Geology and Ground-Water Resources of the Fairfax Quadrangle Virginia

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1539-L

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By PAUL M. JOHNSTON

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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GEOLOGY AND GROUND-WATER RESOURCES OF THE FAIRFAX QUADRANGLE, VIRGINIA

By Paul M. Johnston

ABSTRACT

Rapid development of the suburban area surrounding Washington, D.C., since World War II has created an urgent need for ground-water information.

The Fairfax quadrangle, the northeast corner of which is about 11 miles west of the White House in Washington, D.C., is underlain by metamorphic rocks of the Wissahickon formation and associated silicic (granitic) and mafic (basaltic) intrusives. These rocks are overlain by sediments of Triassic and Recent age, which are thin and cover relatively small areas.

The Wissahickon formation is composed of phyllite derived from shale and siltstone, interbedded with coarser quartz-mica schist and quartzite. Intruded into the Wissahickon is a large body of strongly altered mafic igneous rock of heterogeneous composition, which is mapped as greenstone. Large and small bodies of granite intrude the Wissahickon, and smaller bodies intrude the greenstone.

The principal structural feature of these rocks is the schistosity, which is most highly developed in the Wissahickon and which generally follows the regional northeastward trend. The dip of the schistosity is generally vertical or to the northwest. Two sets of joints are prominent, one striking northeastward and dipping 30° to 40° SE., and the other striking northwestward to westward and dipping 60° NE. to vertically.

Until 1957 the entire population of 16,510 in the Fairfax quadrangle was supplied with water from wells and springs. A pipeline connection with the Falls Church system (for which water is obtained from the District of Columbia system) in 1957 furnished water to the town of Fairfax for peak demands.

Most of the water from wells in the Fairfax quadrangle is obtained from fractures in the bedrock, but some comes from the weathered residual soils overlying the bedrock; small amounts are obtained from alluvium.

Records of 434 wells and springs were collected and are listed in a duplicated report (Johnston, 1960). Wells are of three types of construction—drilled, bored, or hand dug. Drilled wells generally furnish a permanent supply and are least subject to pollution when properly constructed. Bored and dug wells have a greater storage capacity and are satisfactory in some locations, but are easily polluted. If not favorably located or if too shallow, they may fail in dry weather.

Ground-water supplies adequate for domestic use, 5 to 10 gpm (gallons per minute), are obtainable in most places, except in parts of the areas underlain by greenstone and granite. The largest yields are obtained in the greenstone contact complex, where domestic wells 52 to 250 feet deep produce 5 to 55 gpm. The least productive aquifer is the greenstone, from which privately owned wells 40 to 160 feet deep yield only 0.4 to 12 gpm. Intermediate yields, 1 to 32 gpm, are obtained from the Wissahickon formation and the granite, through wells 31 to 550 feet deep. Fairfax municipal wells, not included above, penetrating the Wissahickon, the greenstone contact complex, and the greenstone are 165 to 809 feet deep and yield 15 to 125 gpm.

Careful selection of well sites, taking into account the geology (including rock type and structure) and the topography, usually results in greater yields and may mean the difference between success and failure in developing a water supply.

Ground water in the Fairfax quadrangle is generally of good quality, although excessive iron content and corrosiveness are problems in some places. Water from the greenstone is harder and contains more dissolved solids than that from the other formations.

It is estimated that an average of 1,650,000 gpd (gallons per day) was being pumped from wells in the Fairfax quadrangle as of 1957. In years of normal precipitation an average of 23 million gpd is estimated to be available for recharge (p. 39). It therefore appears that the withdrawal could be increased considerably without exceeding the potential recharge. Records of an observation well near Fairfax show no evidence of a sustained downward trend of the water level.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

Since World War II, the suburban area surrounding Washington, D.C., in common with most other metropolitan centers in this country, has developed rapidly. The movement of the population to the suburbs brings with it the demand for new homes; towns and villages in the suburban area are overrunning their limits, and subdivisions are springing up in the outlying open country. The construction of new schools, the movement of some Government agencies to the suburbs, and the establishment of military installations and new industry in the suburbs all bring demands for additional water supplies. Many of these developments are far from city water lines and from usable streams; hence, ground water is the only feasible source of supply.

Published ground-water data on the District of Columbia and the Virginia portion of the Washington area are now out of print (and also out of date), and recent information on the Maryland part of the area is published only in the reports of that State.

This report is a byproduct of an investigation on the geology and ground-water resources of Washington, D.C., and vicinity. No recent geologic map of the Virginia portion of the Washington metropolitan area was available, although an unpublished map of the Fairfax 15-minute quadrangle was completed by A. P. Bennison and Charles Milton of the Geological Survey in 1950. In 1953, after the topographic map of the Fairfax quadrangle was published in the 7½-minute series, it was considered advisable to remap the geology on the new base for publication and to trace the rock units into the Washington area. It was remapped, accordingly, at the larger scale by Charles Milton and the author, and is to be published as part of the geologic quadrangle map series of the Geological Survey at a scale of 1:24,000. Meanwhile, a modified version of this map at a scale of 1:48,000 is included as plate 1 of this report and, together with the ground-water data, is being published preliminary to the report on the Washington metropolitan area in order to make the information available to the public as soon as possible.

The fieldwork for this project was done concurrently with other assignments in the years 1954 to 1957. A total of 403 wells and 31 springs were inventoried, which probably represent not more than 20 percent of those existing at the time the survey was made, but which are typical of wells and springs throughout the quadrangle.

Physical data for each well and spring were collected and are presented in a duplicated report (Johnston, 1960). The locations of the wells and springs are shown on plate 2. Analyses of 35 water samples form the basis of the section on "Quality of water." Well data and water-bearing characteristics for each rock unit were compared.

In summary, the purpose of this report is to provide information on the geology and ground-water resources of the Fairfax quadrangle for use in planning future development and to point out sources of ground-water supplies in the Washington area.

The work was done under the supervision of V. T. Stringfield of the Ground Water Branch of the U.S. Geological Survey. Chemical analyses of water samples were made under the supervision of D. E. Weaver, chemist in charge, Quality of Water Laboratory, Washington, D.C.

LOCATION OF THE AREA

The Fairfax quadrangle is bounded by latitudes 38°45′ and 38°52′30″ N. and longitudues 77°15′ and 77°22′30″ W. and comprises 58 square miles. (See fig. 1.) Its northeast and southwest corners are 11½ and 21 miles (airline) southwest of the White House in Washington, D.C. Its principal town, Fairfax, the county seat of Fairfax County, is about 17 miles southwest of the White House via U.S. Routes 50–29–211.

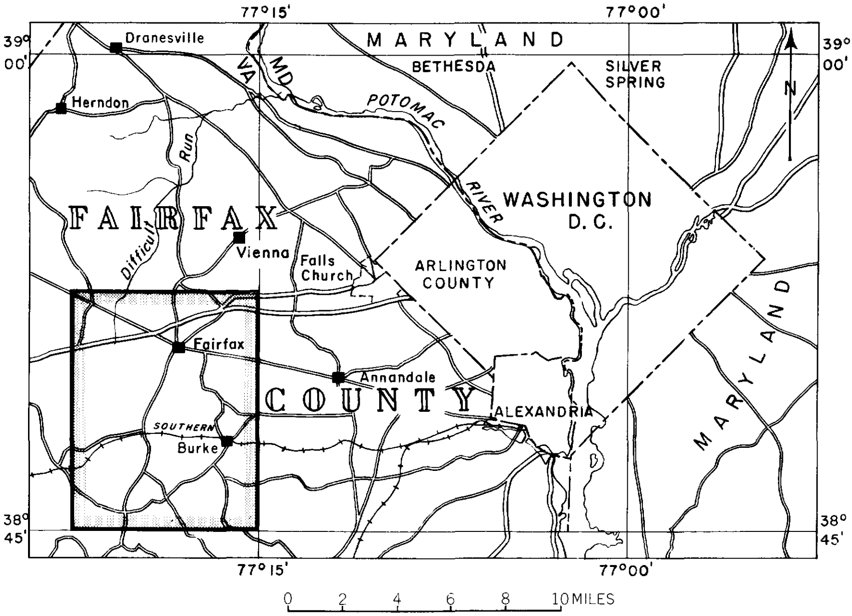

Figure 1.—Map showing location of the Fairfax quadrangle.

PREVIOUS INVESTIGATIONS

Previous reports (Cady, 1933, 1938) describing the ground-water resources of the Fairfax quadrangle were published by the State of Virginia in cooperation with the U.S. Geological Survey. The 1938 report, which superseded the one published in 1933, included six counties in northern Virginia, including Fairfax. The geologic map accompanying the report is based on the "Geologic Map of Virginia," (Virginia Geol. Survey, 1928). Lonsdale, in a report published in 1927, described and mapped the geology of the gold-pyrite belt in an area extending into the southern part of the Fairfax quadrangle.

ACKNOWLEDGMENTS

Acknowledgment is made to the author's associates in the U.S. Geological Survey: to Charles Milton for petrologic and geologic data, a part of which were abstracted from unpublished notes, and especially to Edward C. T. Chao for helpful cooperation in field and laboratory; to Arthur R. Levey, who collected many of the well data and assisted in other ways; and to William W. Kephart, who tabulated well data and assisted in statistical studies.

Well drillers, without exception, generously gave access to their records, and the public cooperated by furnishing information on wells.

Information was supplied on population, industry, and transpor-

tation by the Fairfax County Planing Commission; on agriculture by the Fairfax County Agent, Department of Agriculture; on population by the Bureau of the Census; on climate by the U.S. Weather Bureau; and on water supply by the Engineer's Office of the town of Fairfax.

WELL-NUMBERING SYSTEM

For the purpose of locating and identifying wells, the Fairfax quadrangle (pl. 2) was divided into nine parts bounded by the 2½-minute parallels and meridians. The rectangles thus formed were lettered "A," "B," and "C" from top to bottom and "a," "b," and "c" from left to right, as shown on plate 2.

The wells were then numbered consecutively within each rectangle, the letter prefix indicating the rectangle in which the well was located. For example, well Aa–1 was the first well inventoried in the extreme northwest rectangle, and Cc–42 was the last well inventoried in the southeast rectangle.

GEOGRAPHY

SURFACE FEATURES

The Fairfax quadrangle lies near the east edge of the Piedmont province, a dissected peneplain that extends from Maine to Alabama. The peneplain in the latitude of Fairfax is approximately 40 miles wide between the Blue Ridge and the Fall Line. Southeast of the Fall Line, which may be defined as a line passing through the falls of the major rivers and which marks the boundary between the Piedmont and the Coastal Plain provinces, the hard rocks which are exposed in the Piedmont lie beneath unconsolidated gravel, sand, and clay of post-Jurassic age. None of these Coastal-Plain sediments has been recognized in the Fairfax quadrangle; probably they were once present but have since been removed by erosion. The nearest remaining Coastal-Plain deposits are 2½ miles to the east and northeast, in the Annandale and Falls Church quadrangle.

The upland surface of the Fairfax quadrangle is a somewhat dissected plain sloping about 12 feet to the mile from northwest to southeast. The total relief is about 290 feet, from the highest point north of Pender, at 490 feet above sea level, to the lowest points in the beds of Pohick Creek, Middle Run, and Wolf Run, at about 200 feet above sea level.

PHYSIOGRAPHIC HISTORY

In pre-Cretaceous time, more than 125 million years ago, the Piedmont was worn down almost to a plane surface. Before burial by Cretaceous sediments, the Piedmont was tilted eastward, so that the pre-Cretaceous surface east of the Fall Line is preserved beneath the Coastal Plain. West of the Fall Line, the streams were rejuvenated and began to cut deeper into the bedrock. Subsequent intermittent uplift (Fenneman, 1938, p. 161) resulted in increased cutting by the streams. The region was raised to its present height at a relatively late time (Fenneman, p. 158).

The stream pattern of the Fairfax quadrangle shows considerable control by the bedrock structure. Pohick Creek and the lower course of Accotink Creek may have been given their original direction by the seaward tilt of the land surface; but this is also the direction of a major set of joints in the rocks, and many small tributaries are carved out in the same direction. The upper courses of Accotink Creek, Difficult Run, Popes Head Creek, and many smaller streams tend to follow the regional schistosity, which is about at right angles to the general southeastward slope. Headwater streams that have not cut through the mantle of weathered rock are not controlled by the bedrock structure.

A body of resistant greenstone not yet deeply dissected by streams forms an even upland surface, which is followed from southwest to northeast by Braddock Road, Shirley Gate Road, and Jermantown Road.

DRAINAGE

All the streams in the Fairfax quadrangle drain into the Potomac River. The northwest corner of the quadrangle is drained by Difficult Run and its tributaries. Difficult Run rises near Lee Highway west of Fairfax and flows northward and northeastward to join the Potomac River just below Great Falls. The waters of Popes Head Creek and its tributries, which drain a large area south and west of Fairfax, reach the Potomac by way of Bull Run and Occoquan Creek. Wolf Run and Sandy Run and their tributaries drain the southwestern part of the quadrangle and flow into Occoquan Creek. The area east of Germantown Road and Ox Road (State Route 123), more than half the area of the quadrangle, is drained by Accotink and Pohick Creeks and their tributaries. Both these streams flow southeastward into Gunston Cove on the Potomac River.

CLIMATE

The climatological data given in this report were furnished by the U.S. Weather Bureau (1956) and are based on records compiled at the M Street station and at Washington National Airport, which is about 14 miles east of Fairfax and about 400 feet lower in altitude. Except that the average temperature must be slightly lower because of the altitude, the climate of the Fairfax quadrangle is similar to that at Washington.

As the Weather Bureau report states, "Summers are warm and humid and winters mild; generally pleasant weather prevails in spring and autumn. The coldest weather normally occurs in late January and early February, when average low temperatures are in the upper twenties and average high temperatures in the middle forties. The warmest weather normally occurs in the middle of July, with average daily high temperatures in the upper eighties. The record high temperature of 105.6° occurred on July 20, 1930. The record low temperature of −14.9° occurred on February 11, 1899."

The normal annual precipitation at Washington is about 41 inches, rather evenly distributed throughout the year. The maximum rainfall for a 24-hour period was 7.31 inches, recorded on August 11–12, 1928. The longest period without appreciable rainfall lasted 28 days, from October 15 to November 11, 1901.

The average annual snowfall is about 20 inches; the greatest recorded single fall was 28 inches, on January 27–29, 1922. "Snowfalls approaching the magnitude of this storm, however, are rare and the snow accumulation of the normally bad winter storms is nearer 10 inches than 30." Usually the 10-inch falls melt off in 2 to 4 days.

"The average length of the growing season is 200 days. The average date of the last killing frost in spring is April 10 and the latest recorded date May 12, 1913. The average date of the first killing frost in the fall is October 28, and the earliest recorded date, October 2, 1899."

ECONOMIC DEVELOPMENT

Fairfax County has an area of 406 square miles; the Fairfax quadrangle includes about 58 square miles, approximately 14 percent of the area of the county. In 1950 the population of the Fairfax quadrangle was about 7,100, including 1,946 in the town of Fairfax. In January 1957, the population of the quadrangle was about 16,510, which included 6,300 in the town.

AGRICULTURE

Although the area is rapidly becoming urbanized, agriculture is still important in the Fairfax quadrangle. Forage and grain crops, cattle, hogs, and poultry are raised, and two dairy farms are operated. About 75 percent of the area is in woodland and brush; most of the timber is hardwood (ash, oak, yellow poplar, and hickory), but there is some softwood (pine and cedar). Portable sawmills are operated in several places.

INDUSTRY

As of 1957, the Fairfax quadrangle had very little industry. A radio station, a General Motors training schol, and a supply warehouse at Fairfax Station constituted the main industries in the area.

TRANSPORTATION

The Southern Railroad crosses the quadrangle from east to west. It makes one freight stop, at Fairfax Station, but gives no passenger service. Bus service to Arlington and Washington, D.C., is provided by the Washington-Virginia-Maryland Coach Co., and through bus service is provided by the Virginia Trailways and Greyhound Lines.

MINERALS

No minerals are now produced in the area. Greenstone was once quarried near Westmore, but the quarry has been abandoned for many years. Prospect pits in quartz veins and talc deposits have been opened in many places, but no further work has been done. Small quantities of gold can be panned from some of the streams.

PUBLIC WATER SUPPLIES

As of April 1957, the entire municipal and domestic water supply of the Fairfax quadrangle was obtained from wells within the quadrangle. The town of Fairfax has a municipal system supplied from 12 wells; however, many private wells still are in use within the town limits. Since April 1957, to furnish water for peak demands, the town has constructed a pipeline to connect with the Falls Church system, which in turn is supplied from the Potomac River by the District of Columbia. Fairfax also has a plan to obtain a surface-water supply from a proposed dam on Goose Creek, about 20 miles to the northwest.

The following information on the water supply of Fairfax was obtained from the town engineer:

Period	Number of wells in use	Total consumption (gallons)	Number of services (outlets)	Pumpage (gpm)	Consumption (gallons per day per service)
July 1-31, 1953	7	6,375,500	956	155	222
Feb. 15-Mar. 15, 1957	12	16,119,200	2,200	386	253

The Annandale Water Co. has two wells at Pine and Hill Streets in Fairfax Acres, north of the corporate limits of Fairfax, which supply water to 90 homes in that area.

GEOLOGY

GEOLOGIC HISTORY

The rocks of the Fairfax quadrangle and adjacent regions include representatives of the three broad groups of rocks—sedimentary, metamorphic, and igneous. Only small areas are covered by sedimentary rocks, which include stream-channel and colluvial deposits (slope wash) of Recent age and a remnant of the Manassas sandstone of Roberts (1923), of Triassic age, which caps the hill at Pender.

The sedimentary rocks everywhere are underlain by igneous and metamorphic rocks of pre-Triassic age. The metamorphic rocks were derived from much older sediments and from igneous rocks. Intermediate in age between the Triassic and Recent sediments and these older metamorphic rocks are igneous intrusive rocks, which include mafic (basaltic) and silicic (granitic) types.

The metamorphic rocks, which underlie the greater part of the quadrangle, include the Wissahickon formation and the greenstone, which is intrusive in the Wissahickon formation. These rocks have had a long and complicated history, and their age has been the subject of controversy for many years.

In most literature published since 1910 the age of the Wissahickon is given as Precambrian. However, some earlier geologists considered it to be of Cambrian and Ordovician age, a conclusion which seems to be strengthened by later work in Pennsylvania and Maryland (Miller, 1935; Mackin, 1935; Woodward, 1935; Cloos and Hietanen, 1941; Scotford, 1951; Whitaker, 1955). The lack of fossils in the Wissahickon thus far has precluded absolute proof, but evidence points to the conclusion that the rocks of the Wissahickon are the metamorphic equivalents of Paleozoic rocks farther west. The problem may in time be resolved by geochemical dating methods, or diagnostic fossils may yet be discovered, but for the present the age is considered to be early Paleozoic.

The history of these rocks began with the deposition of sediments in the sea at least 350 million years ago. After consolidation, the rocks were raised above the sea and were invaded by mafic magmas, which in some places reached the surface and issued as volcanic rocks. Much later, in late Paleozoic time, strong compressive forces acting from the northwest or southeast buckled the earth's crust and compressed the beds into tight folds. During and after this mountain-building activity, probably in late Paleozoic time (Cloos and Hershey, 1936, p. 80), the Wissahickon was invaded by another series of intrusions, involving both silicic and mafic magmas. These magmas congealed at some depth below the surface, producing granitic and gabbroic rocks. Lonsdale (1927) mentioned post-Cambrian and post-Ordovician granitic rocks in the Piedmont in Stafford and Prince William Counties, Va., a few miles south of Fairfax County; Knopf and Jonas (1929) described Paleozoic granitic rocks in Baltimore County, Md.

After the mountain-building period, erosion removed much of the roof rock before the region again sank beneath the sea. Triassic sediments that were deposited upon the eroded surface were later invaded by another series of mafic intrusions (Triassic "trap," or diabase). At the close of the Triassic, the area was tilted and faulted and low mountains were formed, but the geologic record gives no evidence of further extensive folding in this area.

During the Jurassic this region probably remained above sea level, for no Jurassic sediments have been recognized. Erosion reduced the region to a peneplain; eastward tilting brought its eastern part beneath the sea and increased stream cutting in the western part. Cretaceous and younger sediments were deposited in and near the sea. During Pleistocene time, sea level declined and recovered with the advance and retreat of the continental glaciers (Cooke and others, 1952, p. 42). However, the continental ice sheets never advanced south of central Pennsylvania and northern New Jersey.

Coastal-Plain sediments of post-Jurassic age probably once covered the Fairfax region but have since been removed by erosion. The nearest deposits are remnants at Annandale and Tysons Crossroads, east and north of the Fairfax quadrangle.

Relatively minor faulting has taken place in the Piedmont since Cretaceous time, as shown by faulting of the Wissahickon over Cretaceous sediments in the District of Columbia (Carr, 1950, p. 21) and elsewhere (White, 1952, p. 745).

GEOLOGIC FORMATIONS

WISSAHICKON FORMATION

The oldest and most extensive rocks in the Fairfax quadrangle are those which make up the Wissahickon formation of early Paleozoic(?) age. (See table 1.) The Wissahickon, which is composed of phyllite, schist, and quartzite, is the southwest extension of the formation mapped as the Carolina gneiss by Darton and Keith (1901) and shown as the Wissahickon schist on the "Geologic Map of Virginia" (Virginia Geol. Survey, 1928).

Originally considered by Bascom (1905) to be Ordovician, the Wissahickon was named by her from exposures along Wissahickon Creek in Fairmount Park, Philadelphia, Pa. Exposures of the formation extend from Pennsylvania to Alabama, passing beneath the sedimentary rocks of the Coastal Plain on the north and south, and in some places on the east.

TABLE 1.—*Geologic formations and their water-bearing properties, Fairfax quadrangle, Virginia*

System	Series	Formation	Lithology	Water-bearing properties
Quaternary	Recent	Alluvium	Gravel, sand, silt, and clay beneath flood plains and along stream channels.	Not important as a water-bearing formation because of thinness and small areal extent.
		Colluvium (slope wash).	Sand, silt, and clay containing quartz fragments, on uplands and terraces.	Areally extensive but not important as a water-bearing formation because of thinness. A few dug wells may obtain at least some water from this unit.
Triassic	Upper Triassic	Diabase	Coarse-grained gray to black diabase ("traprock").	Outcrops only in one small area near Burke. Insignificant as a water-bearing formation.
		Manassas sandstone of Roberts (1923).	Red or purplish sandy clay containing scattered pebbles and cobbles of schist, sandstone, and quartz.	Not important as a water-bearing formation because of thinness and small areal extent. A few dug wells near Pender tap it.
Age undetermined		Granite	Fine- to coarse-grained gray, white, or pink massive to schistose granite. Maximum depth of weathering reported to be 143 feet.	Domestic supplies available in most places, especially where rock is sheared. Average yield of wells, 12 gpm. In some areas massive granite yields little water. Water generally of good quality.
Age undetermined		Greenstone contact complex.	Includes chlorite schist, sericite-chlorite schist, quartz schist, talc schist, and minor amounts of quartzite. Rocks distorted to a varied degree. Maximum depth of weathering reported to be 88 feet.	Most productive aquifer in quadrangle. Domestic wells average 18 gpm. Town of Fairfax has 7 wells, 165 to 612 feet deep, that tap this formation; their yields average 57 gpm. Domestic supplies are available almost everywhere. Quality variable but generally good; water contains excessive amounts of iron locally.
Age undetermined		Greenstone	Mafic rocks including metabasalt, metadiabase, metagabbro, amphibolite, serpentine, soapstone, chlorite and talc schist. Mostly resistant to weathering; maximum depth of weathering reported to be 48 feet.	Poorest aquifer in quadrangle. Well yields average 6 gpm. Bored wells generally not feasible because of hardness of rock. Water generally of good quality but hard locally.
Early Paleozoic(?)		Wissahickon formation.	Phyllite, schist, and quartzite containing quartz veins. Average depth of weathering ranges from 59 feet in gullies to 102 feet on uplands.	Most extensive and thus most important aquifer in quadrangle. Average yield to wells is 12 gpm. Domestic supplies available almost everywhere. Quality variable but generally good. Water contains excessive amounts of iron locally.

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The "Geologic Map of Virginia" indicates that the Fairfax quadrangle area is underlain by the Wissahickon schist, intruded by granite on the east and south. The legend describes the Wissahickon as "chlorite-muscovite schist with quartzite in lower part; containing thin greenstone lava flows near base; garnetiferous biotite schist locally containing staurolite, sillimanite, and kyanite."

In the Fairfax quadrangle the quartzite beds are a minor part of the Wissahickon, which appear to be distributed throughout the section. The "Geologic Map of Virginia" does not distinguish the large body of greenstone in the northwestern part of the quadrangle (pl. 1), which is intrusive rather than extrusive. No staurolite, sillimanite, or kyanite has been found in the Fairfax quadrangle.

The Wissahickon in the Fairfax quadrangle is predominantly a platy phyllite, derived from shale and siltstone; it is interbedded with coarser quartz-mica schist and sandstone, which in part have been altered to quartzite. In the finer grained phases the cleavage of the rocks commonly is platy, but some crumpling has been noted, especially northwest of Fairfax. The fresh, unweathered rocks are gray, bluish gray, greenish gray, buff, or various shades of brown. The principal constituents are sericite, very fine grained quartz, and variable amounts of chlorite. Accessory minerals are pyrite, magnetite, and ilmenite. With increasing abundance and coarseness of the quartz, the rocks grade into a quartzite that in places resembles fine-grained granite in hand specimens. Some of the quartzite contains biotite and small octahedrons of magnetite.

Along the Southern Railroad west of Fairfax Station, and along Guinea Road, the finer grained phyllitic rocks are well exposed. (See fig. 2.) Farther west and southwest along the railroad, the rocks become more sandy. In road cuts along U.S. Route 50 just east of Difficult Run (fig. 3) and along the road leading from Jermantown Road to Waples Mill, beds of slightly altered brownish sandstone 2 to 3 inches thick alternate with silty beds. In these localities, the schistosity parallels the bedding. Quartzite occurs also along Rabbit Branch northwest of Burke, along the lower course of Long Branch, and near Ilda.

The Wissahickon formation weathers rapidly, producing a buff-colored, reddish, yellow, or drab clayey silty soil. The finer grained rocks are relatively unresistant to weathering; the coarser grained are more resistant, but in general the formation is weathered so deeply that its is exposed only in creek beds or in deep road or railroad cuts.

The average depth of weathering, estimated from the depth to which well casing can be driven, is about 100 feet on uplands, 95 feet on hilltops, 90 feet on hillsides, and 60 feet in gullies.

FIGURE 2.—Wissahickon formation, phyllitic phase, along Guinea Road northeast of Pohick Road.

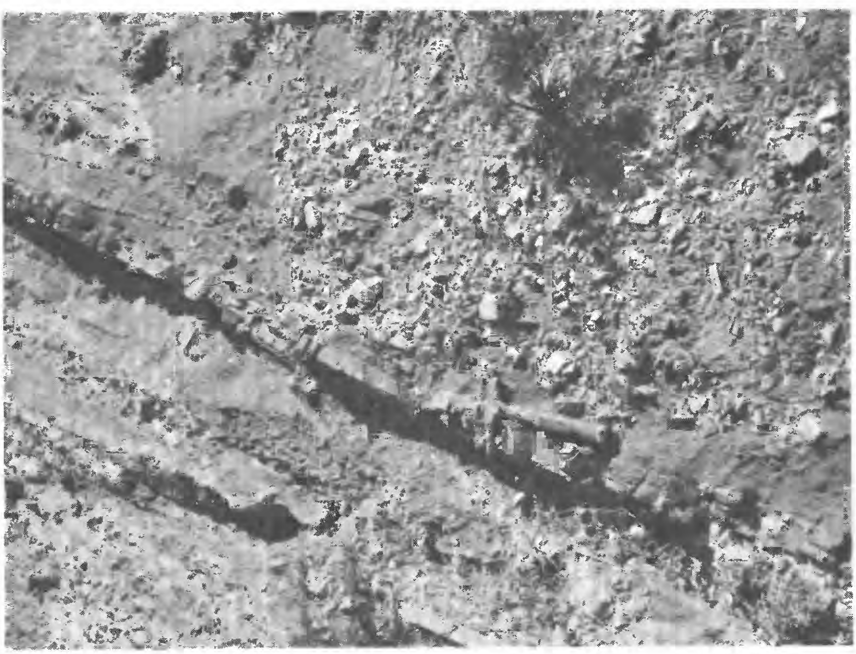

FIGURE 3.—Wissahickon formation showing interbedded quartzite, U.S. Route 50, east of Difficult Run.

The schistosity of the Wissahickon formation follows generally the northeastward trend common to the rocks of the Piedmont. The strike in the Fairfax quadrangle ranges generally from N. 17° W. to N. 53°E., but most commonly it is between N. 8° E. and N. 53° E. On the east and south, near the granite intrusions, the trend is deflected somewhat to the west. Here the strike averages nearly north, ranging between N. 17° W. and N. 13° E. The dip of the schistosity ranges from 45° NW. to vertical, but commonly is between 60° and vertical; it is almost vertical near the northwest corner of the quadrangle.

Observations of the joint system are few because of the deep weathering, but a set of nearly vertical joints strikes northwest to west and a set striking northeast dips about 30° SE. A third set, less prominent, also strikes northeast but dips 40° NW.

GREENSTONE

A sinuous body of greenstone, the only large body of mafic metamorphic rock in the quadrangle, crosses the northwestern part of the quadrangle from Blevinstown and Robeys Mill on the west to the vicinity of Jermantown Road on the north, where it passes out of the quadrangle. It ranges in width from 0.5 mile to 1.3 miles.

The greenstone occurs in an area shown as the Wissahickon schist on the "Geologic Map of Virginia" (Virginia Geol. Survey, 1928). However, the legend on the map indicates "thin greenstone lava flows near the base of the Wissahickon." Although not truly descriptive, this statement may refer to the intrusive body described here. Mafic and ultramafic rocks are described by several authors as being included in the Wissahickon. Knopf and Jonas (1923) described amphibolite schists derived from mafic intrusives and volcanic rocks in the Wissahickon in southern Pennsylvania and Maryland as "lithologically similar to the greenstone schists in Catoctin Mountains and probably represent basaltic flows * * * epidotized and recrystallized, but show amygdule-shaped areas of quartz and feldspar that indicate original effusive structure."

Postel and Adelhelm (1943) described a body of hydrothermally altered ultrabasic rocks 100 feet wide in the Wissahickon at its type section in Pennsylvania as "mappable zones of talc-anthophyllite, talc-serpentine and chlorite rocks."

The mafic and ultramafic rocks of the Fairfax quadrangle making up the rock unit called greenstone are a heterogeneous assemblage of hard to soft coarse- to fine-grained massive (fig. 4) to schistose rocks (fig. 5) in various shades of gray and green to black. Included in the unit are metabasalt, metadiabase, metagabbro, amphibolite, serpen-

FIGURE 4.—Massive greenstone in abandoned quarry, 1.4 miles west of Fairfax courthouse.

FIGURE 5.—Greenstone, chlorite schist phase, U.S. Route 50, 0.5 mile west of Jermantown.

tine, soapstone, chlorite schist, talc schist, and chlorite-talc schist. E. C. T. Chao of the Geological Survey (oral communication, 1957) reported norite (hypersthene gabbro) in the adjoining Manassas quadrangle southwest of Blevinstown, probably extending into the Fairfax quadrangle, where the mafic rocks have not been subdivided. Minor amounts of magnetite, sphene, zoisite, actinolite, and asbestos are found. Many small granitic dikes, sills, and irregular granitic bodies intrude the greenstone.

Most of these rocks are moderately resistant to weathering, and some are extremely so; hence, they are exposed in many places, even on the uplands. The thin brownish soils that develop on the greenstone surface are not very fertile; usually they are not cultivated but are allowed to grow up in woodland and brush. In places where the weathered zone is more than a few feet thick, the iron in the soil tends to leach out and a light-greenish-gray silty clay develops on the surface. The rocks are well exposed in stream bottoms, along Shirley Gate Road and Braddock Road west of their intersection, and along U.S. Route 50 east of Difficult Run.

In many areas underlain by greenstone, particularly southwest of Fairfax, the use of septic tanks is impractical because of the general low permeability of the rocks, and primitive sanitary facilities are the only alternative.

The depth of weathering of the greenstone has been estimated from the depth to which well casing is driven. Only a few feet of casing is necessary in the massive varieties, but casing may be driven considerably deeper in the chlorite and talc schists. Well records show an overall range of 7 to 48 feet in length of casing and an average of 22 feet of casing on the uplands. Not enough information is available for estimates on other areas.

The trend of the schistosity in the greenstone is more erratic than in the Wissahickon formation. The main body of rock follows generally the regional northeastward strike, and the schistosity commonly is parallel to the contacts. In general, the strike ranges from N. 17° W. to N. 80° E. However, most of the observations fall between N. 7° W. and N. 43° E. Observations on the dip of the schistosity indicate a range from vertical to 40° NW., but most dips are steeper than 70°.

Three major joint sets strike and dip as follows:

1. Strike, N. 60° W.; dip, 85° S.
2. Strike, N. 80° E.; dip, 30° S.
3. Strike, due N.; dip, 45° W.

Besides the main body of greenstone, minor bodies of mafic and ultramafic rocks are intruded into the Wissahickon formation. Most of these are too small to show at the scale of plate 1, but one amphibole dike is shown about 1.5 miles north of Burke. It is about 30 feet wide and can be traced for about 1,800 feet.

No evidence has been found that any of the greenstone bodies of the Fairfax quadrangle originated as lava flows, as described by other authors. No amygdaloidal, scoriaceous, or vesicular structures have been recognized. On the other hand, areas on both sides of the major greenstone body show evidence of contact metamorphism.

GREENSTONE CONTACT COMPLEX

The enclosing rocks on each side of the greenstone intrusive are altered to a varied degree, the principal effect being the development of chlorite and serpentine. The finer grained rocks—schist and phyllite—appear to have been the most susceptible to alteration; the quartzites, the least. In general, however, the rocks retain many of the characteristics of the normal Wissahickon.

Along the eastern border of the intrusive, the contact zone is wider and the rocks are more strongly altered than on the west. This may be due to differences in susceptibility to alteration, to the shape of the intrusive, or to both. The contacts are gradational on both sides, and show a gradual diminution of ferromagnesian minerals outward from the intrusion.

The contact complex comprises a variety of rocks including chlorite schist, sericite-chlorite schist, chlorite-quartz schist, talc schist, and minor amounts of quarzite. Bodies of both mafic and felsic intrusive rocks, none of large size, cut the schists in many places. The dark-colored intrusive rocks commonly are concordant with the schistosity; the granitic rocks in many places follow the joints as well as the schistosity. Mafic intrusive rocks show a greater degree of shearing and crushing than the granitic rocks and are intruded by them. The largest granitic intrusion observed in the contact complex is a body having indefinite boundaries, which occurs along a tributary of Accotink Creek about three-fourths of a mile northwest of Fairfax Circle. Aplite dikes and quartz veins, both large and small, can be seen in many places.

Weathering of the contact rocks is extremely varied. The less competent members have been sheared and crushed and weather deeply. On the other hand, in a few places—notably near Waples Mill and north of Fairfax High School—the rocks are extremely hard and tough and are highly resistant to weathering. In the areas of deep weathering, many of the rocks are stained black on fractured surfaces, and the more massive rocks may show various shades of red or yellow from the iron oxides; contrasting with these are the white aplite dikes, which cut the rocks in all directions.

Where the hard rocks crop out at the surface, wells require only a few feet of casing. However, in the rocks of the contact complex this is the exception rather than the rule. The depth to hard rock ranges from as little as 12 feet on the lower parts of the slopes to 88 feet on uplands. The average depth of weathering is about 50 feet.

The schistosity of the contact rocks is generally concordant with the regional trend, most strikes ranging between N. 3° E. and N. 58° E. The schistosity in the zone east of the greenstone is generally N. 3° E. to N. 48° E. On the west side, the schistosity generally trends between N. 42° E. and N. 58° E. The attitude is nearly vertical or steeply west dipping, but in places west of the greenstone it is as low as 30° W.

Two joint sets in the contact complex strike and dip as follows:

1. Strike, N. 22° W. to N. 87° W.; dip, 65° N. to 65° S.
2. Strike, N. 65° E.; dip, 35° SE.

TALC AND SOAPSTONE

Talc and soapstone occur in small, scattered bodies in the greenstone, and in schist and phyllite of the adjacent contact complex. The largest body is in the greenstone along the dirt road between Robeys Mill and Blevinstown, near the cemetery about half a mile north of Mount Zoar Church. Its boundaries could not be determined, but it is a massive dark-gray soapstone, passing into greenstone on the south. Talcose rocks, including talc schist, also are found about half a mile north of Fairfax High School, between Chain Bridge Road and Jermantown Road. Lenses of talc schist 1 to 2 inches thick can be seen in the road ditch half a mile southeast of Waples Mill.

CHIASTOLITE ZONE

A deeply weathered, rusty-looking, greenish-brown bed of chiastolite schist, ranging in width from 50 to 300 feet, roughly parallels the greenstone on its west side. It marks the northwest edge of the greenstone contact complex south of U.S. Route 29–211. Scattered throughout the schist matrix are cigar-shaped dull slate-gray crystals of chiastolite, 1/8 to 1 inch thick and 1/2 to 2 inches long. The cross sections of broken crystals have rude to well-formed crosses, white on a dark-gray background. The crystals are strongly resistant to erosion, and although many are shattered, they weather out of the crumbly matrix and accumulate on the surface. Wherever exposed, the schist is deeply weathered; the author has seen no fresh rock. The weathered trace of the chiastolite zone can be followed from the west edge of the quadrangle near Blevinstown in an arc to the Capitol Tourist Court on Route 29–211, 1¼ miles west of the intersection at Westmore. Attempts to trace it farther north failed.

GRANITE

The major granite intrusions occupy areas in the southern and eastern parts of the Fairfax quadrangle and extend into the adjoining quadrangles. The largest body extends diagonally across the southeast corner of the map from near the midpoint of the south edge of the quadrangle, the contact following a sinuous line passing just north of Lee Chapel, east of Five Forks and Burke, and out of the quadrangle near Rolling Road. Farther west, two large tonguelike intrusive bodies roughly occupy the drainage basins of Sandy Run and Wolf Run. Smaller granite bodies occur near Ilda and west of Burke. Small-scale granitic intrusive bodies including aplite dikes are found in all the crystalline rocks of the Fairfax quadrangle, but only a few of these are large enough to be shown on the geologic map (pl. 1). Small dikes are indicated on plate 1 by the symbol "ap."

The granite of the Fairfax quadrangle is included in the Precambrian granite shown on the "Geologic Map of Virginia" (Virginia Geol. Survey, 1928). Cady (1938) referred to it as "granite of the eastern belt." Lonsdale (1927) mapped the granite as far north as the Southern Railroad and named it the Occoquan granite from exposures on Occoquan Creek about 6 miles south of the Fairfax quadrangle. Although Lonsdale included it in the Precambrian rocks, he stated that there was some evidence that it was intrusive into, and therefore younger than the Ordovician Quantico slate at Occoquan.

In the Fairfax quadrangle the granite generally is highly siliceous, fine to coarse grained, gray to white, or, in some places, pink. Some of it is massive, but most of it is somewhat schistose, grading into schist at the contacts. (See fig. 6.) Microscopic study of the granite of the Sandy Run area, which is typical, shows that it is composed of quartz, albite, and (or) oligoclase (partly replaced by mica and zoisite), and brown or green biotite. Accessory minerals are zircon, epidote, minor amounts of small titanite grains, and garnet.

The rocks west of Burke, shown on plate 1 as granite, contain a large amount of coarse, contorted muscovite-biotite-quartz schist, together with white or pink muscovite granite or biotite granite. These rocks are tough and resistant to weathering and form knolls in this area. The granite is intrusive into the schist, but the pattern is intricate and no separation has been made. A body of deeply weathered red white aplite is exposed a short distance to the north near bench mark (BM) 344.

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FIGURE 6.—Granite outcrop along Accotink Creek, 2 miles east of Fairfax quadrangle.

At Ilda a body of coarse granite is associated with a light-colored fine-grained siliceous rock containing about 95 percent white quartz 5 percent calcite, and small amounts of biotite and pyrite. This rock probably was a sandstone that was altered to quartzite by the intrusive granite.

In the larger areas underlain by granite, remnants of schist in the form of roof pendants are embedded in the granite. A large schist body within the granite crosses Sydenstricker Road and passes into the adjacent Annandale quadrangle. Smaller bodies of schist within the granite occur along Keene Mill Road and near the south end of Ox Road. Other small bodies doubtless exist but have not been mapped.

In most places the granite weathers rather uniformly, producing a sandy or sandy-clay soil. The feldspar minerals break down into kaolin in the humid climate, but the quartz is highly resistant and the grains accumulate on the surface. Where the granite is somewhat schistose, the flattened quartz grains resemble grains of wheat. On the uplands, where the rock is not exposed, the accumulation of quartz grains aids in mapping the contacts. The depth to solid rock ranges from 49 to 143 feet and averages 98 feet, as estimated from casing depth in 10 wells.

Where schistosity is developed in the granite, it commonly is nearly vertical, but in some places it dips westward. The strike ranges from N. 3° E. to N. 16° E. Schistosity in the small granite intrusive south of Belleair has a nearly vertical dip and strikes N. 52° W., parallel to its contacts. Two sets of joints were observed in the large intrusive bodies:

1. Strike, N. 10° E.; dip, 30° SE.
2. Strike, N. 60° W.; dip, 60° NE.

APLITE

Like the quartz veins, aplite bodies are intrusive into all the rocks older than Triassic. These intrusive bodies take the form of dikes, sills, and irregular bodies (fig. 7) that range from a fraction of an inch to 50 feet across. Unlike those of quartz veins, exposures of aplite are deeply weathered, except in stream channels, and resemble aggregates of loose granulated sugar. They do not form prominences and may be concealed because of the deep weathering and movement of slope wash.

All the aplite bodies are white and are composed of quartz and feldspar. In some places small amounts of tourmaline and white mica are accessory minerals.

FIGURE 7.—Irregular bodies of aplite in schist, Vienna, Va., just north of Fairfax quadrangle.

Commonly the aplite bodies are intruded along the planes of schistosity, but in some places they follow cross joints. Most show some schistosity, although some are massive. In some contact zones near the margins of the large intrusions of coarse-grained granite, swarms of very small aplite dikes, less than an inch in width, have intruded the adjacent schistose rocks.

During the grading for the construction of the General Motors building on U.S. Route 50 near Chain Bridge Road, a deeply weathered aplite dike intrusive in the greenstone contact complex could be traced for 1,000 feet along a strike of N. 32° W. This dike was concealed at both ends but was 50 feet wide at the southeast end of the exposure and 8 feet wide near the highway.

An irregular body of aplite near the head of a small stream 0.8 mile northeast of Jermantown, which trends S. 43° W., has a maximum width of 50 feet and narrows southwestward to 1 foot in a distance of 200 feet. This body is intrusive into the greenstone. It is comparatively fresh at the surface in the stream valley and contains very small tourmaline crystals. There are several small dikes 6 inches wide in the same locality.

About a mile northwest of Burke, at the head of a small stream, a large exposure of deeply weathered aplite about 1,000 feet long and 500 feet wide extends across the road.

Many other small aplite intrusions occur throughout the Fairfax quadrangle. Some of those too small to show at the scale of the geologic map (pl. 1) are indicated on the map by the symbol "ap."

QUARTZ VEINS

Quartz veins ranging in width from a fraction of an inch to tens of feet occur in all the rocks of the Fairfax quadrangle older than Triassic. Some of the larger veins may be traced half a mile or more, the smaller ones only a few feet.

As a rule the veins are greatly distorted and in many places are so badly shattered that fragments no larger than the thumbnail litter the ground. Compression has crushed the quartz, and shearing forces have pulled some of the veins apart so that they are no longer continuous. In some exposures a rude schistosity parallels the regional trend of the enclosing rocks; in others schistosity is not apparent. Most of the quartz is white or slightly iron stained. In places it contains a few small black tourmaline crystals or, more commonly, cubes of pyrite, some of which have been replaced by hematite. Many fracture surfaces have crusts of manganese oxide. Fragments of quartz weather out of the bedrock and accumulate on the surface, in time becoming heavily iron stained.

Although the larger veins tend to follow the schistosity of the bedrock, some of the smaller ones were injected along joints as well as along the cleavage, passing from one to the other and back again. The quartz is more resistant to weathering than most of the enclosing bedrock; thus the larger bodies tend to produce ridges and hills. Large bodies crop out south of Long Branch, north and west of Burke School, southwest of Makleys Store, and elsewhere. Smaller bodies crop out almost everywhere in the quadrangle.

TRIASSIC MANASSAS SANDSTONE OF ROBERTS (1923)

An eastern outlier of the Manassas sandstone of Roberts (1923), of Triassic age, occupies a roughly circular area about half a mile across at Pender in the northwest corner of the quadrangle. Its maximum thickness is estimated to be about 40 feet at Pender, where it lies directly upon the truncated edges of the Wissahickon formation. In a road cut at Pender it is seen to consist of scattered pebbles and cobbles of schist, sandstone, and quartz as much as 10 inches in diameter in a matrix of red or purplish sandy clay, which probably is best described as sandy shale. The bedding is obscure but seems to be nearly horizontal.

TRIASSIC DIABASE

Diabase ("traprock") of Triassic age was noted only at one place in the Fairfax quadrangle. It crops out for 200 feet in the railroad cut at Burke, immediately west of the road that runs from Braddock Road to Burke School. It could not be traced south of the railroad and apparently dies out about 400 feet to the north. It has weathered into brownish clay soil containing spheroidal boulders a foot or more in diameter that consist of fresh rock at their centers. It is a rather coarse-grained rock of mottled gray and black. In thin section the rock is seen to contain plagioclase feldspar, pyroxene, olivine, ilmenite, magnetite, and minor amounts of brown biotite and apatite.

COLLUVIUM

In addition to the thick residual weathered mantle characteristic of the Piedmont, large areas are covered to various depths with transported deposits, generally called colluvium. The transported nature of these materials is not apparent on the surface but is readily seen in excavations. (See fig.8.) Characteristically they are composed of a pavement of angular weathered quartz fragments as much as 6 inches in length lying directly upon the deeply weathered bedrock surface and overlain by several feet of reddish or buff clayey silt, which generally contains scattered quartz fragments. In some sec-

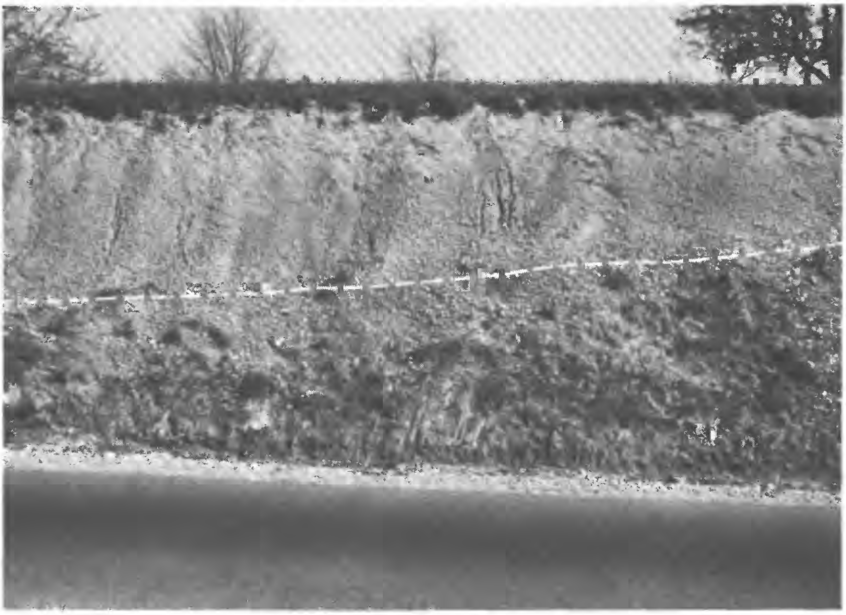

FIGURE 8.—Colluvium overlying Wissahickon formation, U.S. Route 50, east of Fairfax Circle.

tions one or more thin beds of weathered quartz fragments, alined roughly parallel to the bedrock surface, may interrupt the finer material, in which the bedding may otherwise be obscure or lacking.

In the Fairfax quadrangle these deposits are exposed mostly above an altitude of 300 feet, on uplands and hillsides alike, and have a maximum thickness of about 15 feet. They probably are the result of rapid deposition of slope wash, as outlined below.

Quartz veins, which are common in all the basement rocks, are generally more resistant to erosion than the enclosing bedrock, and fragments tend to accumulate on the surface while finer materials derived from the bedrock are carried away by sheet wash or by the wind. Downhill creep slowly spreads the accumulation of quartz fragments over the surface. The characteristic glossy, iron-stained appearance of the quartz in many places indicates long exposure to the elements. Later, deposition of slope wash buried the quartz pavement beneath an accumulation of clay and silt, which also contained scattered fragments of quartz throughout. Still later, erosion removed a part of the silt from the surface, leaving a second accumulation of quartz, which in turn was buried beneath a second accumulation of silt, accounting for the interbedded quartz fragments. Subsequent erosion and dissection by streams has removed much of the material but has left remnants on the uplands and hillsides.

A somewhat similar deposit (fig. 9), which appears to have been laid down by small tributary streams through a process that can be observed today, contains subangular to subrounded quartz fragments intermixed with clay, silt, and sand. The quartz fragments are only slightly rounded, which indicates that they have not been carried very far. Later erosion has left the deposits above present stream courses.

The widespread distribution of the colluvium greatly increases the difficulty of mapping the bedrock on the uplands and on the gentler slopes. The boundaries of the deposits themselves are hard to distinguish because of their resemblance to residual soils. Because the deposits of colluvium are scattered and generally are thin, the unit has not been mapped in detail and is not shown on the geologic map (pl. 1).

ALLUVIUM

Alluvium younger than the colluvium is confined to the flood plains and channels of the present streams and generally is only a few feet thick. Along Pohick and Accotink Creeks it is considerably thicker. For instance, in a well near Fairfax Circle, in the flood plain of

FIGURE 9.—Coarse colluvium overlying Wissahickon formation along Southern Railroad at Sideburn.

Accotink Creek, 20 feet of alluvium lies upon weathered schist. Clay, sand, and quartz cobbles and pebbles commonly coated with a thin film of manganese oxide form the bulk of the alluvium, but cobbles and pebbles of other rocks are common in the lower courses of the streams.

GROUND-WATER RESOURCES

THE HYDROLOGIC CYCLE

Ground water in the Fairfax quadrangle is derived from precipitation in nearby areas, not more than a few miles distant. Rain falling and snow melting upon the ground surface may run off immediately, seep into the ground, be transpired by plants, or evaporate. The relative proportions of the precipitation that follows each course is dependent upon many factors, including the duration and rate of precipitation, the topography, the physical properties of the soil and subsoil, the kind and amount of vegetation, and season of the year.

Of that part of the rainfall which infiltrates into the ground, a part may be returned to the atmosphere through transpiration by vegetation or through direct evaporation from the soil. The remainder, acted upon by the force of gravity, may move downward toward the water table, or, in response to capillary forces, it may move upward, downward, or laterally in the direction of decreasing moisture content. The drier the soil, the greater is its capillary attraction for water.

Between the land surface and the water table is the zone of aeration, which contains water held by molecular attraction within the interstices of the earth materials. This water is called suspended or vadose water. The zone of aeration may be divided into three parts: (1) the zone of soil water, (2) the intermediate zone, and (3) the capillary fringe. (See fig. 10.)

The zone of soil water, which lies nearest the surface, discharges water to the atmosphere by evaporation and by transpiration from plants.

Below the zone of soil water is the intermediate zone, through which water not retained by the zone of soil water seeps downward to the water table. Where the water table lies close to the surface, the intermediate zone may be absent (fig. 10).

Just above the water table is the capillary fringe, which contains capillary interstices, some or all of which are filled with water that is pulled up from and is continuous with water in the zone of saturation. The height of the capillary fringe is determined by the texture of the material in which it lies; its height is greatest in the fine-grained materials and least in coarse-grained materials.

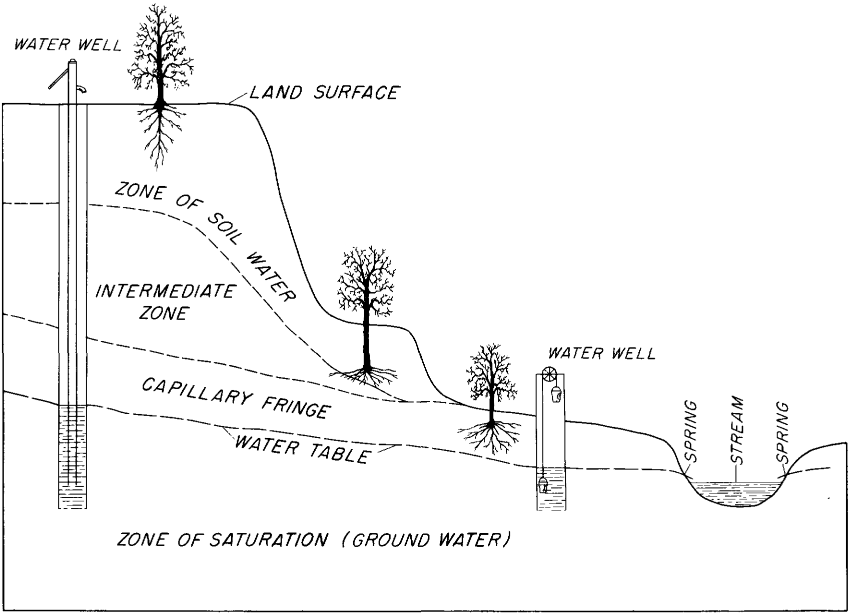

FIGURE 10.—Zones of subsurface water.

In granular materials some water is held at all times in the zone of aeration by molecular attraction. If, in the zone of aeration, the soil is more moist at the land surface than below, capillary forces act downward, aiding gravity in moving the water toward the water table. When the soil at the land surface becomes drier than the soil below, capillarity tends to pull water upward. If the capillary forces acting upward balance the force of gravity, the water in the zone of aeration is in equilibrium with the water in the zone of saturation and no movement occurs.

After the water, seeping downward, reaches the zone of saturation (the zone which is filled with water under hydrostatic pressure and the top of which is the water table), it moves laterally, by gravity, toward lower elevations and ultimately, unless intercepted by wells, reaches places of discharge, which may be springs, seeps, or surface-water bodies such as rivers or lakes.

OCCURRENCE OF GROUND WATER IN CRYSTALLINE ROCKS

The movement of ground water described in the preceding paragraphs applies particularly to granular materials, such as alluvium or the weathered residual blanket which overlies the crystalline bedrock of the Piedmont. Below the top of the bedrock, however, movement in appreciable quantity is controlled by the bedrock structure

In the Fairfax quadrangle, ground water is obtained almost exclusively from crystalline metamorphic and igneous rocks or from the residual materials developed upon them. Only a few dug wells obtain water from alluvium in the stream valleys or from colluvium (slope wash), and still fewer from the small area of the Manassas sandstone of Roberts (1923). Several drilled wells tap bedrock overlain by alluvium.

Crystalline rocks themselves, because of their compactness, yield little or no interstitial water to wells. Ground water moves in these rocks largely along fractures—joints, openings along cleavage planes, and faults—and in places through openings developed along contacts between different rock bodies. Most of the rocks in this area have been considerably disturbed by earth movements and thus contain water-bearing openings.

Joints—cracks developed in the rock as a result of compressional or tensional forces—commonly occur in sets of three, together called a joint system. Each set consists of approximately parallel fractures, which may be closely or widely spaced, a few inches to many feet apart. The three sets, as a rule, are roughly at right angles to each other; two sets are approximately vertical and a third set is nearly flat or slightly inclined.

In most schistose rocks, cleavage planes are the result of shearing or compressional forces, which tend to orient the rock minerals in parallel, creating planes of weakness along which the rock tends to split.

In some places, one wall along a fracture tends to move with respect to the opposing wall, and a shear zone or fault results. The movement may create a brecciated (crushed) zone, which could serve as a channel for the movement of ground water. On the other hand, a relatively impervious zone of clay (gouge) may be formed, according to the type of materials, the nature of the forces involved, and the depth below the surface at which the movement occurs. Such a clay-filled structure could serve as a barrier to the movement of ground water.

Contacts between country rock and igneous intrusive bodies similarly may control the movement of ground water; that is, the rocks along the contact may be shattered, thus creating a passage for ground water, or may be effectively sealed, creating a barrier.

Large rock masses break down into smaller units along the joints. Weathering tends to enlarge the openings created by most structural features, and so the movement of ground water in relatively impervious rocks is facilitated.

Thus, in the metamorphic and igneous rocks below the deeply weathered zone, the movement of ground water is controlled by the rock structure. If the water table lies in the crystalline rocks, water seeping downward instead of moving straight down to the water table, moves along open fractures at a rate depending upon the amount of water supplied by the weathered overburden, the size and inclination of the openings, and the location and altitude of the points of discharge. If the openings are interconnected, one water table only will result; however, isolated fractures or groups of fractures may have separate water tables, according to the location and altitude of the points of discharge.

Ground water in the piedmont rocks is usually considered to be unconfined; that is, it is under water-table conditions rather than artesian conditions. Artesian water is defined as ground water that is under sufficient pressure to rise in a well above the level at which it is reached in the formation, but not necessarily to or above the surface of the ground. (See Sayre, 1936, p. 33.) Some drilled wells in the Piedmont qualify as artesian wells. The artesian pressure is caused by water moving downward along an inclined structure such as a joint or fault, the upper block, or so-called hanging wall, acting as a confining layer. These conditions are limited to small areas, so that as far as larger areas are concerned it may be considered that water-table conditions prevail.

In this connection, an erroneous belief prevails that ground water in the Washington-Fairfax region originates at a considerable distance, such as in the Blue Ridge or even the Pennsylvania mountains. This cannot be true, because no single water-bearing structural feature in this region extends more than a few miles. The water from wells in the Fairfax quadrangle originates as precipitation in or near the local drainage basin.

WELLS

CONSTRUCTION METHODS

Wells in the Fairfax area are of three types: drilled, bored, and hand dug. Drilled wells are constructed by two methods: cable-tool, known also as percussion or churn drilling, and rotary drilling. Bored wells are similar in some respects to dug wells but are excavated by large-diameter (usually 24- to 36-inch) mechanically driven augers. Most wells drilled for domestic supplies are 6 inches in diameter; those drilled for municipal or industrial supplies are 6 to 18 inches in diameter. Cable tools are used almost exclusively; only one rotary drill was in use in the area in 1957, but it is reported to operate very efficiently. The cable-tool rigs used in the area are capable of drilling most of the hard rock of the Piedmont, though some of it very slowly.

Boring machines are not suited for drilling in hard rock. They operate best in soft residual or alluvial materials. In spite of this limitation, the Fairfax quadrangle has a large number of bored wells, and in favorable locations they provide an adequate and permanent water supply for the average household.

COMPARISON OF WELL TYPES

Drilled, bored, and dug wells each have certain advantages as well as disadvantages. Drilled wells in the area generally obtain their water from openings in the bedrock. Rainwater or snowmelt seeping downward from the surface through the soil enters the natural openings in the hard rock beneath and then moves along these openings to the well. A drilled well 100 feet or more in depth is not likely to go dry in dry weather, and if the casing is properly seated in bedrock and is grouted with cement or clay the chance of pollution from surface sources is minimized.

A bored or dug well receives all its water from the weathered materials overlying the bedrock. Where the weathered materials are thin, the water table may fall below the bedrock surface in dry weather, causing the water supply to fail. When a well is bored, if water is not found above the bedrock surface, the hole must be abandoned or deepened by hand. Hand digging is difficult below the water table; consequently, many wells are not deep enough to provide for natural fluctuations of the water table. For this reason, bored or dug wells are best adapted to sites where the water table is near the surface, as low on a hillside or in a valley. Being of large diameter, they provide a greater storage capacity than small-diameter drilled wells.

Locally, especially in some of the granite intrusions, the bedrock is little fractured and yields only very small amounts of water to drilled wells. If the weathered zone of these rocks is sufficiently thick, a bored or dug well may be the only practical means of obtaining a water supply.

Bored or dug wells are most commonly subject to pollution because they are supplied by near-surface water. Chlorination of the water may be advisable, or periodic tests should be made to insure that the water is free from contaminants. On the other hand, water from bored or dug wells usually does not contain objectionable amounts of iron—a common solute in water from some drilled wells.

CASING-OFF THE SHALLOW GROUND WATER

Many drilled wells are fed, at least in part, by water from the weathered zone. Attempts to seal off the upper water are not always effective, even if the driller makes a conscientious effort to seat the the casing in the hard rock. Furthermore, sealing may not always be desirable, as it may reduce the yield below the minimum requirement. On the other hand, if the bottom of the casing is not driven tightly into the rock, pollution may result, or, in certain types of rock, silt and mud may be drawn into the well. In some places iron leaches out of the weathered zone and tends to accumulate near the top of the bedrock, and the water will contain objectionable amounts of iron. In the phyllitic rocks, the casing may appear to be firmly seated, but, after the well is in use for a few days, the rock tends to soften and large amounts of micaceous silt may be pumped. It may then be posssible to drive the casing down still farther and thus eliminate the trouble. If this is not effective, the application of cement to the bottom of the casing (grouting) may stop the silting. When the high iron content of the water is a problem, it can sometimes be eliminated by installing a packer around a smaller inner pipe in the open hole, if the iron is entering the upper part of the hole. A more permanent seal might be effected by grouting the upper part of the open hole.

SPRINGS

A large number of springs, issuing either from fissures or from the contacts of geologic formations, occur in the Fairfax quadrangle. Most are unimproved; a few, however, have been improved, equipped with pumps, and now furnish water for domestic and stock use. Thirty-one springs are listed in the basic-data report (Johnston, 1960); their estimated yields range from ½ to 10 gpm.

SELECTION OF WELL SITES

The topography in many places in the Piedmont province is controlled by the geologic structure. The surface traces of the major structural features have been etched in relief by erosion. Interpretation of structure by topographic features can be an aid in selecting favorable well sites, a principle suggested by several hydrologists as summarized by Mundorff (1948, p. 25–27).

The two principal structural features reflected in the topography are the cleavage or schistosity, and the joint system. In the Fairfax quadrangle, the schistosity and one set of joints parallel to it generally have a northeastward trend. Another set of joints strikes northwestward nearly at right angles. Commonly the schistosity and the two joint sets described are steeply inclined. A third set of joints, which may carry water, is inclined only slightly and does not influence the topography greatly. Other structural features that may be expressed in the topography and that may carry water in greater than average quantities are fault and contact zones. Where the streams have cut into the bedrock, they are commonly adjusted to the structural pattern, and their locations indicate zones of fracture where the rocks are permeable and yield water freely. Wells drilled along these zones or, better, at the intersection of two zones, have the greatest possibilities of success. However, unless the structural zone is nearly vertical or very wide, a vertical hole drilled on its surface trace may not be in the zone at depth. Therefore, the dip of the zone should be considered in selecting the site of a well. Few zones, however, maintain a constant dip. Furthermore, these principles cannot be used with any assurance of success near the heads of gullies, where the streams have not yet become adjusted to the bedrock structure, or in wide alluviated valleys, where zones of fracture may be concealed beneath the alluvium.

If gullies and larger valleys indicate zones of weakness in the rocks, hills conversely indicate harder, more resistant rock. This is one reason that low hillsides, gullies, and valleys are more favorable sites for wells than hilltops. Also, the water table as a rule is near the surface in low areas, whereas on hilltops it generally is deeper and tends to fluctuate more widely in response to climatic variations.

In many places in the Piedmont, quartz veins of various sizes cut the bedrock and may be highly productive sources of ground water. Quartz, called flint by drillers, is a brittle mineral and commonly is greatly shattered. A few wells in the Fairfax quadrangle obtain their water from quartz veins, which in the main were struck by chance. If a fractured quartz vein is intercepted at depth below the water table it is likely to yield a higher than average supply of water to wells.

In selecting a site for a bored or dug well, topography is an important factor. As is true for drilled wells, wells bored or dug in low places generally have larger yields and are more dependable than those on other sites. On hilltops or high on hillsides, the water table may lie below the top of the hard rock, below which a boring machine cannot operate, and laborious hand digging and even blasting may be necessary to reach the water table. Then, too, the water table under the hilltops and high hillsides is subject to greater fluctuation; a hilltop well that contains 5 feet of water in early spring or during periods of above-normal rainfall may become dry in the fall and during drought. (See section on water-table fluctuations, p. 39.) Practically all the wells in the Fairfax area that fail in periods of drought are bored or dug wells.

WATER-BEARING FORMATIONS

WISSAHICKON FORMATION

The Wissahickon formation, because of its large areal extent, is the most important aquifer in the Fairfax quadrangle. It underlies about 40 square miles, or seven-tenths of the total area. The 164 recorded drilled domestic wells that tap the Wissahickon average 130 feet in depth and yield an average of 12 gpm. (See table 2.) This yield equals the average for all formations in the quadrangle.

Not included above are four wells in the Wissahickon owned by the town of Fairfax. These range in depth from 318 to 800 feet and produce 35 to 110 gpm; their average yield is 55 gpm.

The 83 dug wells that tap the Wissahickon ranged in depth from 12 to 68 feet and averaged 31 feet. No records of the yields of dug wells are available; but of the 83 dug wells, 19—or 23 percent—were reported to be dry or nearly so during droughts. The 34 bored wells in the formation averaged 38 feet in depth, ranging from 18 to 59 feet.

Of 14 recorded springs in the Wissahickon formation, 9 were in use and were estimated to flow at the rate of ½ to 10 gpm.

GREENSTONE

The greenstone is the least productive water-bearing formation in the Fairfax quadrangle. It underlies slightly more than 4 square miles, or about 7 percent of the total area of the quadrangle. North of U.S. Route 29–211, where much of the rock is schistose and contains shear zones, yields of 5 drilled wells average 9 gpm. The lowest yields are obtained in the area of massive greenstone south of U.S. 29–211, where a yield as small as 0.4 gpm. was reported, and 13 drilled wells average only 5 gpm.

Well Ab-13, drilled in the greenstone by the town of Fairfax to a depth of 809 feet, produced only 15 gpm. Other drilled wells for both domestic and public supply, 24 in number, range in depth from 40 to 160 feet and average 71 feet (table 2). They range in yield from 0.4 to 12 gpm and average 6 gpm.

The yield of three springs issuing from the greenstone was estimated to be 2½ to 3 gpm.

Only three dug wells and one bored well in the greenstone were recorded. The dug wells were 12, 20, and 41 feet deep, and the bored well was 43 feet deep. The hardness of the rock in some places makes digging or boring wells in the greenstone extremely difficult, if not impossible.

GREENSTONE CONTACT COMPLEX

The greenstone contact complex is the most productive aquifer in the Fairfax quadrangle (table 2). It underlies about 5 square miles, or 8.5 percent of the total area of the quadrangle. The 23 drilled privately owned wells in this unit range in depth from 52 to 250 feet and average 98 feet. Of these, 19 range in yield from 5 to 55 gpm and average 18 gpm.

The town of Fairfax has 7 drilled wells in the contact complex, not included in the 23 mentioned above. They range in depth from 165 to 612 feet and average 479 feet. They range in yield from 20 to 125 gpm and average 57 gpm.

The rocks in the contact complex appear to be considerably more fractured and distorted than the Wissahickon, which probably accounts for their greater productivity.

Only two dug wells and no bored wells or springs that tap the contact complex were located. The dug wells are 27 and 28 feet deep.

GRANITE

Granite underlies about 9 square miles in the Fairfax quadrangle, or about 15 percent of the total area. Inventories were made of 15 drilled wells that tap granite (table 2), ranging in depth from 56 to 258 feet and averaging 125 feet. Of these, nine ranged in yield from 5 to 20 gpm and averaged 12 gpm. This is about the average for all the formations in the quadrangle and equal to the average yield of the Wissahickon formation. However, because of the small number of wells reported, this figure probably does not represent a true average for the unit.

The 15 dug wells in granite range in depth from 12 to 57 feet and average 29 feet. Of these, four are reported to be inadequate or dry at times. In the area underlain by granite, six bored wells were located; these range in depth from 31 to 64 feet and average 46 feet. One of these was reported to be dry in 1954.

Issuing from the granite are four springs estimated to yield ½ to 5 gpm, but only one of these is in use.

FORMATIONAL CONTACTS

Wells on or near geologic contacts commonly are above average in yield (table 2). In the Fairfax quadrangle, nine drilled wells were located on formational contacts, ranging in depth from 56 to 141 feet and averaging 99 feet. Data were available for five wells yielding 8 to 25 gpm and averaging 16 gpm, 4 gpm more than the average for all aquifers in the quadrangle.

Of 10 springs along contacts, 6 are at the contact of the granite with the Wissahickon formation. Of the 10 springs, 1 was dry in 1955; the yield of the remaining 9 was estimated to be 2 to 5 gpm.

STUDIES OF WELL YIELD AND DEPTH, AND TOPOGRAPHIC POSITION

The 434 wells and springs recorded in the Fairfax quadrangle, are divided as follows:

Drilled wells:	
Privately owned	240
Municipal	12
Dug wells	108
Bored wells	43
Springs	31
Total	434

In the following section the factors affecting the yield, depth, and water level of drilled wells are considered. The depths and yields of wells in the several geologic units are compared, and the relation of yield to depth of well, depth of weathering, and topographic position is considered. Yield figures for dug and bored wells are not available; hence only the relation of the depth and water level to topographic position is shown.

DRILLED WELLS

DEPTH AND YIELD OF WELLS BY GEOLOGIC UNITS

Table 2 shows that depth of drilled wells range from 31 to 809 feet. The Fairfax municipal wells are shown separately because of their much greater average depth and yield.

TABLE 2.—*Depth and yield of drilled wells, by geologic units*

	Number of wells	Depth		Number of wells	Yield (gpm)	
		Range (feet)	Average (feet)		Range	Average
Wissahickon formation	164	31–550	130	139	1–32	12
Greenstone	24	40–160	71	21	4–12	6
Greenstone contact complex	23	52–250	98	19	5–55	18
Granite	15	56–258	125	9	5–20	12
Formational contacts	9	56–141	99	5	8–25	16
Fairfax municipal wells [Not included above]						
Wissahickon formation	4	318–800	480	4	35–110	55
Greenstone	1		809	1		15
Greenstone contact complex	7	165–612	479	7	20–125	57

Yields of drilled wells range from 0.4 gpm from a privately owned well to as much as 125 gpm from a Fairfax municipal well. Wells in the greenstone contact complex have the highest average yield, 57 gpm from municipal wells and 18 gpm from domestic wells. The Wissahickon formation and the granite are about equal in average yield to private wells, 12 gpm. Four town wells tapping the Wissahickon average 55 gpm. Private wells drilled along formational contacts average 16 gpm. The poorest aquifer in the quadrangle is the greenstone, which yields an average of 6 gmp to wells. One Fairfax municipal well in greenstone, the deepest well in the quadrangle (809 feet), is reported to yield 15 gpm for short periods. The long-term yield of the well may not exceed 7 gpm.

Of all the characteristics listed for the wells, the reported yields are the least accurate. Most domestic wells are tested by bailing for short periods, which at best indicates only an approximate yield but which is usually satisfactory for domestic requirements. On the other hand, most municipal or industrial wells are tested by pumping at a known rate for 24 hours or more; this procedure generally gives a good indication of the true of capacity of the well.

RELATION OF YIELD TO DEPTH OF WELL

Table 3 indicates that the yields of wells in the Fairfax quadrangle are not proportional to their depth. This is to be expected, as the rocks are not of uniform permeability. The highest yields per foot of depth are obtained from wells 31 to 49 feet deep and 400 to 499 feet deep. However, not enough wells shallower than 49 feet or deeper than 199 feet were inventoried to give a true picture. Furthermore, the deeper wells probably obtain much of their water from comparatively shallow depths. Table 3 shows that 93 percent of the drilled wells are less than 300 feet deep, and 89 percent are less than 200 feet deep. About 41 percent of the wells are between 100 and 150 feet deep.

TABLE 3.—*Yield of drilled wells, by depth intervals*

Range in depth (feet)	Average depth (feet)	Number of wells	Percent of total	Yield (gpm)		
				Range	Average	Per foot of well
31–49	42	5	2.4	1– 20	7.4	0.18
50–99	79	63	30.6	2– 25	11.3	.14
100–149	121	84	40.8	2– 42.5	12.6	.10
150–199	165	31	15.0	0.4– 30	9.8	.06
200–249	215	6	2.9	7– 22	14.5	.07
250–299	253	3	1.5	6– 55	24.3	.10
300–399	321	2	1.0	10– 35	22.5	.07
400–499	409	5	2.4	2–125	62.6	.15
500–599	550	2	1.0	6– 90	48.0	.09
600–809	684	5	2.4	15– 55	34.0	.05

RELATION OF YIELD TO DEPTH OF WEATHERING

Yield in relation to depth of weathering, based on the length of the casing used in drilled wells is given in table 4. The table shows a rise in average yield to the 50- to 74-foot depth interval, a considerable decline in the 75- to 99-foot interval, and a further decline in the 100- to 150-foot interval. These data probably are reasonably reliable; for greater depths only a few data are available. Furthermore, at depths of more than 200 feet the casing depth probably does not indicate accurately the depth of weathered rock. Recent studies by Dingman and Ferguson (1956) show a correlation between depth of weathered mantle and yield in nearby parts of Maryland, a correlation that does not seem to hold true in the Fairfax quadrangle. However, some drilled wells in the Fairfax quadrangle have been reported to be turbid after rains, indicating that the casing is not firmly seated in bedrock and that at least some of the water is obtained directly from the weathered zone or that surface water is moving down the outside of the casing. On the other hand, so many other factors affect the yield of a well that depth of weathering alone should not be the sole criterion.

TABLE 4.—*Relation of yield to depth of weathering based on length of casing in drilled wells*

Lengths of casing (feet)	Number of wells	Average length of casing (feet)	Yield (gpm)	
			Range	Average
7–24	19	14.8	1–15	6.6
25–49	21	39.3	0.4–20	10.1
50–74	34	60.5	5–55	15.3
75–99	45	86.6	4.5–27	12.9
100–150	46	116.1	1.5–40	11.8

RELATION OF DEPTH, LENGTH OF CASING, AND YIELD OF DRILLED WELLS TO TOPOGRAPHIC POSITION

With respect to topographic position, average yields of wells are least on hilltops and greatest in valleys. Wells on hillsides and nearly level uplands have somewhat higher yields than wells on hilltops, and wells in gullies have considerably higher yields. This information, together with average depth and casing length, is shown in table 5. The differences in average yield are due first to the fact that harder, more resistant rocks commonly underlie the hilltops; whereas fractured, and hence more permeable, rocks underlie the gullies and valleys; second, in the lower places, to the fact that the water table is nearer the surface, and greater drawdowns are possible because the wells in the low places have a higher ratio of saturated section to depth.

Wells on hilltops have a greater average depth than those on uplands and hillsides and in gullies. The greater average depth of wells in valleys is due to the fact that four of the deep wells owned by the town of Fairfax are in valleys. The depth of weathering, as indicated by the average length of casing used in wells, is greatest on hilltops, least in gullies, and intermediate on uplands and hillsides. The average length of casing in wells in valleys is not necessarily indicative of the depth of weathering in the bedrock because alluvium overlies the bedrock in most valleys. The length of casing therefore generally indicates the thickness of both alluvium and weathered bedrock. In contrast, weathering products do not tend to accumulate in gullies, because the steep gradient of the gullies permits rapid removal of those products by the streams.

TABLE 5.—*Depth, length of casing, and yield of drilled wells by topographic position*

Position of well	Depth of wells		Length of casing		Yield	
	Number of wells	Average depth (feet)	Number of wells	Average depth (feet)	Number of wells	Average yield (gpm)
Hilltop	27	157	20	96	23	11.4
Upland	81	118	64	83	64	12.0
Hillside	104	133	83	87	88	12.2
Gully	17	142	16	63	16	17.0
Valley	16	223	15	71	14	32.0

DUG AND BORED WELLS

RELATION OF DEPTH OF WELL AND WATER LEVEL TO TOPOGRAPHIC POSITION

The relation of depth of well and depth to water of dug and bored wells to the topography is shown in table 6. The average depth of wells on hilltops is almost two and one-half times that of wells in the valleys. Depths of wells on uplands, hillsides, and gullies fall between these extremes. The depth to water is greatest beneath hilltops and progressively less under uplands, hillsides, gullies, and valleys, in that order. The average depth to the water table beneath hilltops is more than four times as great as in the valleys.

TABLE 6.—*Relation of depth of well and depth to water to topographic position in dug and bored wells*

Position of well	Number of wells	Average depth of well (feet)	Number of wells	Average depth to water (feet)
Hilltop	28	41.2	25	29
Upland	32	34.3	31	27
Hillside	71	31.8	64	21
Gully	9	28.3	8	17
Valley	11	16.8	10	7

POTENTIAL DEVELOPMENT OF GROUND-WATER RESOURCES

On the assumption that the per capita consumption of ground water is 100 gpd an average of 1,650,000 gpd of ground water was being pumped in the Fairfax quadrangle in 1957.

The Rock Creek basin in nearby Maryland is comparable to drainage basins in the Fairfax quadrangle in both geology and topography. Dingman and Meyer (1954) estimated ground-water runoff (equal to the ground-water recharge less a negligible proportion discharged by evapotranspiration) (Meinzer, 1923, p. 59) from the Rock Creek basin to be about 20 percent of the precipitation. The mean annual precipitation at Washington for the period 1910 through 1957 was 41.98 inches; for the period 1941 through 1956 it was 41.65 inches. In the following estimates the latter figure is used, inasmuch as it is based on observations at Washington National Airport under conditions similar to those in the Fairfax quadrangle.

By assuming 20 percent of the mean annual precipitation to be reasonably correct for ground-water recharge, it is estimated that the average recharge in the Fairfax quadrangle is approximately 23 mgd (million gallons per day). Thus, only about 7 percent of the recharge was being utilized as of 1957. In practice the total recharge could never be recovered economically, as to do so would require the establishment of a network of closely spaced wells and intensive pumping. Furthermore, streams would be dry or low for long intervals between periods of heavy rainfall. However, probably several times more ground water than was being pumped in 1957 is available in the Fairfax quadrangle.

WATER-TABLE FLUCTUATIONS

In order to record ground-water levels, the Geological Survey maintains throughout the United States a net of observation wells in which water levels are measured periodically. Among other uses for these records are those for estimating ground-water supplies and defining changes due to climate, season, and pumping in the area. One such observation well is in the Fairfax quadrangle near U.S. Route 50, west of Difficult Run. Records for this well, Aa–20 (pl. 2), named the Bacon well, date back to the fall of 1931, when extreme drought affected a large part of the United States.

The Bacon well is on an upland flat about 400 feet above sea level. It is a dug well penetrating weathered mica schist, is 4 feet in diameter and 24 feet deep, and has an uncemented stone casing which permits water to enter.

In a shallow dug well such as this, the water level responds quickly to precipitation that results in recharge. In this area the ground is seldom frozen for long periods in winter; and, although precipitation is fairly well distributed throughout the year, most recharge takes place during the late fall and winter. In a normal year the ground-water levels begin to rise in November and continue to rise until April or May, when the growing season begins. During the growing season much of the rainfall (perhaps 70 percent in Baltimore and Harford Counties, Md., according to Dingman and Meyer, 1954, p. 39) is returned to the atmosphere by evapotranspiration and never reaches the water table. In April or May the water table begins a steady downward trend, interrupted only by short periods of heavy rainfall in some years, until killing frosts in the fall terminate the consumption of water by plants. In dry years the downward trend may continue into the winter, and unless winter precipitation is sufficient to cause recharge, there is little rise before the next growing season begins. The month-end water levels in the Bacon well and monthly precipitation from August 1931 to December 1957 are shown in figure 11. The record low occurred in January 1932, a level of 23.16 feet below the ground surface; the second lowest level of record, 20.11 feet, was reached during the drought of 1954–55. The record high occurred in April 1952, when the water rose to 9.63 feet below the ground surface.

The relation between ground-water levels and precipitation is shown in figures 11 and 12, and the seasonal effect on water levels is shown in figure 11.

During each drought some shallow wells fail, and it is rumored that the ground-water supply has been depleted, never to recover. When it is realized that during the period of record (1931–57) a maximum seasonal fluctuation of nearly 9 feet (in 1942) and a total fluctuation of 13.5 feet were recorded in the Bacon well, it is easy to see why shallow wells sometimes fail.

Water-level records in this locality as well as in other parts of the United States (Fishel, 1956) show no sustained downward trend except in areas of heavy pumping, a condition that does not apply in the Fairfax quadrangle.

EMERGENCY WATER SUPPLIES

If public-utility systems were destroyed and surface-water supplies were contaminated as a result of nuclear-bomb attack or other disaster, wells and springs would be the only source of potable water. Outside the area of total destruction it would be necessary to utilize undamaged wells and springs to the fullest extent. As public power presumably would not be available, it would be imperative to have on hand some portable powerplants to operate electrically powered pumps. It would be desirable also to have pumps with independent power supplies available for use in wells where the pumping equipment was inadequate or damaged.

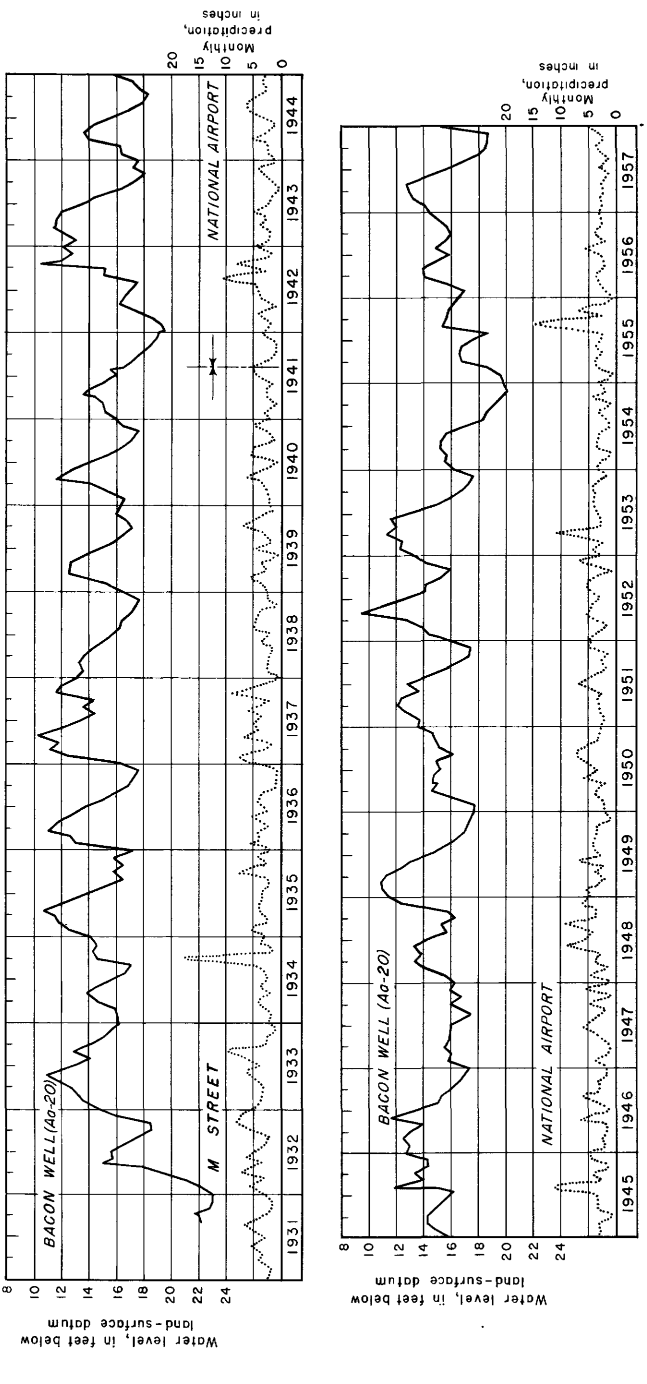

FIGURE 11.—Month-end water levels in the Bacon well near Fairfax, Va., and monthly precipitation at Washington, D.C., 1931–57.

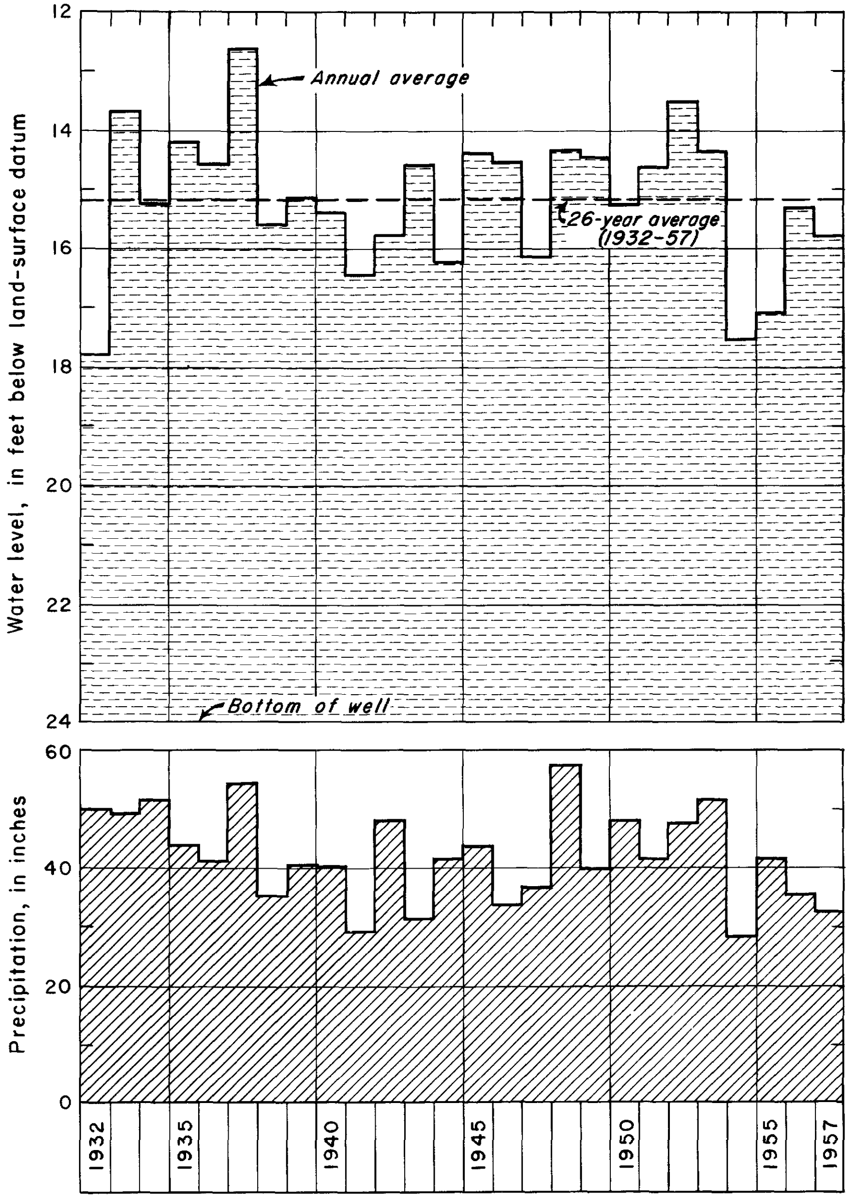

FIGURE 12.—Annual average of month-end water levels in the Bacon well, Fairfax, Va., and annual precipitation at Washington, D.C.

With the development of more powerful nuclear bombs, the ultimate radius of destruction cannot be estimated, nor can the fallout pattern be predicted with accuracy; but in the event of war it can be assumed that Washington would be a prime target area.

The present report includes only a small part of Virginia close to Washington. A ground-water report including about 500 square miles in the District of Columbia and vicinity is being prepared. Ground-water reports for nearby Maryland are now available, published by the State in cooperation with U.S. Geological Survey (Cooke and Meyer, 1952; Dingman and Meyer, 1954; and Otton, 1955). The remainder of Fairfax County and adjacent Loudoun and Prince William Counties in Virginia have not been studied in detail.

CHEMICAL QUALITY OF THE GROUND WATER

By Bruno V. Salotto

The objectives of water-quality studies in the Fairfax quadrangle were to obtain present data on the quality of water in the aquifers as an aid in developing and utilizing the ground-water resources, and to evaluate the geochemical relations between the waters and the rocks in which they occur.

The current analytical data also provide a basis for comparison of changes in quality that may occur with time, such as those caused by rapid urbanization of the area. Indeed, the effect of population growth on the quality of shallow ground water in unsewered areas of the quadrangle may soon become a matter of concern.

The water-quality studies were based on a modest sampling program begun early in 1954. Efforts were made to select wells and springs that were considered on the basis of available geologic and hydrologic information to be representative of a particular aquifer. Principal emphasis was given to the most important aquifers, but subsequent examination of the data has indicated some deficiencies in coverage.

Table 7 gives the results of analyses of samples, arranged according to geologic source. A few data from previous studies of areas that include the Fairfax quadrangle are added for their historical value. The significance of the chemical and physical properties of water are summarized in table 8.

The extent to which water can be utilized effectively is associated closely with its chemical quality. Water users are many, and each user may have water-quality requirements different from another. Present water consumption in the quadrangle is largely domestic and commercial. Public water supplies and domestic wells provide the principal water facilities. For these, iron, hardness, fluoride, chloride, nitrate, corrosiveness, and turbidity are of principal interest.

TABLE 7.—*Chemical analyses of*

[Chemical constituents

Location	Well	Depth of well (feet)	Date of collection	Temperature (° F.)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
Wissahickon formation										
West of Pender	Aa-2	42	6-24-54	57	9.8	2.8	2.3	1.0	8.3	
South of Pender	Aa-6	135	2-26-57	-------	26	4.5	4.4	1.4	4.8	0.3
U.S. 50, west of Fairfax	Aa-20	24	10-21-31	-------	-------	-------	4.0	2.7	1.9	
Fairfax Farms	Aa-28	80	5-11-54	55	17	.24	2.1	.7	2.7	.4
Jones St., Fairfax	Ab-17	318	10-23-31	-------	44	.91	9.1	9.6	8.8	2.0
Theater on U.S. 50	Ab-31	400	5-11-54	56	23	1.1	5.9	3.8	5.3	.5
Fairview Subdivision	Ac-17	400	5-11-54	55	23	2.5	-------	-------	16	
Little River Hills	Ac-20	152	12-7-55	59	33	2.1	2.3	3.0	7.6	.5
Sherman Road	Ac-31	154	10-21-57	-------	31	5.4	4.9	.2	20	
Fairlee Lot 4	Ac-50	144	12-7-55	-------	-------	-------	-------	-------	4.7	
Do	-------	144	12-7-55	-------	-------	-------	-------	-------	3.4	
Do	-------	144	1-4-56	55	-------	4.1	-------	-------	----	
Ox Road	Bb-10	160	10-11-55	-------	-------	-------	-------	-------	14	
SE. of Court House Country Club.	Bb-14	39.5	4-3-57	-------	18	.06	12	1.4	4.5	.5
Braddock Road	Bc-6	58	6-29-54	58	13	.14	9.9	1.9	3.1	.8
Near Makleys Store	Ca-27	45	2-27-57	54	27	.65	1.4	.2	4.8	.1
Makleys Store	Ca-28	29.5	6-29-54	58	18	.19	18	1.0	3.4	.9
South of Fairfax Station	Cb-1	119	6-29-54	66	27	.48	2.5	1.7	4.8	.7
Belleair	Cb-24	38	6-24-54	65	9.2	.45	1.3	.4	1.1	1.1
Greenstone										
Shirley Gate Road	Aa-46	41	6-29-54	62	31	0.52	35	22	5.8	0.7
Germantown Road	Ab-4	76	5-11-54	59	29	.41	11	7.3	2.9	.6
William Place, Westmore Subdivision.	Ab-13	809	5-11-54	58	25	.06	44	10	2.2	.1
Greenstone contact complex										
Off Shirley Gate Road	Aa-47	Spring	5-11-54	53	-------	0.67	-------	-------	6.3	
NW. of Fairfax Circle	Ac-1	85	5-11-54	57	12	.19	-------	-------	11	
Do	-------	85	6-29-54	61	11	.12	7.1	5.0	6.9	2.0
Granite										
Ilda	Ac-80	105	10-31-55	-------	28	0.54	12	1.1	7.8	0.8
Do	-------	258	1-4-56	55	-------	1.1	-------	-------	-------	-------
Little River Pines, Ilda	Ac-85	98	2-18-54	-------	31	.16	11	1.2	7.3	.2
Yates Ford Road	Ca-9	173	6-24-54	60	34	.07	6.4	.6	6.6	.6
Near Clifton	Ca-13	Spring	4-5-54	-------	-------	-------	-------	-------	3.5	
East of Makleys Store	Cb-11	57	6-29-54	55	12	.38	3.3	.4	3.9	.7
Manassas sandstone of Roberts 1923										
Pender	Aa-3	31	6-24-54	61	17	0.23	1.4	0.8	3.4	0.7
Do	Aa-4	18.3	6-24-54	60	20	.39	3.3	1.6	9.8	.7

ground water in Fairfax quadrangle

in parts per million]

Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids: Residue on evaporation at 180° C.	Dissolved solids: Calculated	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C.)	pH	Color
Wissahickon formation—Continued													
17	0	3.4	4.7	------	4.5	------	------	42	10	0	56.0	6.2	2
38	0	1.2	.5	0.1	.0	0.0	60	57	17	0	63.0	6.4	1
25	0	1.0	5.0	------	2.5	------	------	------	21	------	------	------	------
16	0	.4	1.9	.1	.2	.1	37	34	9	0	30.5	6.3	5
83	0	3.1	6.0	------	.2	------	105	------	62	0	------	------	------
32	0	2.2	6.9	.2	7.0	.0	83	71	30	4	100	6.3	3
112	0	20	3.0	------	.2	------	------	------	83	0	194	7.6	8
43	0	.0	2.5	.1	.1	.8	70	73	22	0	72.9	6.7	7
64	0	.2	1.7	.1	.5	1.4	91	92	13	0	81.6	7.2	55
31	0	.4	1.2	------	.6	------	------	------	17	0	57.4	6.6	------
16	0	.0	1.2	------	.4	------	------	------	7	0	24.8	6.1	------
13	0	------	------	------	------	------	------	------	------	------	24.6	5.9	------
69	0	.1	2.2	------	.3	------	------	------	30	0	114	6.4	------
44	0	1.8	3.8	.1	4.3	------	75	68	36	0	94.7	6.9	1
48	0	4.8	3.9	.1	.1	.0	71	65	40	1	89.4	6.6	2
16	0	.2	3.0	.1	2.2	.0	52	49	4	0	42.1	6.3	1
70	0	.4	.2	.1	.3	.0	83	78	51	0	118	6.6	2
27	0	.5	2.5	.1	.2	.3	------	55	17	0	49.1	6.4	2
18	0	1.0	.5	.1	.5	.0	------	28	14	0	36.3	6.1	4
Greenstone—Continued													
205	0	11	11	0.1	0.2	0.0	235	220	181	13	358	7.0	3
54	0	6.0	3.1	.1	11	.0	------	99	58	14	132	6.5	3
188	0	2.4	2.1	.0	.3	.0	183	179	152	0	294	7.4	2
Greenstone contact complex—Continued													
54	0	3.0	2.1	------	0.3	------	------	------	35	0	95.4	6.7	8
11	0	3.0	13	------	41	------	------	------	40	31	142	5.9	6
8	0	.4	14	0.1	42	0.0	------	93	39	32	141	5.8	3
Granite—Continued													
47	0	0.4	4.2	0.0	6.4	0.1	91	84	35	0	116	6.5	7
108	0	------	------	------	------	------	------	------	------	------	198	6.9	------
55	0	.0	5.7	.0	.3	.1	86	84	37	0	98.1	6.4	5
45	0	1.6	2.3	.1	.5	.4	76	78	23	0	74.9	6.7	3
13	0	3.2	2.7	------	1.2	------	------	------	11	0	37.9	6.2	4
18	0	.4	11	.1	.9	.0	------	45	17	2	65.0	6.2	4
Manassas sandstone of Roberts 1923—Continued													
13	0	0.2	3.1	0.1	1.6	0.0	28	35	8	0	31.0	5.9	2
13	0	1.2	22	.1	.9	.0	------	68	17	7	102	5.7	3

TABLE 8.—*Significance of the chemical and physical properties of water*

Constituent or physical property	*Source or cause*	*Chemical characteristics that affect usability of the water*
Silica (SiO_2)	Dissolved from practically all rocks and soils, usually in small amounts—as much as about 25 ppm. However, waters draining from deposits high in silicate minerals, particularly feldspars, commonly contain as much as 60 ppm.	Forms hard scale in pipes and boilers. Carried over in steam of high-pressure boilers to form deposits on blades of steam turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. Usually less than 1 ppm in surface water. Higher amounts occur in acid waters from mine drainage or other sources.	More than about 0.3 ppm stains laundry, utensils, and fixtures reddish brown. Objectionable for food processing, beverages, dyeing, bleaching, ice manufacture, brewing, and many other processes. Federal drinking-water standards state that iron and manganese together should not exceed 0.3 ppm.
Manganese (Mn)	Dissolved from some rocks and soils. Usually less than 1 ppm in surface waters. Large quantities often associated with high iron content and with acid waters.	Same objectionable features as iron. Causes dark-brown or black stains.
Calcium (Ca) and magnesium (Mg).	Dissolved from practically all rocks and soils, but especially from limestone, dolomite, gypsum, and gypsiferous shale.	Cause most of the hardness and scale-forming properties of water; soap consuming. (See Hardness.) Water low in calcium and magnesium desired in electroplating, tanning, dyeing, and textile manufacturing.
Sodium (Na) and potassium (K).	Dissolved from practically all rocks and soils. Found also in sewage, industrial waste, and waste brines.	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers.
Bicarbonate (HCO_3 and carbonate (CO_3).	Action of carbon dioxide in water on carbonate rocks and soil materials, containing particles of limestone and dolomite.	Bicarbonate and carbonate cause alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot-water facilities to form scale and release corrosive carbon dioxide gas.

Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Usually present in drainage from mines and in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives a bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. Federal drinking-water standards recommend that sulfate content should not exceed 250 ppm.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in waste brines and some other industrial wastes.	In large amounts in combination with sodium gives salty taste to drinking water. In large quantities increases the corrosiveness of water. Federal drinking-water standards recommend that the chloride content should not exceed 250 ppm.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Present in salt water from oil wells and in industrial waste from processing of insecticides, disinfectants, and preservatives.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of calcification of enamel. However, it may cause mottling of the teeth, according to its concentration, the age of the child, and the amount of drinking water consumed (Maier, F. J., 1950, p. 1120–1132). Federal drinking-water standards set a limit of 1.5 ppm on fluoride content.
Nitrate (NO_3)	Decaying organic matter, sewage, and nitrate in soil.	Concentrations much greater than the local average may suggest pollution. There is evidence that more than about 45 ppm of nitrate (NO_3) may cause a type of methemoglobinemia in infants, sometimes fatal. Water of high nitrate content should not be used in baby feeding (Maxcy, K.F., 1950, p. 271). Nitrate is helpful in reducing intercrystalline cracking of boiler steel. It encourages growth of algae and other organisms that produce undesirable tastes and odors.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Includes any organic matter and some water of crystallization.	Federal drinking-water standards recommend that the dissolved solids should not exceed 500 ppm. Water containing more than 1,000 ppm of dissolved solids is unsuitable for many purposes.

TABLE 8.—*Significance of the chemical and physical properties of water*—Continued

Constituent or physical property	*Source or cause*	*Chemical characteristics that affect usability of the water*
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All the metallic cations other than the alkali metals, and free acid, also cause hardness.	Causes consumption of soap before a lather will form, and deposition of soap curd in bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness and can be removed by boiling. Any hardness in excess of this is called "noncarbonate hardness." Water whose hardness is less than 60 ppm is considered soft; 61 to 120 ppm, moderately hard; 121 to 200 ppm, hard; more than 200 ppm, very hard.
Specific conductance	Ionized mineral constituents in the water	Specific conductance is a measure of the ability of the water to conduct an electric current. Varies with concentration and degree of ionization of the constituents. Varies with temperature; reported in micromhcs at 25° C.
Hydrogen-ion concentration (expressed as pH).	Acids, acid-generating salts, and dissolved carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. The pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters also may attack metals.
Color	Apparent color is due to suspended matter and precipitated iron. True color is due to dissolved color-producing material such as tannins, animal wastes, and industrial pollutants.	Suspended material can be removed by flocculation and filtration, processes that also remove most color. Color due to dissolved material cannot be removed by simple filtration. True color affects the use of water for municipal supply and many industrial needs, such as for dyeing, textiles, chemicals, brewing, food processing, and ice making.

Except for iron, ground water from the principal fresh-water sources is well within limits of the drinking-water standards of the U.S. Public Health Service, which are discussed in table 8. In general, the waters can be described as soft, low in dissolved solids, slightly acid on the pH scale, and corrosive to metal surfaces. In composition, waters from the Wissahickon formation and granite are described as mixed types; the amount of the alkaline earths (calcium and magnesium) and the alkali metals (sodium and potassium) is about the same when these constituents are expressed in chemical equivalents. Bicarbonate is the principal cation, or negative ion.

Water from the greenstone tends toward a somewhat larger content of dissolved solids and is harder than that from principal sources. In places, hardness as calcium carbonate exceeds 150 ppm (parts per million), which is within the range of hard waters. (See table 8.)

Fluoride, chloride, and nitrate in the ground water of the Fairfax quadrangle are commonly low in content, although a few samples had an above-normal content of nitrate, indicating possible pollution of the source.

FACTORS AFFECTING THE CHEMICAL QUALITY OF THE WATER

Rainwater, containing dissolved gases from the atmosphere, is a powerful chemical weathering agent and solvent. The part of the rainwater that infiltrates the soil dissolves minerals from the soil and subsoil. Decay of organic material in the soil releases carbon dioxide and organic acids to the water, thereby enhancing its solvent power. The water that eventually reaches the ground-water reservoir has a content and distribution of dissolved solids that is determined by the chemical and physical characteristics of the rock materials and the hydrologic environment with which the water is associated.

Several factors contribute to the differences in quality observed in the quadrangle, none of which alone completely controls water quality. Probably the two most important are source and amount of recharge and the chemical and physical characteristics of the saturated materials near the wells. There is no well-defined regional pattern of water quality, such as can be found in some areas where substanial recharge occurs from outside the area.

Water-quality characteristics support the conclusion that local precipitation must be the important source of recharge to the water table. Accordingly, the quality of the water from each well is governed largely by local conditions surrounding the well.

Although the chemical and physical nature of water-bearing deposits is a dominant factor in determining water quality, it is difficult to isolate these characteristics conclusively. However, the following section is a discussion of the aggregate effect of geology on water quality.

QUALITY OF WATER IN RELATION TO SOURCE

The chemical characteristics of several representative waters from the quadrangle are illustrated in figure 13, in which the principal

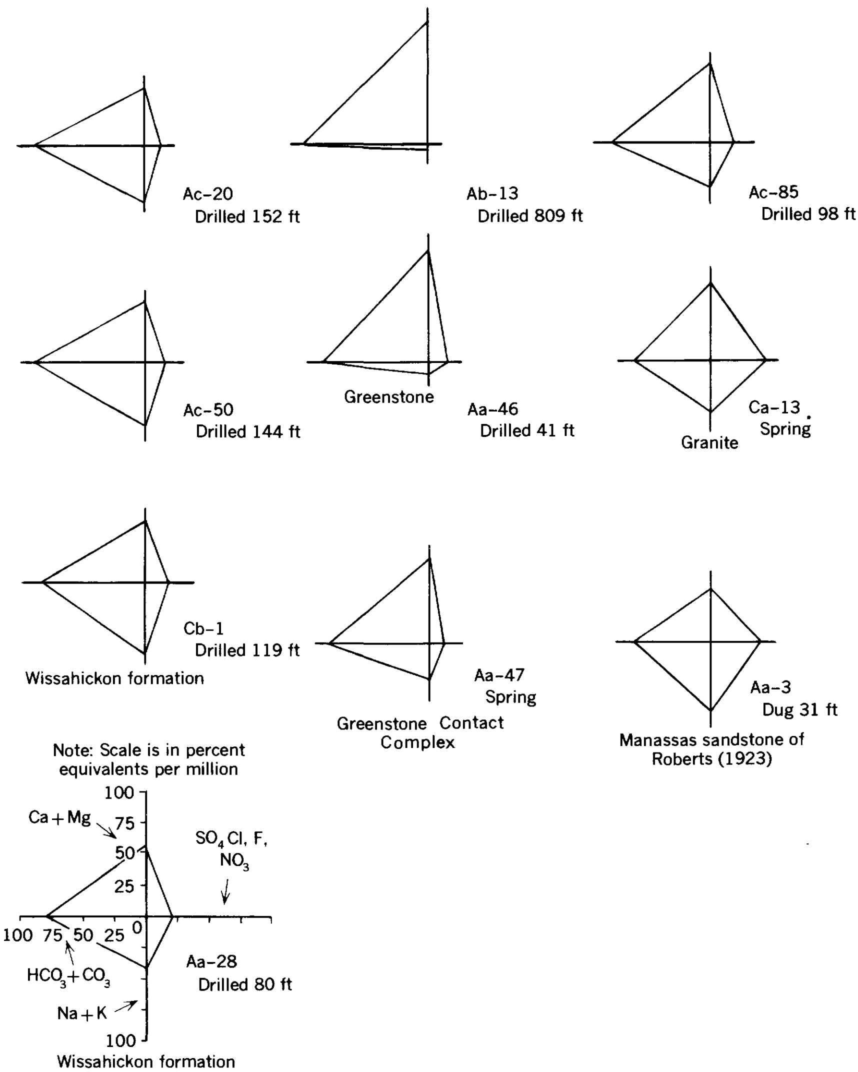

Figure 13.—Graphical representation of analyses of water from principal aquifers in Fairfax quadrangle.

cations and anions are plotted in percent equivalents per million (combining power) on a two-dimensional coordinate system. Percent equivalents per million of calcium and magnesium are plotted along the upper vertical axis, sodium and potassium below. Similarly, percentages of bicarbonate and carbonate are plotted to the left, and sulfate, chloride, fluoride, and nitrate to the right, from the midpoint of the bisectors. The extremities are connected by straight lines forming a quadrangle whose shape depends upon the chemical character of the water.

The following discussion is based on 33 analyses of water from the Wissahickon formation, greenstone, greenstone contact complex, granite, and Roberts' Manassas sandstone. Data for 2 springs and 27 wells are included in table 7.

WISSAHICKON FORMATION

The sampling program included good coverage of the Wissahickon formation, the principal aquifer in the area. Individually, the water samples from the Wissahickon show no outstanding differences in chemical characteristics from random samples from other aquifers in the area, but collectively they reveal some distinguishing features. The chemical composition of ground water from the Wissahickon is more uniformly a mixed type than water from other sources, except water from granite. Note in figure 13 that a distinctive, nearly symmetrical "kite" is formed from data representing the Wissahickon formation.

The median (middle-value) hardness of the water from the Wissahickon, 19 ppm, was slightly lower than that of the water from granite and much lower than that of waters from the greenstone and greenstone complex. (See tables 7, 9, and 10.) The siliceous character of the rock is reflected in the prominent silica content of the water, (not shown on the diagrams of fig. 13) which composes about one-third of the dissolved solids (median value). The dissolved solids in representative water from the Wissahickon is uniformly low; more than half the samples had less than 75 ppm of dissolved solids. Dissolved-solids content does not differ appreciably from that of water from the granite, but it is much less—by a factor of 2 or more—than that of the typical water from the greenstone.

The abundant chlorite and biotite and the accessory minerals, such as magnetite, ilmenite, and pyrite, are the sources of significant quantities of iron in some water samples from the Wissahickon. On the whole, iron is more troublesome in water from the Wissahickon than in that from other sources. This problem is twofold and is discussed more fully on page 54.

TABLE 9.—*Range in selected chemical and physical characteristics of water from the Wissahickon formation*

[Based on 17 samples; constituents in ppm except as indicated]

	Maximum	Minimum	Median
Depth of wells feet	400	24	119
Temperature °F	66	54	57
Silica SiO_2	44	9.2	23
Iron Fe	5.4	.06	1.1
Calcium Ca	18	1.3	4.2
Magnesium Mg	9.6	.2	1.4
Bicarbonate HCO_3	112	13	35
Dissolved solids, residue or calculated	105	37	81
Hardness as $CaCO_3$	83	4	19
pH units	7.6	5.9	6.4

GREENSTONE

The greenstone, the poorest aquifer in the Fairfax quadrangle, yields water markedly different in quality from that of the other crystalline and sedimentary rocks. The content of dissolved solids, consisting mostly of silica, calcium, magnesium, and bicarbonate, is substantially higher than that of other waters. The content of magnesium is characteristically higher than of other sources. Hardness from calcium and magnesium is greater also.

Differences in composition of the water are depicted clearly by the shape of the diagram representing samples from the greenstone (fig. 13). The symmetry of the Wissahickon "kite" contrasts with the "sail" shape formed by the predominantly calcium magnesium bicarbonate water of the greenstone.

GREENSTONE CONTACT COMPLEX

The analyses of water from the greenstone contact complex cannot be considered representative for that source. The quality of Dewey Spring water (Aa–47) resembles that of typical water from the Wissahickon in total mineral content, but calcium and magnesium bicarbonate are slightly more prominent. Water from the complex may be expected to be slightly harder than that from the Wissahickon and slightly softer than water from the greenstone. (See table 7 and fig. 13.) Dewey Spring is near the contact with the Wissahickon, and the water in large part may originate in the Wissahickon.

The samples from well Ac–1 in the contact complex show rather definite signs of contamination. Resampling has verified the fact that water from the 85 foot well has an above-normal chloride content and excessive nitrate, which suggest local surface seepage either around the well casing or through adjacent rock fractures. Also, some fine-grained granite (aplite) was observed in the geologic section, which is not typical of the complex.

Because of the potential importance of this aquifer, future studies in the area should include careful selection of additional sites at which representative water-quality information can be obtained.

GRANITE

Typical waters from granite, like those from the Wissahickon formation, are uniformily low in dissolved solids, soft, and slightly acid on the pH scale. (See tables 7, 9, and 10.) Iron, at least in the analyzed samples, was lower than in water from the Wissahickon; the median value of iron in five samples was 0.38 ppm. However, the writer has observed that some users of water from wells along the granite contacts near Ilda have severe problems with iron, owing to a combination of factors to be discussed. As in those of waters from the Wissahickon, the analyses identify the siliceous character of the rocks; silica composes as much as 34 percent of the residue.

There is no readily discernible areal pattern for silica, although water from granite having appreciable amounts of the relatively soluble silicates, such as feldspar, could be expected to contain larger concentrations of silica than do others. Quartz, which is the predominant mineral in the granite, is the most resistant of the common rock materials. Granite in the Fairfax quadrangle characteristically contains considerable feldspar, such as albite. Because the ground water in the area normally contains an appreciable amount of dissolved carbon dioxide—as much as 54 ppm in analyzed samples—a typical reaction yielding silica is as follows:

$$2\ NaAlSi_3O_8 + H_2O + CO_2 \rightarrow Al_2Si_2O_5(OH_4) + Na_2CO_3 + 4SiO_2.$$

Thus 4 molecules of silica are formed for each 2 molecules of feldspar.

TABLE 10.—*Range in selected chemical characteristics of water from granite*

[Based on 6 samples; constituents in ppm except as indicated]

	Maximum	Minimum	Median
Depth of wells ... feet	258	57	105
Silica (SiO_2)	34	12	30
Iron (Fe)	1.1	.07	.38
Calcium (Ca)	12	3.3	8.7
Magnesium (Mg)	1.1	.4	.8
Bicarbonate (HCO_3)	108	13	46
Dissolved solids, residue or calculated	91	45	84
Hardness as $CaCO_3$	37	11	23
pH ... units	6.9	6.2	6.4

MANASSAS SANDSTONE OF ROBERTS (1923)

Water from Roberts' Manassas sandstone, the only sedimentary-rock aquifer sampled, is represented by two analyses in table 7. Both sources are shallow dug wells, a factor that suggests potential surface contamination. The analysis for Aa-3 can be considered representative.

The very low dissolved-solids content, 28ppm, is evidence that recharge from rainwater has not circulated very far, as the chemical content of the water, other than the amount of silica, is not much different from that of rainwater. The water is very soft and is likely to be corrosive to metal surfaces; however, dissolved iron is not a problem.

Water from Aa–4 appears to be contaminated, as indicated by the excessive sodium and chloride contents. Otherwise the individual constituents are very similar in the two samples.

OCCURRENCE OF IRON IN GROUND WATER

Although the analyses in table 7 show that troublesome amounts of iron in water for general use (concentrations exceeding 0.3 ppm) occur principally in the Wissahickon, it should be noted that five of the samples were collected primarily because of their excess iron content. However, excess iron in water is a continuing problem in most of the other rocks in the Fairfax quadrangle. The problem seems to be related to two principal factors:

1. Partly decomposed rock, such as may be found near the top of the solid rock below the soil zone, is a source of iron, being leached by percolating recharge water. The processes by which iron in its various forms can be dissolved are rather complex; the chemistry of its solution has been discussed by Hem (1959). The amount of iron that can be present in natural ground water depends principally on the pH and the oxidation-reduction, or redox potential (Eh). Theoretically, at a pH of 5 to 8, which is the normal range in pH units observed in the Fairfax quadrangle, and at an oxidation-reduction potential of 0 to 0.50 volt, only about 0.01 ppm of ferric iron (Fe^{+++}) can be dissolved. This amount is only a fraction of that usually found in the water.

In contrast, ferrous iron is comparatively soluble. For example, at a pH of 5 and an Eh of 0.30 volt, as much as 60 ppm of ferrous iron can be in solution. Thus, it can be assumed that samples that were clear at the time of collection contained iron in the ferrous state when the iron concentration was more than a few hundredths of a part per million.

2. The second, and probably principal source of iron in pumped water is finely divided suspended sediments. In places the casing of a well may be firmly seated when the well is completed, but after further development of the well the rock softens, and silt and clay may be pumped from below until the casing is firmly reseated by further driving or grouting. The importance of suspended sediment to the iron problem was demonstrated several times in this study of the Fairfax quadrangle. For example, 4 samples were obtained from

well Ac–80 on January 8, 1956, after this domestic well had remained idle overnight about 9 hours. The well had been used heavily prior to the shutdown.

Sample	*Collection at pump*	*Iron (ppm)*
1.	1 minute after starting. Not filtered	2.7
2.	As above, but filtered immediately through two thicknesses of S.S. No. 597 filter paper	.92
3.	30 minutes after starting. Not filtered	.36
4.	30 minutes after starting. Filtered immediately	.16

Sample 1 was slightly turbid and rust colored; the others had only a slight amount of opalescence. Therefore, iron in sample 1 is attributed to iron in solution and in the suspended sediment. The analytical procedure for iron determines the total iron from all sources, dissolved and suspended. Sample 2 represents the dissolved iron content in water in storage in the pressure tank and well casing and would include natural iron in solution plus that dissolved from the metal surfaces by corrosive action. On the basis of conductivity measurements and hardness, it is considered that samples 3 and 4 were different in quality from samples 1 and 2 and, therefore, were more representative of water from the aquifer. In addition, they may reflect a contribution from the deeper part of the rock that is greater after a period of pumping than immediately after the pump is started.

SUMMARY AND CONCLUSIONS

The Fairfax quadrangle is underlain by phyllite, schist, and quartzite of the Wissahickon formation, and with associated silicic and mafic intrusive rocks. No evidence has been found in the Fairfax quadrangle that any of these rocks are of volcanic origin. Sedimentary rocks of Triassic age and alluvium of Recent age occupy small areas, and colluvium of Recent age occupies larger areas, but none of these are important as aquifers.

The dominant regional structural feature is the schistosity, which trends northeastward and dips vertically or northwestward. Two sets of joints are prominent, one striking northeastward and dipping 30° to 40° SE., the other striking northwestward to westward and dipping vertically to 60° NE.

Until 1957, when a pipeline connection was made with the Falls Church municipal water system, the entire Fairfax quadrangle was supplied by water from wells and a few springs. Some of the wells obtain water from the residual mantle rock or the alluvium overlying bedrock, but most of the water comes from fractures in the bedrock.

Privately owned wells in the greenstone contact complex have the highest yields, 5 to 55 gpm. Wells that tap the Wissahickon formation have intermediate yields, which range from 1 to 32 gpm. The lowest yields, 0.4 to 12 gpm, are obtained from the greenstone.

Well sites may be selected most advantageously—where space permits—by considering the rock type and structure and the topography. The choice between drilled and bored wells also should be determined by these factors.

Ground water in the Fairfax quadrangle generally is of good quality, except locally where problems are created by excessive iron, corrosiveness, and pollution from domestic waste. Only problems caused by excessive iron and corrosiveness are considered in this report. The present water-quality studies adequately define the chemical characteristics of the waters associated with the Wissahickon formation and the granite, but data for other aquifers are deficient.

No evidence of depletion of the ground-water supply was seen in the quadrangle; it appears that only a fraction of the available supply is now being pumped. Although wells in these metamorphic and igneous rocks do not yield large supplies, 5 to 10 gpm can be obtained in most places (except in parts of the greenstone and granite), and yields as high as 125 gpm are on record.

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