Ground-Water Supplies in Shale and Sandstone in Fairfax, Loudoun, and Prince William Counties, Virginia

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By Paul M. Johnston

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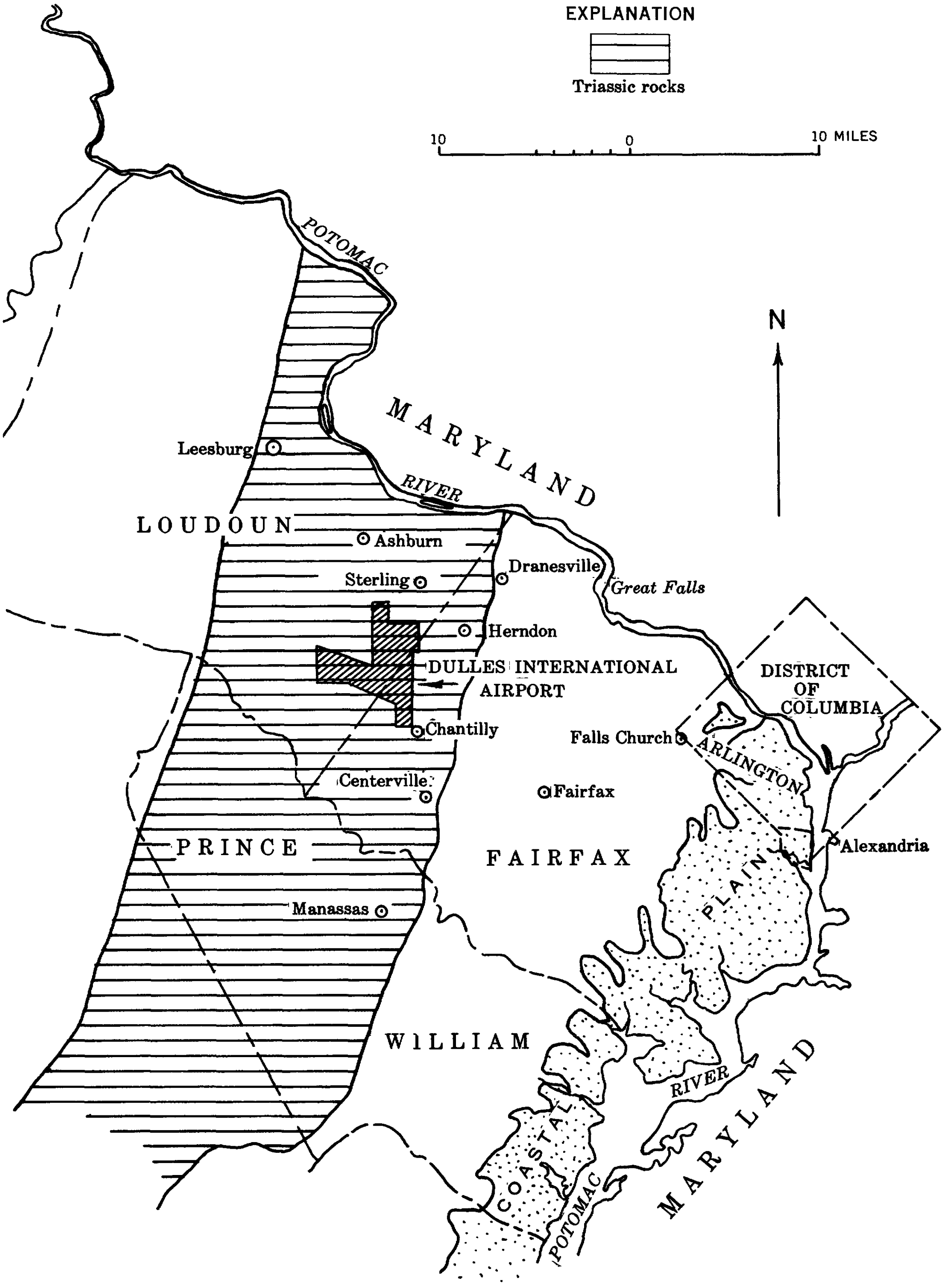

Figure 1.—The Triassic rocks of northern Virginia

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ABSTRACT

The Triassic rocks of northern Virginia may be a potential source of moderately large supplies of ground water for municipal and industrial use if the performance of two deep wells drilled at the site of the new Dulles International Airport is a criterion. These two wells produced 327 and 600 gpm (gallons per minute) from depths of 860 and 955 feet in sedimentary rocks in an immediate area where the previous maximum depth reported was 180 feet and the maximum yield 12 gpm.

Chemical analyses of the water indicates that it is extremely hard—533 and 500 ppm (parts per million) in the two wella—and would require treatment to be satisfactory for domestic and some industrial uses. However, water of better quality may be present at greater depths, and it may be possible to case off the more highly mineralized water. Further exploration and sampling of water from various depths will be necessary for efficient development of the Triassic ground-water reservoir.

INTRODUCTION

Water-bearing characteristics of Triassic rocks, as shown by two wells drilled at the site of the new Dulles International Airport at Chantilly, indicate that these rocks may be of substantial importance as sources of moderately large water supplies for municipal and industrial use, in addition to their traditional role as sources of small domestic and farm water supplies.

Since the Chantilly area was selected as the site for Washington's new international airport, much interest has developed regarding the ground-water resources of the area.

The Dulles International Airport is about 20 air-line miles west of Washington, D. C., just northwest of the town of Chantilly, Va. It lies north of U. S. Route 50 and straddles the Fairfax-Loudoun County line.

PREVIOUS WORK

The most comprehensive geologic study of the Triassic of Virginia made to date was that by Joseph K. Roberts (1938). Most of the geologic description included here is adapted from that report.

A geologic map covering a part of the area at a scale of about 1:125,000 is available for consultation at the U. S. Geological Survey, 18th and F. Streets N. W., Washington. The map covers the Fairfax quadrangle and the part of the Seneca quadrangle lying south of the Potomac River. The geology was mapped by A. P. Bennison and Charles Milton, U. S. Geological Survey.

A geologic map of Virginia, scale 1:500,000 published by the State in cooperation with the U. S. Geological Survey in 1928, is now out of print but is available in some public libraries.

GEOLOGY

The Triassic of northern Virginia is part of a long southwestward-trending belt which enters the Commonwealth from Maryland at the Potomac River between Point of Rocks and Seneca Creek. It is a thick wedge of westward-dipping sedimentary rocks and associated intrusive igneous rocks, in contact on the east with the Wissahickon formation and on the west with the Loudoun formation and the Catoctin greenstone. The ages of some of the older rocks are somewhat uncertain. The Catoctin is considered to be of Precambrian age and the Wissahickon, possibly early Paleozoic. Yet, the two may be contemporaneous in part, and the Catoctin in part may be even younger than the Wissahickon. The Loudoun formation is regarded as of Early Cambrian age. The formations are listed below without reference to age.

Wissahickon formation.— Schist, Phyllite, quartzite, and granitic and basaltic intrusive rocks.

Catoctin greenstone.— "Altered diabase, with lenses of epidote and quartz, and associated with great masses of....granite" (Keith, 1894).

Loudoun formation.— "...dark-colored slates and shales grading into sandstones containing lenses of slate and limestone, all more or less metamorphosed" (Roberts, 1928, p. 65).

Newark group.— Border conglomerate of Roberts, 1923. Includes limestone conglomerate, quartz conglomerate, arkose conglomerate, schist conglomerate, trap conglomerate, and quartz arkose. The quartz conglomerate is common on the eastern margin of the Triassic between Centerville and Herndon, where it is colored gray to black. North of Herndon light-gray schist conglomerate is exposed. The limestone conglomerate is exposed along the western margin of the Triassic in Loudoun County. It has been called Potomac marble or calico marble and has been quarried in Virginia and Maryland. About 90 percent of the pebbles are limestone, the rest quartz and feldspar, all in a red or white calcareous matrix.

Manassas sandstone of Roberts, 1923.— Includes coarse to very fine-grained sandstone, but grades from conglomerate to shale. Colors are gray, red, and yellow. The gray sandstone is generally coarser than the red. In some places the sandstone was altered by the heat associated with intrusion of diabase.

Bull Run shales of Roberts, 1923.—The youngest Triassic sedimentary rocks; alternating fine- to coarse-grained shale colored red, gray, blue and black, altered in places by intrusive diabase.

Diabase.— Diabase or "trap rock" in flat bodies called "dikes" (cutting across beds), "sills" (intruded between beds), and irregular bodies called "stocks" are intruded into the Triassic sedimentary rocks and into the underlying Wissahickon formation.

The widest section of the Triassic in Virginia is exposed between Herndon and Leesburg, a distance of about 15 miles. Roberts (1928) estimated the thickness in this area to be 1,000 to 1,500 feet.

In general the structure of the Triassic sedimentary rocks in monoclinal. The strike ranges from N. 15° W. to N. 45° E. The dip is westward to northwestward and ranges from 0° (horizontal) to 45°. Locally the rocks are faulted, or the dip is altered as a result of the intrusion of diabase.

There are two sets of joint cracks in the sedimentary rocks. The most conspicuous set strikes parallel to the bedding (N. 15° W. to N. 45° E.) and dips steeply. The second set, less conspicuous, strikes at right angles to the first and also has a steep dip.

Two sets of joints are present in the diabase. One set strikes northerly, the other westerly; both dip steeply.

The most accurate delineation of the outcrops of diabase is shown on the map by Bennison and Milton (1950). Other available maps are too small in scale to show the outcrops in detail.

Beneath the surface the location and extent of the intrusives are largely conjectural. The diabase body whose outcrop surrounds Herndon is thought to be a saucer-shaped sill of which only the edges are exposed. An exploratory hole was drilled in the east rim of this body in 1955 by Jack Ange on Annadale, Va. This hole is about 0.3 mile east of Chestnut Grove cemetary, which is on State Route 28 about a mile north of the Washington and Old Dominion tracks in Herndon. The hole was 1,000 feet deep and was still in diabase at that depth, but the rock was softer and coarser, than above probably indicating that the well was nearing a contact. A scanty supply of highly mineralized water was produced. (See analysis.)

Faulting is common in the Triassic rocks, both in sedimentary rocks and in the diabase. Reverse and normal faults both are present, but they are difficult to locate and trace because of deep weathering and the lack of extensive distinctive beds.

GROUND WATER

PREVIOUS DEVELOPMENT

The following summary of ground-water conditions in the Triassic rocks of northern

Virginia is based in part on data reported by Cady (1938). They, of course, represent ground-water development at that time, but the conditions and principles are still applicable.

Most of the wells in the Triassic rocks are drilled. Dug wells are generally unsatisfactory, as they have low yields, tend to fail in droughts, and are subject to pollution. The diabase is very resistant to weathering and in many places is very hard at the surface. For this reason it is very difficult to dig and impossible to bore (auger) a well in the diabase.

In the sandstone and shale, wells are generally less than 100 feet deep and yield less than 10 gpm (gallons per minute.) The deepest wells in these rocks in Fairfax and Loudoun Counties as reported by Cady (1938) were at Herndon and near Sterling. The Herndon well penetrated 300 feet of red shale but struck diabase at the bottom and produced only ½ gpm of water. The Sterling well also was 300 feet deep in red shale and produced 3½ gpm. On the other hand, two wells half a mile west of Floris in red shale, 96 and 100 feet deep, produced 55 and 50 gpm. Cady pointed out that the comparatively shallow wells commonly furnished adequate supplies for domestic use and there was no reason to drill deeper. However, he thought that if large supplies were needed they might be obtained by drilling "several hundred feet down..."

In the diabase most of the water is in the upper weathered zone, which is commonly less than 100 feet thick. Yields are generally low, but at least one well produced as much as 60 gpm. This well, only 36 feet deep, was 1¼ miles south of Chantilly. Another well in diabase near Ashburn was only 18 feet deep but yielded 10 gpm. In contrast, a well 802 feet deep at Goose Creek and Leesburg turnpike, where the rock was comparatively fresh near the surface, produced only 3 gpm.

No records are available for wells in the conglomerate at the eastern margin of the Triassic but these rocks seem to be tight and probably are not very productive. On the western margin the limestone conglomerate has yielded ½ to 60 gpm to wells 28 to 360 feet deep. A few holes were dry.

PRESENT MUNICIPAL SUPPLIES

Leesburg, the county seat of Loudoun County, and Herndon in Fairfax County both obtain public water supplies from the Triassic rocks. (See tables 1 and 2.)

Leesburg has a population of about 2,800 and is supplied by three wells and a spring, all presumably in the limestone conglomerate. About 73 percent of the water comes from the wells, the rest from the spring. The following records were obtained from the town authorities:

Date	Number of connections	Total consumption (gallons)
Jan. 1–31, 1959	759	12,708,000
July 1–31, 1959	771	15,192,400

The town of Herndon has a population of about 2,100, supplied by three wells in the Triassic sandstone and shale. These records were furnished by town authorities:

Date	Number of connections	Total consumption (gallons)
Jan. 1–31, 1959	440	3,820,000
July 1–31, 1959	446	3,473,000

RECENT DEVELOPMENT

During 1956 two wells were drilled in the Triassic rocks near Manassas by the Hagmann Co. of Vienna, Va. One of these wells, at Manassas Park, was 1,000 feet deep and was pumped for 46 hours at 327 gpm, which was the maximum capacity of the pump. This well passed through 996 feet of shale, into sandstone. The static water level was 56 feet below the land surface. The other well was 612½ feet deep and produced 260 gpm with a drawdown of 283 feet after 51 hours.

In December 1958, for the construction of the Dulles International Airport, it was proposed to establish a concrete-mixing plant southeast of the intersection of State Routes 607 and 608 (the community of Willard). To furnish water for concrete mixing and for fill compaction, two wells were drilled for C. J. Langenfelder, the contractor, by the Hagmann Co. in the spring of 1959. These wells, numbered 1 and 2, are reported to be entirely in shale. Pertinent data are shown in table 3.

Table 1.—*Municipal wells of Leesburg, Va.*

Town well no.	Driller	Date Completed	Depth (feet)	Water Level (feet)		Yield (gpm)
				Static	Pumping	
1	Wortman, Ashburn, Va	Before 1912	150	30	145	40
2	Hagmann, Vienna, Va	10-28	360	35	250	65
3	Thomas, Berryville, Va	10-54	350	28	200	165

Table 2.—*Municipal wells of Herndon, Va.*

Town well no.	Driller	Date Completed	Depth (feet)	Water Level (feet)	Yield (gpm)
1	Zoll Brothers	1931	200	165	50
2	The Hagmann Co., Vienna, Va	1954	400	150	100
3[1]	do	1958	420	40	25

[1] Used only in emergencies.

Table 3.—*Construction wells for Dulles International Airport*

Airport well no.	Driller	Date completed	Depth (feet)	Casing		Water level (feet below land surface	Yield (gpm)	Remarks
				Diameter (inches)	Length (feet)			
1	The Hagmann Co., Vienna, Va.	1959	860	8	8	8	327	Drawdown to 52 feet after 48 hours at 327 gpm.
2	do	1959	955	8	7	4	600	Drawdown to 155 feet after 52 hours at 600 gpm.

CHEMICAL QUALITY OF THE WATER

Chemical analyses of the water from the airport wells indicate that it is extremely hard (533 and 500 ppm for wells 1 and 2) and that maximum limits recommended by the Public Health Service for certain constituents are exceeded.

Water from the airport wells is satisfactory for concrete mixing, fill compaction, and irrigation, but water for most other uses will require treatment. Mixing equal parts of water from wells 1 and 2 would bring the iron and manganese within the acceptable limit, but not the sulfate and dissolved solids.

Constituent	Concentration, in parts per million		
	Well No. 1	Well No. 2	Public Health Service maximum
Iron and manganese	0.38	0.21	0.3
Sulfate	462	327	250
Dissolved solids	942	856	[1]500

[1] If such water is not available a total solids content of 1,000 ppm may be permitted.

It may be possible to obtain water of better quality from the Triassic sedimentary rocks

Table 4.—*Chemical analyses of water from wells in Triassic rocks of Fairfax, Loudoun, and Prince William Counties, Va.*

[Analyses by U. S. Geoligical Survey. Results in parts per million except as indicated]

Well No.	Airport No. 1	Airport No. 2	1021[1]	1333[1]	1046[1]	1115[1]	1116[1]	684[1]	725[1]	773[1]	1029[1]	Ange
Rock type	Shale	Shale	Shale	Shale	Sand-stone (?)	Sand-stone	Sand-stone	Limestone Con-glomerate	Limestone Con-glomerate	Diabase	Diabase	Diabase
Depth (feet)	860	955	65	196	70	297	505	53	360	42	80	1000
Date of collection	7-59	5-59	1931	1931	1931	1931	1931	1931	1931	1931	1931	1955
Silica (SiO_2)	25	67	-----	-----	-----	50	38	-----	17	-----	67	11
Aluminum (Al)	.0	.2	-----	-----	-----	-----	-----	-----	-----	-----	-----	.2
Iron (Fe)	.33	.15	-----	-----	-----	.25	1.1	-----	.18	-----	2.3	3.4
Manganese (Mn)	.05	.06	-----	-----	-----	-----	-----	-----	-----	-----	-----	.00
Copper (Cu)	.00	.00	-----	-----	-----	-----	-----	-----	-----	-----	-----	.00
Zinc (Zn)	.00	.00	-----	-----	-----	-----	-----	-----	-----	-----	-----	.00
Calcium (Ca)	175	131	35	24	72	39	31	50	68	100	36	1,860
Magnesium (Mg)	21	42	-----	-----	17	11	23	15	19	23	21	42
Sodium (Na)	64	54	-----	-----	15	12	12	3.5	19	14	12	777
Potassium (K)	1.2	1.3	-----	-----		1.6	1.4		4.7		1.0	2.7
Lithium (Li)	.1	.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	11
Bicarbonate (HCO_3)	194	275	212	162	204	181	219	206	239	338	204	1.8
Carbonate (CO_3)	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	7.9
Sulfate (SO_4)	462	327	3	4	67	5.4	5.8	5	19	11	11	177
Chloride (Cl)	14	13	6.0	10	14	10	5.0	5.0	29	40	15	4,500
Fluoride (F)	.3	.2	-----	-----	-----	-----	-----	-----	-----	-----	-----	.0
Nitrate	12	.4	1.8	.57	31	4.6	1.8	16	50	36	2.0	3.6
Phosphate (PO_4)	.1	.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	.1
Residue on evaporation at 180°C	942	856	-----	-----	330	212	202	209	331	411	254	7,390
Hardness as $CaCO_3$	533	500	176	122	250	143	172	186	248	344	176	4,810
Noncarbonate hardness as $CaCO_3$	374	274	-----	-----	-----	-----	-----	-----	-----	-----	-----	4,800
Alkalinity as $CaCO_3$	-----	226	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Free Carbon Dioxide (CO_2) (Calc)	6.9	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	.0
Specific conductance (micromhos at 25°)	1,200	1,010	-----	-----	-----	-----	-----	-----	-----	-----	-----	12,400
pH	7.4	7.8	-----	-----	-----	-----	-----	-----	-----	-----	-----	9.0
Color	2	8	-----	-----	-----	-----	-----	-----	-----	-----	-----	3
Temperature (°F)	64	62	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

[1] Well numbers from Cady (1938).

by locating and casing off the mineralized water if it enters the well from thin zones. Careful sampling during or after completion of the wells is necessary to obtain representative samples.

Table 4 gives analyses of water from various rock types at different depths. Water from the Ange well in the diabase contains a large amount of calcium chloride, suggesting that connate water (deposited with the sediments) is present in the sedimentary rocks below.

FUTURE DEVELOPMENT

In locating the wells at Dulles International Airport it was assumed that water under artesian pressure would be found in the Manassas sandstone beneath the Bull Run shales. However, the driller's well logs show shale for the entire depth of both wells. Therefore, if the sandstone is present it must lie still lower in the section. If Roberts' estimate (1928) of 1,000 to 1,500 feet as the thickness of the Triassic rocks is correct, not more than 500 feet of sandstone could underlie the shale at the site of Well 2.

If future high-yield wells are to be drilled, the structure of the Triassic rocks must be taken into account. Although not enough deep drilling has been done as yet to give more than rudimentary data on subsurface conditions, the most promising areas appear to be 3 to 4 miles west of the eastern contact of the Triassic. Furthermore, wells should be located as far as possible from diabase bodies. If wells must be located near diabase bodies they should be on the updip (east) side of the intrusive. In the few places where the writer has seen the contacts of the intrusive, adjacent sedimentary rocks have been baked and the contact virtually sealed, forming an effective barrier to the movement of ground water. Even if outcropping diabase bodies are avoided consealed ones may be encountered at any depth.

The effect of faulting on the movement of ground water is not known and probably will not be known until more wells or test holes are drilled. It is probable, however, that faults produce barriers to ground-water movement in the shale and sandstone bodies.

It appears unlikely that the quartz conglomerate at the base of the Triassic contains much water unless it is broken by faulting. Where examined at the eastern margin of the Triassic rocks it is a massive, tightly cemented rock without visible bedding or joint planes. However, at the base of the conglomerate, which is presumably in contact with metamorphic basement rocks, some water may be available.

Until more is known about the water-bearing characteristics of the Triassic formations it is suggested that deep wells be kept at least 1,000 feet apart to reduce mutual interference.

SUMMARY

Records of two wells drilled at the site of the new Dulles International Airport in the spring of 1959 lead to the conclusion that moderately large quantities of water are probably available elsewhere in the Triassic rocks of Virginia. Both these wells are in the Bull Run shales of Roberts (1923). Well 1 is 860 feet deep and produces 327 gpm. Well 2 is 955 feet deep and produces 600 gpm.

Analyses of water from these wells shows that the water is extremely hard and moderately mineralized. Although the water is suitable for concrete mixing it will need treatment for domestic and for most industrial uses.

Careful sampling and analysis of water from separate water-bearing zones in deep wells may reveal the source of the mineralized water, which then perhaps could be cased off. Also, the sandstone that presumably lies beneath the shale should be explored for water of better quality.

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