.	Maltby Lakes Volcanics Unnamed units in Maryland and Connecticut.	Greenstone and greenschist, in part containing pods of quartz and lenses or porphyroblasts of epidote. Greenschist locally includes as much as 25 percent muscovite and 20 percent chlorite. Gray green to dark green.	Slaty to schistose, well foliated; slaty cleavage and folia dip steeply. Principal joint sets dip steeply.	Locally weathers to dull grayish yellow or dark purplish red; in south, yields red clay.	Moderately rolling hills.
16. Volcanic rocks, commonly altered and slightly metamorphosed.	Brighton Melaphyre Catoctin Formation (?) Lynn Volcanic Complex Mattapan Volcanic Complex Spencer Hill Volcanics	Lava flows, welded tuffs and pyroclastic deposits with some feeder dikes and sills; strongly altered and slightly metamorphosed in part. Includes felsite, rhyolite, andesite, and some basalt. Textures range from glassy or flinty to finely crystalline; commonly porphyritic. Amygdaloidal rocks abundant. Tough, hard, resistant; commonly fractured. Rock type highly variable within short distances. In Maryland, metamorphosed to schist.	Commonly massive, in places many fractures. Joints strong, commonly closely spaced. Trends and attitudes highly variable.	Rock weathered mostly at surface and along joints except in Maryland where it is weathered deeply to micaceous clay.	Generally hilly, knobby terrain.
17. Sandstone and shale	Bellvale Sandstone Cornwall Shale Kanouse Sandstone Rhode Island Formation Wamsutta Formation	Fine- to coarse-grained sandstone, lithic graywacke, graywacke, arkose, siltstone, shale, and some conglomerate. In southeastern New England, a complex, highly irregular interbedding of all facies, locally including beds of rhyolite, basalt, and meta-anthracite; coarser grained rocks more prevalent to the northeast. Conglomerate contains boulders as much as 4 ft in diameter; stones dominantly quartz and quartzite, felsite common locally. Rocks generally well indurated and strong; color gray to black, locally greenish, chiefly red in northern part of outcrop area. Degree of metamorphism increases southward; rocks essentially nonmetamorphosed in the north; minerals of higher metamorphic grade appear successively southward. In New York and New Jersey, a single sequence of rocks: fine-grained quartz-pebble conglomerate at base, overlain by thick-bedded, weakly cemented, friable, greenish to light-gray sandstone, in part calcareous; thick-bedded, slaty to fissile, dark-gray to black argillaceous and partly siliceous shale; and thin-bedded, strong dark-gray sandstone.	Generally well bedded; dips moderate, synclinal structure predominant. Thicker beds well jointed. Faults present locally. In New Jersey strongly cleaved so that bedding is obscure. In southern Rhode Island metamorphic cleavage and schistosity well developed.	Weathering thin.	Generally low terrain in New England; conglomerates form low ridges. Mountainous in New York and New Jersey.
18. Limestone and shale	Decker Limestone Longwood Shale	Chiefly soft, red shale, about 200 ft thick. Also includes dark-gray limestone, impure, siliceous, shaly; about 50 ft thick.	Shale has slaty cleavage, obscure bedding; limestone well bedded.	------------------------------------	Unit poorly exposed.
19. Conglomerate	Skunnemunk Conglomerate Green Pond Conglomerate Roxbury Conglomerate Pondville Conglomerate Dighton Conglomerate Purgatory Conglomerate	Hard, resistant, coarse to fine conglomerate, containing lenses and beds of sandstone. Stones mostly pebbles and cobbles, but range in size from granules to boulders. Most fragments subrounded or rounded; mainly quartz and quartzite, but locally include a wide variety of plutonic, volcanic, and metamorphic rocks. Matrix is sandstone, graywacke, shaly sandstone, or shale; in many places schistose. Mostly massive layers; bedding indistinct except in sandstone. In parts of Rhode Island and Massachusetts, matrix metamorphosed and pebbles stretched; unit incorporates layers and small bodies of volcanic rocks (map unit 16).	Moderate dips except locally. Broad, open, plunging synclines and anticlines. Joints strong, fairly uniform, and widely spaced; at surface, rock breaks into large rectangular to rhombohedral blocks. Faults common, mostly healed. Fractures commonly mineralized.	In most places weathers to a depth of only a few inches; locally in New Jersey rock disintegrated into sandy gravel. Joints open to moderate depths in small areas. In places near Boston, rock altered to soft white clay.	Mostly low but prominent ridges, commonly cliffed.
20. Chiefly red shale	Brunswick Formation (part) East Berlin Formation Shuttle Meadow Formation	Chiefly thin- to medium-bedded shale, but includes interbedded mudstone, siltstone, and fine-grained sandstone; locally includes thin limestone and gypsum beds. In Pennsylvania and New Jersey, lower beds thicker, upper beds generally thin and wavy. In Connecticut, beds finely laminated and fissile (locally "paper shales") in lower part, thickening upward. Generally weak, soft, breaks with hackly fracture. Chiefly red to reddish brown, in part dark gray to black; in Connecticut locally varicolored. Dominantly argillaceous, in part micaceous; siltstones and some sandstones somewhat arkosic.	Well bedded; gently dipping, generally eastward in Connecticut, west- to northwestward in New York, New Jersey, and Pennsylvania. Normal faults common.	Weathers readily to red clay with sand and silt. Baked to hornfels for 12 to 18 in. from contact with basalt (map unit 23).	Generally forms lowlands, adjacent to basalt (unit 23) or indurated mudstone (unit 21) ridges.
21. Mudstone	Lockatong Formation	Mostly tough, massive to thick-bedded, homogeneous argillaceous mudstone, locally cemented and well indurated; extremely fine grained; breaks conchoidally; mostly dark gray to black; locally red. Composition dominantly illite; chlorite, plagioclase feldspars, dolomite, calcite also common. In some areas includes extensive platy, finely laminated, calcareous mudstone and marlstone, commonly pyritic; medium to dark gray. In southwestern area includes tough, thin-bedded siltstone and fine-grained sandstone, calcareous and micaceous; red to greenish gray.	Well-bedded; gently dipping. Normal faults common.	Generally unweathered.	Generally forms ridges; local relief as much as 200 ft.
22. Red sandstone, shale, and conglomerate.	Brunswick Formation (part) Bull Run Shale Manassas Sandstone New Haven Arkose New Oxford Formation Portland Arkose South Britain Conglomerate Stockton Formation	Mainly medium- to fine-grained, well-sorted, muscovite-rich arkose, and interbedded feldspathic sandstone, siltstone, and mudstone, with some fine- to coarse-grained conglomerate in lower parts, generally as channel fillings and large lenses. Along easternmost margin in Connecticut contains small fanglomerates similar to those of map unit 24. Locally includes thin limestone and gypsum beds. Arkose has interlocking grains, 50 to 70 percent quartz, 15 to 40 percent feldspar, cemented by silica and calcite. Conglomerate pebbles chiefly quartz and quartzite, some phyllite; average 1 in. diameter, maximum about 14 in. Stones moderately rounded to subangular, in coarse-grained matrix, quartz and orthoclase grains rounded to angular. Rock yellowish gray to reddish brown. Maximum thickness about 5,000 ft.	Arkose and finer grained beds thin bedded to massive; crossbedding, pinch-and-swell, lensing, mud cracks, and ripple marks common. Conglomerate poorly bedded, thick to massive. Beds locally warped into open synclines and anticlines; dips generally 5°-20° northward to westward in Pennsylvania and New Jersey, and eastward in Connecticut and Massachusetts. Major faults probably displace underlying metamorphic rocks. Numerous minor faults repeat beds by as much as 33 percent locally. Joints best developed in massive sandstone and arkose. Generally two or more sets, commonly parallel to faults.	Arkose and conglomerate both weather to light gray to dark brown; finer beds disintegrate into red clay, silt, and sand. Adjacent to basalt (map unit 23), arkosic and finer beds thermally metamorphosed to tough, fine-grained, grayish to purplish hornfels; thickness ranges from a few inches under lava flows to about 120 ft adjacent to dikes and sills.	Broad basins with gentle sides, and scattered low ridges and irregularly shaped hills with flat summits. Conglomerate caps more distinct hills and ridges.
23. Basaltic rocks	Hampden Basalt Palisade Diabase Talcott Basalt Watchung Basalt Unnamed or locally named flows, dikes, and sills	Mafic igneous rock; medium gray to black; tough, strong; fine- to medium-grained. Includes lava flows, sills, and dikes. Basal part of some dikes and sills olivine rich. Some sheets contain as many as nine separate flows. Sills and dikes as much as 1,500 ft thick. Multiflow formations 30 to 800 ft thick.	Flows and sills characteristically dip 10°-15°; generally westward in northern New Jersey and New York, eastward in Connecticut. Dikes normally dip more than 45°. Joints of various kinds and scales very common: (1) Subparallel joints as much as 50 ft apart, of two or three sets related to faulting. (2) Columnar joints, columns as much as 3 ft in diameter. (3) Prismatic joints, prisms several inches by 1 ft to several feet. (4) Cooling joints 5 to 15 ft across, curved in three dimensions. (5) Widespread shatter joints, small and highly irregular. Flows, sills and dikes gently to moderately folded in some areas. Major faults have breccia zone several feet thick.	Surface weathers to yellowish brown, and scales in a few years. In nonglaciated area yields punky cobbles and boulders, sand-size material, and bouldery montmorillonoid clay 50–75 ft thick. In glaciated area yields slide rock below large cliffs. Olivine-rich basalt crumbles readily on weathering.	In northern New Jersey and New England, forms prominent subparallel ridges as much as 625 ft high. In central New Jersey and Pennsylvania, generally mildly rolling terrain with hills and ridges. In Virginia and Maryland, smooth terrain or valleys.
24. Conglomerate	Unnamed fanglomerates in Brunswick Formation Lockatong Formation Stockton Formation	Two types of pebble to cobble conglomerate, both with matrix of red to brown coarse sandstone to siltstone. Stones in one type generally rounded, in part subangular; dominantly quartzitic, some conglomeratic, a few limestone. Stones in other type angular and wholly of limestone. Both contain scattered beds of arkosic sandstone and siltstone.	Bedding absent to very crude; enclosed arkosic sandstone and siltstone well bedded. Beds thicken northwestward, wedge out, and interfinger with red shale (map unit 20), black shale, mudstone, and siltstone (map unit 21). Generally massive.	Weathers slowly to stony clay; residual soil cover less than 15 ft.	Caps hills and ridges.

ENGINEERING CHARACTERISTICS

MAP UNIT	Physical properties[2]: Dry unit weight (pounds per cubic foot)	Physical properties[2]: Compressive strength[5]	Physical properties[2]: Young's modulus of elasticity[6]	Evaluation of rock for construction[3]: Relative drillability[7]	Evaluation of rock for construction[3]: Excavation characteristics
1	163–173	Low to high.	Medium to high.	3	Overbreak and rock loads mostly slight to moderate, depending on frequency of fractures (joints and faults), alteration, and orientation of excavation to major joint systems. Scaling moderate.
2	187–200	High to very high.	High to very high.	2	Overbreak reported moderate to excessive depending on orientation of excavation to major joint systems. Rock loads mostly slight. Swelling ground probable in wet shear zones. Contains fibrous minerals which may slow excavation by boring machine.
3	170–187	Medium to high.	Medium to high.	3	Overbreak and rock loads mostly slight to moderate depending on frequency of fractures (joints and faults), alteration, and orientation of excavation to major joint systems. Scaling moderate. Possible squeezing ground in wet shear zones.
4	184–193	High to very high.	High to very high.	2	Overbreak minimal to moderate depending on degree of foliation. In southern part of Corridor foliated rocks included in unit reportedly give excessive overbreak in tunnels oriented obliquely to major joint systems. Clay in prominent joints. Rockfalls probable from wet clayey seams in foliated rocks. Swelling ground expected in wet fault and shear zones. Rock loads mostly minimal in massive rocks. Contains fibrous minerals which may slow excavation by boring machines.
5	181–193	High to very high.	Low to high.	2	Overbreak mostly minimal, probably moderate where rock foliated and orientation of excavation is oblique to major joint systems. Clay in joints and swelling ground probable. Rock loads mostly minimal; excessive in water-bearing faults or shear zone. Very dark rock probably contains fibrous minerals which may slow excavation by boring machine.
6	162–173	Medium to very high.	Low to medium.	4	Overbreak and rock load generally minimal. Rock locally in high state of compression; popping and spalling increases with depth. Very high stress may deform deep underground openings. Open joints water bearing locally and persistent with depth. Fibrous rock will slow excavation by boring machine.
7	161–178	Very low (sheared serpentinite and talc) to very high (unsheared serpentinite).	Very low to high.	2–5	Exceedingly difficult rock to work. Overbreak and rock loads excessive. Swelling and squeezing ground usual along wet shear zones. High stage of stress likely in massive serpentinite bodies.
8	164–170	Medium to high.	Medium to high.	4	Overbreak and rock loads minimal. Scaling slight to moderate.
9	165–172	Medium to high.	Mostly high; schist low.	3	Overbreak and rock loads mostly moderate; excessive in crushed zones. Scaling excessive and hazardous in very blocky to crushed zones. Massive zones may be highly stressed; possible popping and spalling.
10	164–178	Medium (calcite) high (dolomitic marble).	Medium to high.	5	In marble, overbreak, scaling, and rock load minimal to slight. Excavation conditions excellent with depth; commonly decomposed along faults to as much as 400 ft below surface. In limestone and dolomite, overbreak and rock loads slight to moderate. Heavy concentrated flows of water probable from caverns and joints. Differential subsidence of foundations should be anticipated over cavernous limestones.
11	166–176	Low to medium.	Low (schist) to high (gneiss).	5–6	Moderately easy to excavate. Machine boring slowed by quartz pods and other hard inclusions. Overbreak generally slight but depends partly on orientation of excavation to foliation partings. Rock load variable; moderate in altered rock; excessive in shear zones. Squeezing ground in wet shear zones probable.
12	165–181	Very low to medium.	Mostly low, quartzite high.	3–5	Relatively easy to excavate. Machine boring slowed by quartz pods and other hard inclusions. Overbreak and rock loads mostly slight except in large fault and shear zones and in highly altered rock; squeezing ground common in wet shear zones. Scaling slight to moderate, increasing in more brittle rocks.
13	153–182	Low to high.	Medium to high.	3	Overbreak mostly moderate; may be excessive depending on orientation of excavation to joint systems. Rock loads slight, increase toward shear zones.
14	148–177	Very low (phyllite) to high (slate).	Low to high.	5	Moderately easy to excavate. Overbreak and rock loads mostly slight; but excessive where rock altered or faulted. Scaling moderate.
15	168–191	Medium to very high.	High.	1	Overbreak and rock loads slight to moderate depending on frequency and orientation of rock defects and alteration.
16	164–172	High.	High.	1	Overbreak slight to moderate. Rock load mostly slight, increases near major faults. Thin dikes (some similar to map unit 23) generally give moderate to extreme overbreak and rock loads. Generally very wet. Scaling excessive.
17	135–162	Very low (shale) to high (sandstone).	Very low to low.	6	Stability and rock loads variable, depending on frequency and attitude of bedding and jointing. Slight air slaking in shales.
18	135–168	Very low to medium.	Very low to medium.	5–6	Overbreak, scaling, and rock loads excessive where shales interbedded with thin limestones. Shales slake in air. Heavy concentrated flows of water may issue from joints or caverns.
19	165–168	Medium to high.	High (conglomerate) to low (sandstone).	3–4	Overbreak and rock loads minimal. Popping and slabbing may result from high state of stress.
20	140–166	Very low to medium.	Very low.	7	Generally easy to excavate. Overbreak locally excessive because of roof slabbing along bedding. Slakes badly in air. An initial medium rock load will increase in time if rock not well supported. Excessive water in zones of contact below basalt (map unit 23).
21	162–172	Very low to medium.	Low to very low.	5	Excavators have experienced difficulty in removal by blasting because of high capacity to absorb energy. Overbreak may be slight to excessive depending on blasting technique. Moderate scaling and slaking in air probable. Moderate rock loads expected.
22	156–165	Very low to high.	Mostly low, shales very low.	6	Overbreak and rock loads moderate to high. Rock loads excessive in wet zones. Wet squeezing ground in major fault zones. Shales slake in air. Excessive water occurs in zones below contact with basalt (map unit 23).
23	175–189	Medium to very high.	High.	1	Overbreak and rock loads mostly slight to moderate in large bodies; excessive in small sills and dikes. Rock locally in high state of stress. Excessive water in contact zone at base. Small wet seams of swelling ground probable. Altered and crushed zones may stope badly.
24	165–168	Medium to high.	Low.	6	Overbreak and rock loads slight to moderate. May ravel in air.

HYDROLOGIC CONDITIONS[4]

MAP UNIT	Significant hydrologic features	Permeability: Primary	Permeability: Secondary, Fracturing	Permeability: Secondary, Chemical weathering	Depth of wells (feet): Range	Depth of wells (feet): Median	Yield of wells (gallons per minute): Range	Yield of wells (gallons per minute): Median
1	Water occurs in weathered zone near surface commonly from a depth less than 150 ft. Maximum yields from major fault zones.	-----	X	-----	18–3,000	157	0–365	11
1	In New Jersey and Pennsylvania, median yields approximately 5 times regional average. Median yield from major fault zones in this area is 195 gpm. Specific capacity of wells averages 1.6 gpm per foot of drawdown.	-----	X	-----	50–822	230	0–400	50
2	Water occurs in weathered zone at shallow depth, probably not much below 150 ft. Maximum yields from fault zones.	-----	X	-----	35–750	155	0.5–150	12
3	Most of the water is in the upper 100 ft, little below 200 ft. Strong conjugate joint system causes blocky fracture pattern.	-----	X	-----	18–750	144	0.5–350	11
4	Water occurs in weathered zone near surface. Maximum yields obtained from major fault and joint zones.	-----	X	-----	29–450	125	0.5–130	9.5
5	Water occurs in weathered zone near surface. Commonly shallower than 150 ft.	-----	X	-----	23–450	150	0.5–350	9.5
6	Water occurs chiefly in porous and permeable weathered overburden; joints and fractures act as conduits. Highest yields obtained in valleys and draws.	-----	X	-----	14–750	140	0.5–350	10
7	Weathered mantle is thin and clayey. Water generally obtained at or near the contact between weathered overburden and unweathered rock. Rock is closely fractured.	-----	X	-----	11–500	103	2–45	11
8	Little data available, but probably similar to those for map units 7 and 4.	-----	X	-----	-------	104	-------	9
9	Water generally obtained from relatively continuous and well-developed joint systems or from permeable sandy overburden.	-----	X	-----	34–604	170	0–300	9.5
9	Median yields in New Jersey and Pennsylvania are four times the regional average; probably as a result of more extensive fracturing and weathering.	-----	X	X	59–604	200	0–300	44
10	Solution openings along scattered joints and faults. Commonly weathered to calcareous sand, reportedly to depths of 200 ft. Best wells in flat-bottomed valleys; specific capacity ranges from 0.01 to 1.20 gpm per foot, and averages 0.12. Numerous springs in valleys, yield as much as 400 gpm.	-----	X	X	30–1,800	280	0–450	20
10	Relatively large solution openings along many joints and faults. Either water-table or artesian conditions may occur to depths of 1,000 ft or more. Specific capacity ranges from 0.08 to 58 gpm per foot, and averages 6.8. Numerous springs in valleys yield as much as 400 gpm.	-----	X	X	30–2,000	265	1–1,700	166
11	Surface weathering and leaching leave a porous skeleton of silica clay and mica in both soil and upper part of bedrock. Little increase in well yield below 200 feet.	-----	X	X	13–1,000	188	1–250	12
11	Median well yields in southeast Pennsylvania and Westchester County, N. Y., are about four times the regional average. Major well yields are associated with major faults. Schist is generally weathered to depth of 80–100 ft; water table is well within zone of decomposed rock.	-----	X	X	--------	300	-------	44
12	Conditions similar to those for map unit 11, but unit less highly metamorphosed and deformed.	-----	X	X	40–380	103	0.5–135	15
12	In Pennsylvania median average yield is slightly more than five times the regional average. Upper part of unit weathers to a permeable overburden. Water table is well within zone of decomposed rock. Highest yields in small valleys.	-----	X	X	--------	348	25–590	80
13	Highest median yields are in small valleys. Water commonly shallower than 50 ft. Joints and faults act as conduits. Maximum yields are related to major faults.	-----	X	X	21–825	120	0.5–100	11.7
14	Water at shallow depth, probably less than 150 ft.	-----	X	-----	-------	140	-------	10
14	In New Jersey and adjacent Pennsylvania more extensive fracturing and jointing than elsewhere. Specific capacity of wells ranges from 0.2 to 5.3 gpm per foot, and averages 1.3. Maximum yields are related to major faults.	-----	X	X	72–400	200	19–190	60
15	Water obtained from contact between weathered zone and unweathered bedrock; no data available but should be similar to those for map units 7 and 16.	-----	X	-----	-------	76	-------	9.8
16	Water occurs in weathered zone, commonly shallower than 150 ft. Maximum yields from major fault zones.	-----	X	-----	24–226	120	0.5–100	9
17	Primary porosity less than 1 percent; water transmitted along joints, fractures, and bedding planes. Wells with highest median yields occur in plains (45 gpm) and valleys (34 gpm).	-----	X	-----	35–1,436	277	3–500	25
17	In southern Rhode Island median yields similar to those from crystalline rocks.	-----	X	-----	35–750	164	0–96	11.6
18	Water occurs in joints and along bedding and cleavage surfaces. Maximum yields from fault zones.	-----	X	-----	34–345	130	1–150	28
19	Character as an aquifer not well known. Water occurs along joints, bedding surfaces and irregular fractures. Some springs. Weathered, unconsolidated mantle has local yields of 300 gpm.	-----	X	-----	--------	150	4–150	17
20	Brunswick Formation: Water obtained from secondary rock openings; yields decrease with depth. Largest yields are obtained from wells 200–600 ft deep. High sulfate concentrations associated with gypsum beds occur locally at Quakertown, Pa. (420 ppm) and Bound Brook, N. J. (600+ ppm).	-----	X	-----	25–1,515	358	4–765	180
20	Connecticut River Valley: Water obtained from secondary rock openings which decrease in size with depth.	-----	X	-----	25–3,700	180	3–760	20
21	Water obtained from secondary openings. Maximum yield obtained from major fault zones.	-----	X	-----	52–570	150	0.5–78	8
22	In Virginia and Maryland water obtained from near-surface fractures and joints.	-----	X	-----	22–531	120	1–120	9
22	In Pennsylvania, New Jersey, New York, and near Hartford, Conn., coarse materials are permeable and have some intergranular openings. Water occurs under both water-table and artesian conditions. Most wells more than 300 ft deep intercept one or more permeable zones containing water under artesian pressure. Typical median yields: 106 gpm from lower half of formation; 131 gpm from middle part; 19 gpm from thin upper part, greater where weathered. Salt water occurs in the formation in the Newark Bay and Lower Passaic River area of New Jersey (100–3,000 ppm). High sulfate concentrations associated with gypsum beds occur locally at Spring Valley, N.Y. Well yields in the Hartford area average 132 gpm from an average depth of 513 ft; may be typical of other areas in the Connecticut Valley.	X	X	X	31–1,005	400	1–760	117
22	Elsewhere in Connecticut River Valley water obtained from secondary openings interconnected to depths of several hundred feet. 450 ft probable limit of productive water bearing zones. Maximum yields are associated with major faults.	X	X	-----	25–3,700	200	0–760	20
23	Water occurs in weathered zone near surface. Commonly shallower than 150 ft. In Morris County, N. J., and vicinity upper 10 ft of basalt is highly vesicular and produces maximum yield of 75 gpm locally.	-----	X	-----	35–770	150	0–75	6
24	Limestone breccia: water occurs in joints and fractures enlarged by solution. Specific capacity ranges from 0.1 to 15 gpm per ft and averages 5.	X	X	X	-------	400	2–1,500	300
24	Quartz conglomerate: water occurs in secondary openings in joints and fractures. Some primary porosity.	X	X	-----	-------	150	-------	75

[1]The stratigraphic nomenclature used in this report is that of the authors of the various data sources and does not necessarily conform with usage of the U.S. Geological Survey.

[2]Physical data available only for some rock units; where data are lacking, the physical properties are inferred from comparisons with those of rock elsewhere that posses similar composition, structure, and geologic histories.

[3]Reported construction characteristics are limited in number. Evaluations of rock units, for the most part, are inferred from generalized conditions of structure, alteration, hydrology, and state-of-stress. Specific conditions can change within short distance. More refined engineering evaluations must be based on more detailed knowledge of geologic conditions.

[4]The well-yield data used in the preparation of this table are based on public-supply and industrial wells in which the maximum potential of the aquifer was being developed.

[5]Classification is for uniaxial compressive strength of intact rock. Strength is reduced by physical defects and chemical alteration in rock; it may differ with respect to bedding, foliation, or direction of principal residual stress.

Strength class	Range of compressive strength (psi)
Very high	>32,000
High	16,000–32,000
Medium	8,000–16,000
Low	4,000– 8,000
Very low	<4,000

[6]Inferred for intact rock. Modulus is reduced by physical defects and chemical alteration in rock; it differs with respect to bedding, foliation, or direction of principal residual stress.

Modulus class	Range of static modulus of elasticity (psi)
Very high	$>12 \times 10^6$
High	$8 \times 10^6 - 12 \times 10^6$
Medium	$4 \times 10^6 - 8 \times 10^6$
Low	$1 \times 10^6 - 4 \times 10^6$
Very low	$<10^6$

[7]Number "1" indicates rock most difficult to drill. Numbers increase with ease of drilling.

Equivalent geologic units—Continued

Map unit 6, Granitic rocks

Grant Mills Granodiorite
Guilford Quartz Monzonite
Haddam Gneiss
Harrison Gneiss
Hope Valley Alaskite Gneiss
Hubbardston Granite
Kensington Quartz Diorite
Mamacoke Gneiss
Maromas Granitic Gneiss
Maskerchugg Granite
Metacom Granite Gneiss
Middletown Gneiss
Milford Granite
Mine Hill Granite Gneiss
Narragansett Pier Granite
Newburyport Quartz Diorite
Nonewaug Granite
Norbeck Quartz Diorite
Northbridge Granite Gneiss
Occoquan Granite
Peabody Granite
Peekskill Granite
Ponaganset Gneiss
Port Deposit Granodiorite Gneiss
Potter Hill Granite Gneiss
Poundridge Leucogranite
Prospect Gneiss
Quincy Granite
Ravenswood Granodiorite
Redstone Granite
Relay Quartz Diorite
Scituate Granite Gneiss
Sharon Syenite
Sharpers Pond Tonalite
Springfield Granodiorite
Sterling Granitic Gneiss
Stony Creek Granite
Ten Rod Granite Gneiss
Westerly Granite
Westwood Granite
Willimantic Gneiss
Wolfpen Tonalite
Woodbridge Granite
Woodbury Granite
Woodstock Granodiorite
Woodtick Gneiss
Yonkers Granite
Numerous unnamed bodies

Map unit 11, Coarse mica schist and mica gneiss

Nipsachuck Gneiss
Orange Phyllite
Oxford Schist
Partridge Formation
Paxton Quartz Schist
Putnam Gneiss (part)
Quinebaug Formation (part)
Scotland Schist
Southington Mountain Schist
Straits Schist
Taine Mountain Formation (part)
Tatnic Hill Formation (part)
Waramaug Formation
Wepawaug Schist
Wissahickon Formation (eastern sequence)
Woonasquatucket Formation
Worcester Formation (part)
Numerous unnamed units

Description of bedrock samples from beneath Coastal Plain deposits

Sample number and locality	Type of sample	Megascopic description	Mineralogy: Major	Mineralogy: Minor	Probable map unit
I, sheet 2 Well No. 7, Carneys Point Works, E. I. Du Pont Co., Salem County, N. J. Samples from 542 and 555 ft.	Several small pieces of decomposed rock.	Speckled light-bluish-gray highly friable, badly disintegrated rock. Gneissic foliation visible in larger chips. Grain size about 1–2 mm.	Quartz Plagioclase (strongly sericitized) Biotite Chlorite	Muscovite Ilmenite Hematite Zircon	Texture and general composition similar to light-colored layers in Wilmington Complex; pyroxene of that unit may have been altered by weathering. Unit 3 (?).
II, sheet 2 Test holes 1 to 9, Repauno Works, Thompson Point, north of Gibbstown, N. J. E. I. Du Pont Co. Samples from beneath about 100 ft of overburden.	BX core, firm rock (logged in detail by F. J. Markewicz, New Jersey Geological Survey).	Strongly foliated coarse mica schist containing numerous interbeds of amphibolite and granitoid muscovite-quartz-feldspar gneiss; numerous pegmatite dikes.	Quartz Plagioclase Muscovite Biotite Garnet Hornblende in amphibolites		Typical Wissahickon Schist; permeated by granitic rock. Unit 11 and unit 6.
III, sheet 2 Test well at New Brooklyn, Camden County, N. J. Sample from 2,090 ft.	Core, 1 x 3 in.; firm rock, but not fresh.	Dark-gray, biotite-rich, even-textured, medium-grained, well-foliated schist and gneiss.	Quartz Plagioclase (strongly sericitized) Biotite Muscovite Sillimanite (fibrolite)	Sphene Epidote Zoisite Magnetite Zircon Andalusite(?)	Tentatively assigned to unit 11.
IV, sheet 2 Test well at Butler Place, N. J. Sample from 2,273–2,284 ft.	Several chunks of large core; ranges from friable decomposed rock to firm but not fresh rock.	Fine-grained, greenish-gray carbonate rock with good millimeter-scale laminations. Excellent lineation of oriented biotite plates on surfaces of laminae.	Carbonate (40 percent of rock) Phlogopitic biotite Chlorite Assemblage of clay: mostly fine chlorite, montmorillonite, and illite. (40 percent of rock)	Quartz	Origin uncertain: could be weathered, impure, metamorphosed dolomite, or a silicate schist that has been partly replaced by carbonate. Assigned to unit 10 on basis of carbonate content.
V, sheet 3 Test well No. 1, West Windsor, N. J. Sample from 201–205 ft.	Several small pieces of thoroughly decomposed rock.	White, friable decomposed rock retaining good foliation.	Quartz Muscovite Aggregate of white clay minerals; dominantly illite.		Derived from coarse mica schist. Unit 11.
VI, sheet 3 Well at Punk Brothers Farm, Imlaystown, Monmouth County, N. J. Bailer samples from 916–920 ft.	Two small pieces of thoroughly decomposed rock.	Dark-greenish-brown to gray, fine- to medium-grained decomposed rock.	Quartz Biotite Muscovite Aggregates of white clay minerals, probably altered feldspar.	Apatite Carbonate Sphene Zircon Opaques	Probably derived from biotite-rich schist. Tentatively assigned to unit 11.
VII, sheet 3 Probe hole, Strathmore at Matawan, Monmouth County, N. J. Samples from 726–733 ft.	Several small side wall cores in thoroughly decomposed rock.	Red to white muscovite-rich decomposed rock retaining good foliation.	Quartz Biotite (in all stages of "bleaching") Muscovite Aggregate of white clay minerals; both kaolinite and illite present.	Hematite Limonite	Probably derived from mica schist. Tentatively assigned to unit 11.

ENGINEERING GEOLOGY OF THE NORTHEAST CORRIDOR, WASHINGTON, D.C., TO BOSTON, MASSACHUSETTS
BEDROCK GEOLOGY

Prepared by the
United States Geological Survey
at the request of the
United States Department of Transportation
1967

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