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COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND DEVELOPMENT
VIRGINIA DIVISION OF GEOLOGY
WILLIAM M. McGILL, *State Geologist*

BULLETIN 69

Public and Industrial Ground-Water Supplies of the Roanoke-Salem District, Virginia

BY BRUCE F. LATTA

PREPARED IN COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY

CHARLOTTESVILLE, VIRGINIA
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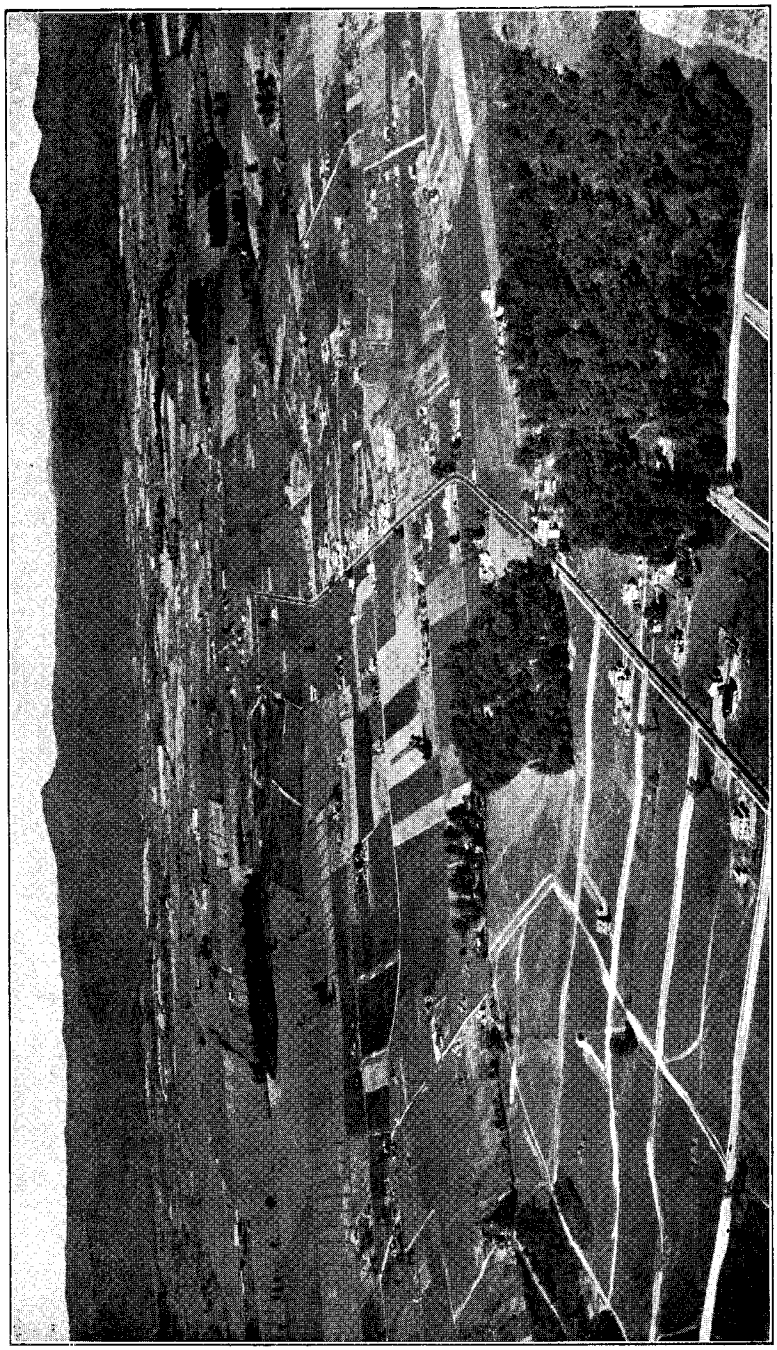
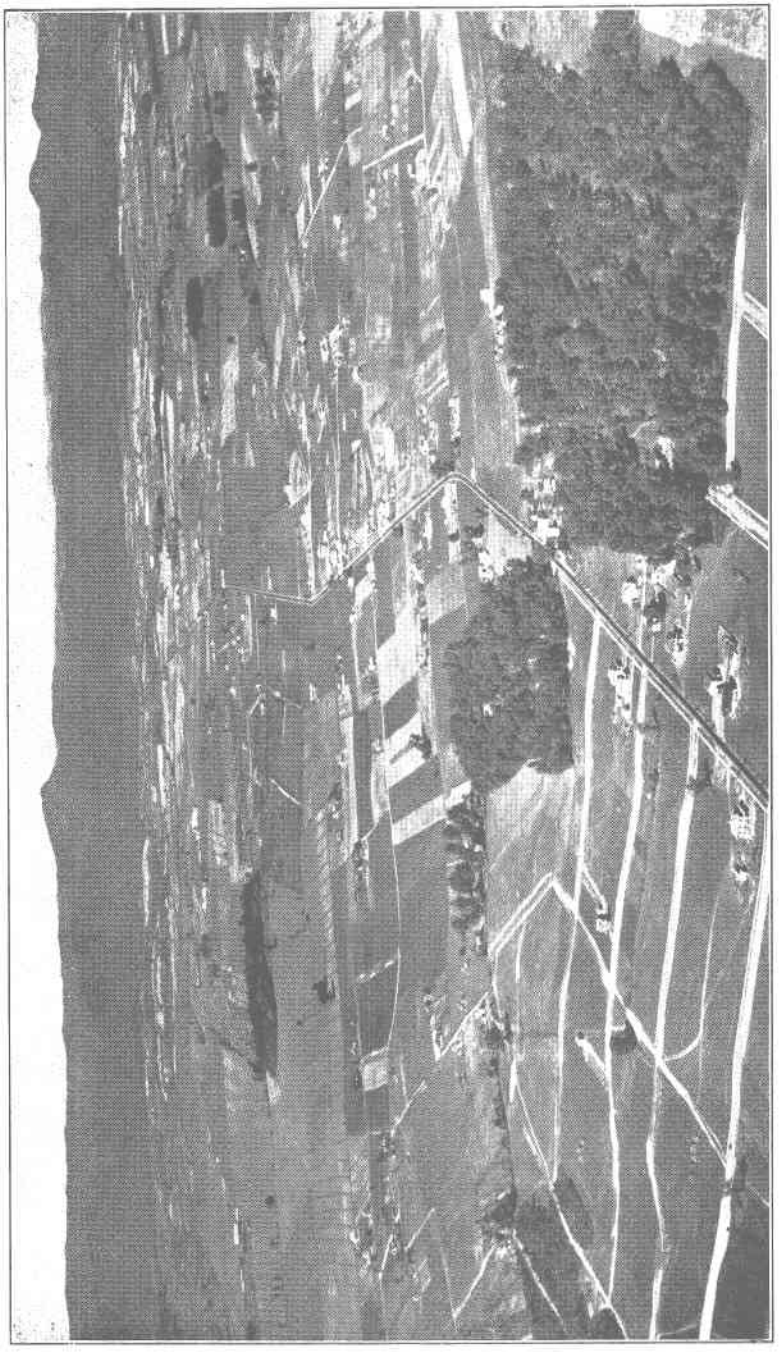


View looking northwest across Roanoke Valley showing ridges of the Appalachian Ridge and Valley province in the background. Aerial photograph by Underwood and Underwood, courtesy of Roanoke Chamber of Commerce. *(From Virginia Geological Survey Bulletin 34.)*



View looking northwest across Roanoke Valley showing ridges of the Appalachian Ridge and Valley province in the background. Aerial photograph by Underwood and Underwood, courtesy of Roanoke Chamber of Commerce. *(From Virginia Geological Survey Bulletin 34.)*

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COMMONWEALTH OF VIRGINIA

DEPARTMENT OF CONSERVATION AND DEVELOPMENT

DIVISION OF GEOLOGY

Charlottesville, Va., May 10, 1956

To the Department of Conservation and Development:

GENTLEMEN:

I have the honor to transmit and to recommend for publication as Bulletin 69 of the Virginia Division of Geology series of reports the manuscript and illustrations of *Public and Industrial Ground-Water Supplies of the Roanoke-Salem District, Virginia,* by Mr. Bruce F. Latta, formerly Geologist with the Ground Water Branch of the United States Geological Survey.

This report is one of a series prepared as a result of detailed investigations of the ground-water resources of Virginia, conducted in cooperation with the United States Geological Survey.

It discusses ground-water conditions and supplies in the Roanoke-Salem district in Roanoke County. In it are summarized the occurrence of ground water in the different types of rocks and the water-bearing properties of the individual formations.

As the amount and distribution of available underground water supplies depend upon geologic conditions, this report should be of particular value to residents, representatives of industries, and well drillers in the Roanoke-Salem district.

Respectfully submitted,

WILLIAM M. MCGILL,

State Geologist.

Approved for publication:
Department of Conservation and Development,
Richmond, Virginia, May 21, 1956
RAYMOND V. LONG, *Director.*

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Public and Industrial Ground-Water Supplies of the Roanoke-Salem District, Virginia

By Bruce F. Latta*

INTRODUCTION

This report describes the public and industrial ground-water supplies of the Roanoke-Salem district, Virginia. The investigation upon which the report is based was made during the spring of 1945 and is part of a continuing cooperative program begun in 1931 by the Geological Survey Division of the Virginia Department of Conservation and Development and the Ground Water Branch of the Geological Survey, U. S. Department of the Interior, to study the ground-water resources of Virginia. The program is under the direction of William M. McGill, State Geologist, and A. N. Sayre, Chief, Ground Water Branch, U. S. Geological Survey. This report was prepared in 1945 under the general direction of Arthur Bevan, then State Geologist, and the late O. E. Meinzer, then Geologist in Charge, Division of Ground Water, U. S. Geological Survey.

The present extensive use of ground water and the increasing development of ground-water supplies resulting from the progressive growth in industries and population of the Roanoke-Salem district have made it desirable that a better understanding of the hydrology of the area be acquired. An effort has been made, therefore, to present data that can be used as a guide in answering questions concerning future ground-water developments.

The district considered is in the southwestern part of Virginia and embraces approximately 77 square miles. The district lies entirely within Roanoke County and includes the City of Roanoke and its suburban district and the towns of Salem and Vinton. The location of the Roanoke-Salem district with respect to its position in Roanoke County and to adjoining counties is shown on Figure 1.

The descriptions of the various geologic formations and structures and the areal distribution of the formations, as shown on Plate 1, were taken largely from a report (1932) and accompanying geologic map on the Geology and mineral resources of the Roanoke area by Herbert P. Woodward. Slight revisions in the geologic map by Woodward were made by the writer as a result of field observations.

The hydrologic data were obtained by the writer through personal interviews with the owners of wells and springs, drillers, and municipal and corporation officials. Information on 70 wells and springs was obtained in this manner. The locations of the wells and springs are shown on Plate 1 and tabular descriptions of them are given in Table 5. Samples of water collected from 12 wells and three springs were analyzed by G. W. Whetstone and Evelyn Holloman in the Water Resources laboratory of the United States Geological Survey at Raleigh, North Carolina, and the results are given in Table 2.

*Formerly Geologist, Ground Water Branch, U. S. Geological Survey; now District Geologist, Kansas State Department of Health, Dodge City, Kansas.

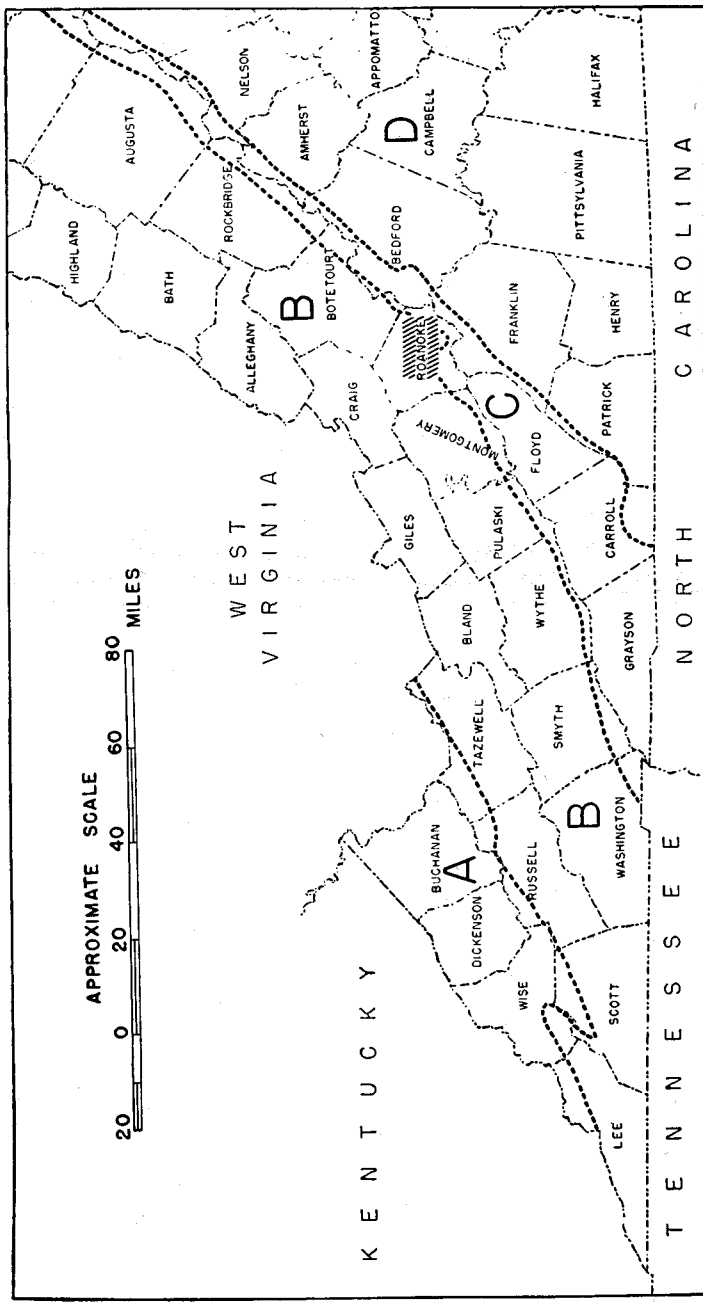


FIGURE 1.—Index map of western Virginia, showing the location of the Roanoke-Salem district and its relation to physiographic provinces. A, Appalachian Plateau province; B, Ridge and Valley province; C, Blue Ridge province; D, Piedmont province.

The writer is indebted to the many well owners and officials in charge of industrial wells who so willingly supplied information concerning their wells; to C. E. Moore, Superintendent of the Roanoke City Water Supplies, and C. A. Johnson, Superintendent of the Salem Water Supplies, for furnishing data concerning the public water supplies in their respective communities; and to B. A. Chappel of the Southern Drilling Company, A. H. St. Clair of the St. Clair Well Drilling Company, J. C. Perry of the Virginia Machinery and Well Company, and Garland S. Sydnor of the Sydnor Pump and Well Company, for furnishing well logs and other data pertaining to wells drilled by their companies. Thanks are also extended to Arthur Bevan, former State Geologist, under whose administration this study was made, to William M. McGill, present State Geologist, and to B. N. Cooper and R. S. Edmundson, former geologists with the Virginia Geological Survey, for their assistance in acquainting the writer with the various geologic formations in the Roanoke area. Plate 1 and Figure 1 were drafted in final form by Miss Nauvoo Morris of the Charlottesville office of the Ground Water Branch of the U. S. Geological Survey.

Data regarding additional wells, drilled since 1945, were obtained by Alfred C. Walker of the Virginia Geological Survey through the assistance of B. A. Chappel of the Southern Drilling Company. C. E. Moore, Superintendent of the Roanoke City Water Supplies, kindly furnished more recent information concerning that city's water supply than was available at the time this report was originally prepared.

GEOGRAPHY

Population.—The population of the Roanoke-Salem district has increased steadily since the first census was taken in 1880, at which time there were less than 1,000 people in the district. According to the 19th U. S. Census, the Roanoke metropolitan area had a total urban and rural population of 141,624 in 1950. Of this number 91,089 persons were living in the City of Roanoke; 6,820 in the Town of Salem; 3,500 in the Town of Vinton; and 40,215 in unincorporated areas.

Transportation.—The Roanoke-Salem district has excellent transportation facilities, being served by main lines of the Norfolk and Western Railway and the Virginian Railway and by local and through passenger busses and freight trucks. Travel within the district is facilitated by a complete network of hard-surfaced Federal and State Highways and local roads. In addition, the City of Roanoke has a modern airport and daily air transportation for passenger, mail, and express service.

Natural resources and industries.—The district herein considered is essentially an industrial area. The principal products from more than 100 manufacturing establishments include rayon yarn, rayon cloth, rail-

road locomotives and cars, fabricated steel products, clothing, foundry products, furniture, tin cans, metal and concrete culverts, chemicals, sole and belting leather, beverages, ice, and food products.

Mineral resources of the area include clay, building stone, crushed rock, and limestone, but the production of none of these is very large. An important natural resource of the Roanoke-Salem district is ground water, with which the major part of this report is concerned.

Climate.—The annual precipitation as recorded at Roanoke averages 40.80 inches and has ranged from less than 25 inches to more than 55 inches. In 1930 the precipitation at Roanoke was only 23.17 inches. Although the precipitation is fairly well distributed throughout the 12 months of the year, the heaviest rainfall occurs in the summer months of June, July and August.

The mean annual temperature at Roanoke is about 56°F. January, with an average temperature of 37.8°F., is the coldest month, and July, with an average temperature of 75.7°F., is the warmest. Temperatures as high as 105°F. and as low as minus 12°F., have been recorded. The first killing frost in the fall generally occurs late in October and the last killing frost in the spring generally occurs in April. The average length of the growing season is about 190 days.

PHYSIOGRAPHY

The relation of the Roanoke-Salem district to the major physiographic provinces of western Virginia is shown on Figure 1. The greater part of the area is in the physical division known as the Valley of Virginia, which occupies the eastern part of the Appalachian Ridge and Valley province and consists of a series of rather broad, elongate valley-like lowlands. Woodward (1932, p. 7) has given the name Roanoke Valley to that part of the Valley of Virginia in Roanoke County since it is separated from the rest of the Valley region by outlying or spur hills and mountains on the southwest and northeast.

All of the area described in this report, except the southeastern and southwestern parts, is in Roanoke Valley. The Valley trends northeast-southwest for 20 miles and its width in this district ranges from less than two miles just west of Salem to about eight miles at Roanoke. Its floor, which is underlain by easily eroded limestone and shale, is undulatory and slopes from an average altitude of about 1,100 feet at the western edge of the district to about 1,000 feet at the eastern edge. (See Plate 2.) Parts of the Valley are moderately hilly with the local relief exceeding 100 feet.

The southeastern and southwestern parts of the Roanoke area are occupied by rugged foothills of the Blue Ridge province. Resistant Precambrian crystalline rocks and Lower Cambrian sandstone and quartzites make up the foothills. Mill Mountain in south Roanoke is one of

the more prominent foothills and rises to an altitude of 1,797 feet, or about 800 feet above the valley floor (Plate 3). The highest point in the Roanoke area, 2,707 feet, is on Twelve O'clock Knob, about three miles southwest of Salem.

The Roanoke-Salem district is drained by Roanoke River and its tributaries, the largest of which are Tinker, Peters, Mason, and Mud Lick creeks. Roanoke River heads in eastern Montgomery County and, after crossing the southern part of Roanoke County, flows through the Blue Ridge southeast of Roanoke, thence southeastward across the southern part of Virginia and across the northeastern part of North Carolina into the Atlantic Ocean.

OUTLINE OF THE ROCK FORMATIONS

The rocks of the Roanoke-Salem district may be classified into three broad groups, based upon the age and lithology of the formations: (1) Precambrian and early Paleozoic metamorphosed sedimentary and igneous rocks; (2) folded Paleozoic limestones, shales, and sandstones of Roanoke Valley; and (3) unconsolidated sediments of Quaternary age that occur in stream valleys and in terrace remnants along the larger valleys.

The consolidated sedimentary rocks that occur at the surface range in age from Lower Cambrian to Devonian, and all geologic periods of that interval are represented.

The stratigraphic sequence and general lithologic character of the rock formations are summarized in Table 1. More complete descriptions of the lithology and water-bearing properties of the different units are given under the heading "Geologic formations and their water-bearing properties" (pp. 33-40).

TABLE 1.—*Geologic formations in the Roanoke-Salem district, Virginia*

Age	Formation or group	Thickness (feet)	Lithology	Water-bearing properties
Quaternary		0-50	Unconsolidated gravel, sand, silt, and clay derived by weathering and erosion of older rocks. Occur along streams and in terrace remnants along the larger valleys.	One shallow well (No. 53) at the American Viscose Co. plant yields about 60 gallons a minute from alluvial deposits in Roanoke River valley. Quality of water reported to be fair. Deposits are too thin in most places to yield large quantities of water.
Devonian	Romney shale	600	Dark-gray to black, fissile carbonaceous shale.	Unimportant in the Roanoke district; small areal extent. No municipal or industrial wells in this district derive their supply from these rocks. However, limestones of this series are important sources of water in other parts of the Appalachian Valley.
	Helderberg group	25	Gray-brown friable sandstone.	
Silurian	Clinton formation and Clinch sandstone	400	Red and white friable sandstone, coarse cross-bedded gray sandstone, and buff and red shale.	
Ordovician	Martinsburg shale	900-1,100	Gray-brown calcareous shale, thin flaggy sandstone, and thinly bedded crystalline limestone.	
	Moccasin formation	150-300	Reddish sandstone and shale.	
	Athens shale	950	Black hackly shale containing thin beds of black limestone in lower part.	
	Stones River group	325±	Crystalline limestone at top and beds of dark knotty and pure limestone below. Not exposed in Roanoke-Salem district, but occurs beneath Athens shale in northwestern part of the district.	

TABLE 1.—*Geologic formations in the Roanoke-Salem district, Virginia (Continued)*

Age	Formation or group	Thickness (feet)	Lithology	Water-bearing properties
Ordovician	Nittany dolomite	800±	Light-gray to blue cherty dolomite. Not exposed in this district, but occurs beneath younger strata in the northwestern part of the district.	One deep well yields 30 gallons a minute with a drawdown of 16 feet; larger yield possible with greater drawdown. Water from this well is of good quality and the hardness is only 81 parts per million.
Cambrian	Conococheague limestone	1,200-1,600	Cherty magnesian limestone and dolomite. Not exposed in this district, but occurs beneath younger strata in northwestern part.	No municipal or industrial wells in this district derive their supply from these rocks.
	Elbrook formation	1,000-1,600	Blue and bluish-gray, generally thinly bedded, limestone alternating with buff and gray calcareous shale. Middle and upper parts are thicker bedded and contain thin beds of dolomite. Underlies most of northern third of the district.	An important source of ground water in this district. Supplies 20 of the recorded wells and 3 of the recorded springs. Thirteen wells less than 300 feet deep yield 5 to 100 gallons a minute and average 38 gallons a minute. Three wells 325 to 785 feet deep, yield an average of 228 gallons a minute. Three springs discharge 485 to 650 gallons a minute. Water is slightly hard to hard. Six samples analyzed had 66 to 246 parts per million of hardness.

TABLE 1.—*Geologic formations in the Roanoke-Salem district, Virginia (Continued)*

Age	Formation or group	Thickness (feet)	Lithology	Water-bearing properties
Cambrian	Rome formation	900±	Consists largely of red, rusty-brown, and purple sericitic shale that weathers yellowish-gray, but contains beds of bluish-gray to dark-blue limestone and dolomite that are from a few feet to 100 or more feet thick. Underlies most of central part of the district.	The limestone and dolomite beds are one of the most important sources of ground water in this district and supply water to 32 of the 70 recorded wells and springs. Twenty-one wells, from 65 to 700 feet deep, yield 7 to 1,000 gallons a minute and average 30.7 gallons a minute. Nine springs discharge from 12 to 750 gallons a minute. Water is hard. Five samples analyzed had 105 to 375 parts per million of hardness, and one sample had 1,410 parts.
	Shady dolomite	1,200-1,500	Massive, coarse-grained, blue to dark-gray, impure dolomite containing interbedded laminated shale and clay. Lower part is generally soft and consists of finely laminated clay and ocher. Base of the formation is generally arkosic. Underlies the district south of Roanoke.	Two shallow wells have small yields; one well, 377 feet deep, yields 50 gallons a minute; 3 deep wells, 656 to 1,230 feet deep, yield 146, 175, and 382 gallons a minute. One spring has small discharge and Crystal Spring, with an average discharge of 2,775 gallons a minute, is the largest in the district. Waters from deep wells are generally highly mineralized.

TABLE 1.—*Geologic formations in the Roanoke-Salem district, Virginia (Continued)*

Age	Formation or group	Thickness (feet)	Lithology	Water-bearing properties
Cambrian	Basal quartzites	2,500-3,000	Sandstone, quartzite, coarse and fine conglomerate, gray shale, and some slate. Basal beds are arkosic and contain pebbles of the underlying rocks. Locally metamorphosed.	Hard, relatively impermeable rocks. One well (No. 66) yields 5 gallons a minute, and one spring (No. 67) yields 5 to 6 gallons a minute from fractures in hard, coarse conglomerate. Water reported to be very soft. Drilling is difficult and large yields probably not obtainable.
Precambrian			Massive igneous and schistose metamorphic rocks.	No industrial or municipal wells in the district derive their supply from these rocks.

GEOLOGIC STRUCTURE

At the close of the Paleozoic era the rocks in the Appalachian Ridge and Valley region were folded and faulted by great compressive forces acting from the southeast. The Precambrian rocks that now form the Blue Ridge were thrust over lower Paleozoic rocks. This overthrust is known as the Blue Ridge fault and extends northeasterly along the northwest side of the Blue Ridge across the entire State. The trace of the fault in the Roanoke-Salem district is shown on Plate 1. Throughout most of this district the Precambrian rocks have been thrust into contact with the Rome formation, but south of Roanoke they are in contact with the basal Cambrian quartzites and the Shady dolomite. The horizontal movement along the fault is believed to be greater than nine miles and the dip less than 20 degrees (Woodward, 1932, p. 80).

Another large fault—the Salem fault—crosses the northwestern part of the Roanoke-Salem district (Plate 1). This fault extends across Roanoke County into Botetourt County on the northeast and into Montgomery County on the southwest. It is a low-angle overthrust fault that has brought the Elbrook formation (Cambrian) into contact with Middle and Upper Ordovician rocks in this area. The general relations of the rocks along the Blue Ridge and Salem faults are shown on Figure 2.

The rocks lying northwest of the Salem fault form part of the south-

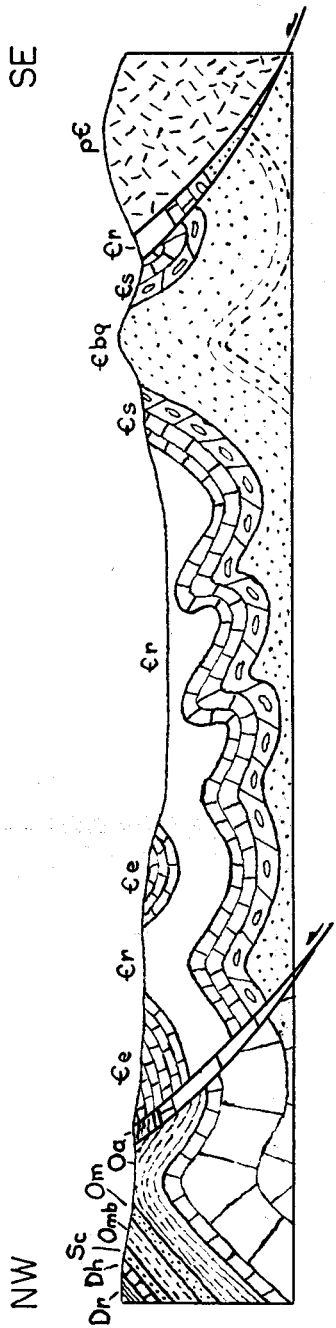


FIGURE 2.—Generalized geologic cross-section across the Roanoke-Salem district, Virginia, from the northwest corner to the southeast corner. Dr, Romney shale; Dh, Helderberg group; Sc, Clinton formation and Clinch sandstone; Omb, Martinsburg shale; Om, Moccasin formation; Oa, Athens shale; Єe, Elbrook formation; Єr, Rome formation; Єs, Shady dolomite; Єbq, basal quartzites; pЄ, Precambrian crystalline rocks. After cross-sections by H. P. Woodward, Virginia Geological Survey Bull. 34, Plate 2.)

east limb of the large Catawba syncline—one of the largest single folds throughout the Valley of Virginia (see Plate 4). The Catawba syncline crosses the northern part of Roanoke County in a northeast-southwest direction and is parallel to the general structure of the Appalachian Ridge and Valley province. The length of the syncline is about 30 miles and its maximum width is about five miles. If the southeastern rim had not been nearly obliterated by the Salem thrust fault, its average width would be about eight miles.

A series of smaller folds occur in the Cambrian rocks that lie between the Salem and Blue Ridge faults. These small folds are especially numerous in the Rome formation and to a lesser extent in the Elbrook formation. They are generally measured in hundreds of feet and as many as eight or ten may occur in a mile.

Round Hill, north of Roanoke, presents a rather unusual structural feature. The hill is capped by the resistant Clinch sandstone of Silurian age and is surrounded on all sides by the Elbrook formation of Cambrian age. The hill is considered by Woodward (1932, p. 88) to be a fenster in the large Pulaski overthrust block. The Pulaski overthrust extends for more than 200 miles, from Rockbridge County, Virginia, southwestward to a point near Greenville, Tennessee. The trace of this overthrust trends northeast along the northwestern edge of Roanoke County.

Other structures in the Roanoke area include minor thrust faults and normal faults with small displacements. Some of the minor thrust faults are entirely separate from the Salem and Blue Ridge thrust faults, whereas others branch off from these major faults. Normal, or gravity, faults in this area are less common and much smaller than the thrust faults.

SOURCE AND OCCURRENCE OF GROUND WATER

General Statement

Ground water, or the water beneath the surface which feeds springs and wells, in the Roanoke-Salem district, is derived almost entirely from precipitation that falls locally in the form of rain or snow. Part of the water that falls as rain or snow leaves the area as surface runoff and a part is evaporated or is transpired by vegetation from the surface of the ground or from the soil, but a part percolates downward into the rocks and joins the main ground-water reservoir. Ground water moves through the rocks in directions or courses determined by the topography and geologic structure, until eventually it is discharged through the wells or springs, seeps into streams, or is lost by evaporation and transpiration in the low areas bordering the streams.

The permeable rocks that lie below a certain level, which in the Roanoke-Salem district ranges from the surface to a depth of more than 100 feet below the surface, are generally saturated with water. These saturated rocks are in the zone of saturation, the upper surface of which

is called the water table. The water table is relatively near the surface in most places in the district. In the valley or lowland areas the depths to the water level in wells, which indicate the depth to the water table, range from a few feet to 20 or 30 feet below the surface; and below the upland areas, such as hills and ridges, they range from about 30 feet to a known maximum of 138 feet below the surface. The many springs represent places where the water table intersects the surface. Some wells in this area encounter water under artesian pressure, and a few flow at the surface. The slope of the water table and therefore the movement of ground water is from the high areas to the streams. As a result, all of the perennial streams in this area gain water from the ground-water reservoir except when they are at flood stage.

The water table does not remain in a stationary position but fluctuates up and down in response to the amount of water being added to it from precipitation or the amount being discharged from it through wells, springs, seepage into streams, and by evaporation and transpiration. The fluctuations of water levels in wells and of the discharge of springs reflect changes in the position of the water table. In general, the water levels in wells will rise and the discharge of springs will increase during periods of abundant rainfall; and conversely, the water levels in wells will decline and the discharge of springs decrease during periods of deficient rainfall.

A discussion of the water-bearing characteristics of the different kinds of rocks found in this district is given in the following paragraphs.

WATER IN UNCONSOLIDATED ROCKS

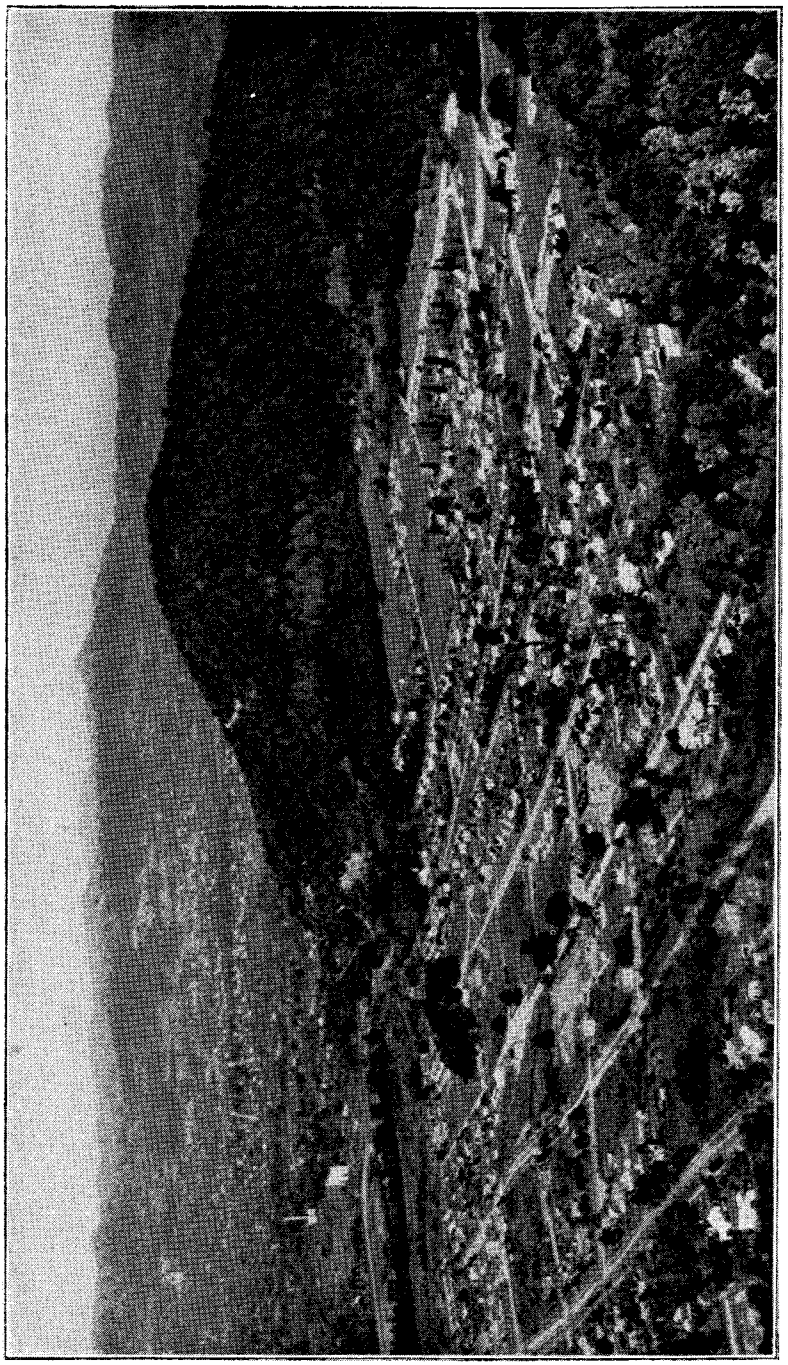
The unconsolidated rocks in the Roanoke-Salem district consist of clay, silt, sand, and gravel of Quaternary age that occur along the streams and in terrace remnants along the larger valleys. Water occurs in these deposits in the primary pore spaces between the individual grains of sand or gravel. In many localities deposits of gravel and sand are the most productive sources of ground water. In this district, however, such deposits are relatively unimportant as indicated by the fact that only one well (No. 53) of the 83 recorded wells and springs derives its water from sand and gravel. A description of this well is given on page 40. Deposits of sand and gravel in the Roanoke-Salem district are in general too thin to be capable of yielding large supplies of water.

WATER IN LIMESTONE AND DOLOMITE

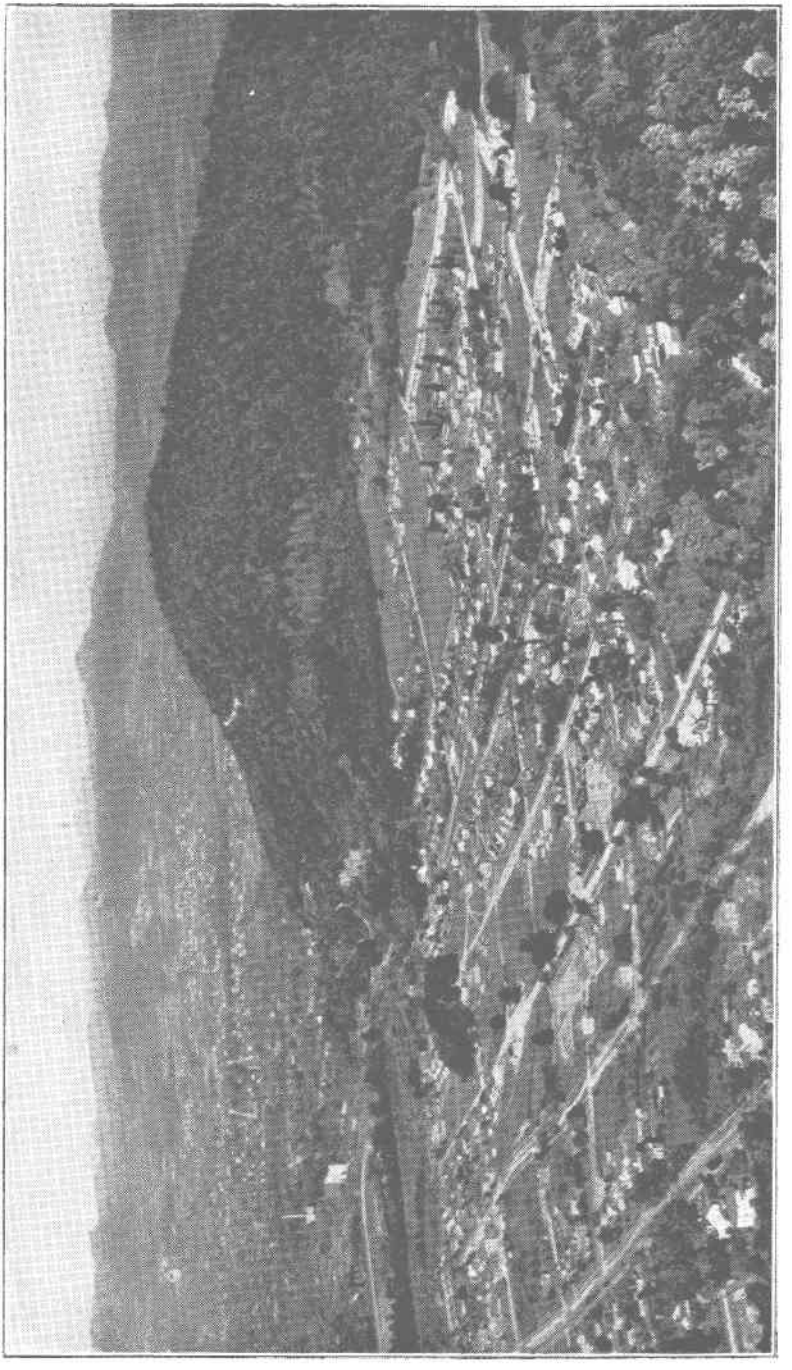
Limestone and dolomite have similar water-bearing properties and both are known as limestone to the drillers and other people in the district. For this reason and for convenience, in this discussion, the term limestone will be used to denote both limestone and dolomite.

Limestones in the Shady, Rome, and Elbrook formations are the most important sources of ground water in this district and supply water to about 95 per cent of the industrial and public-supply wells.

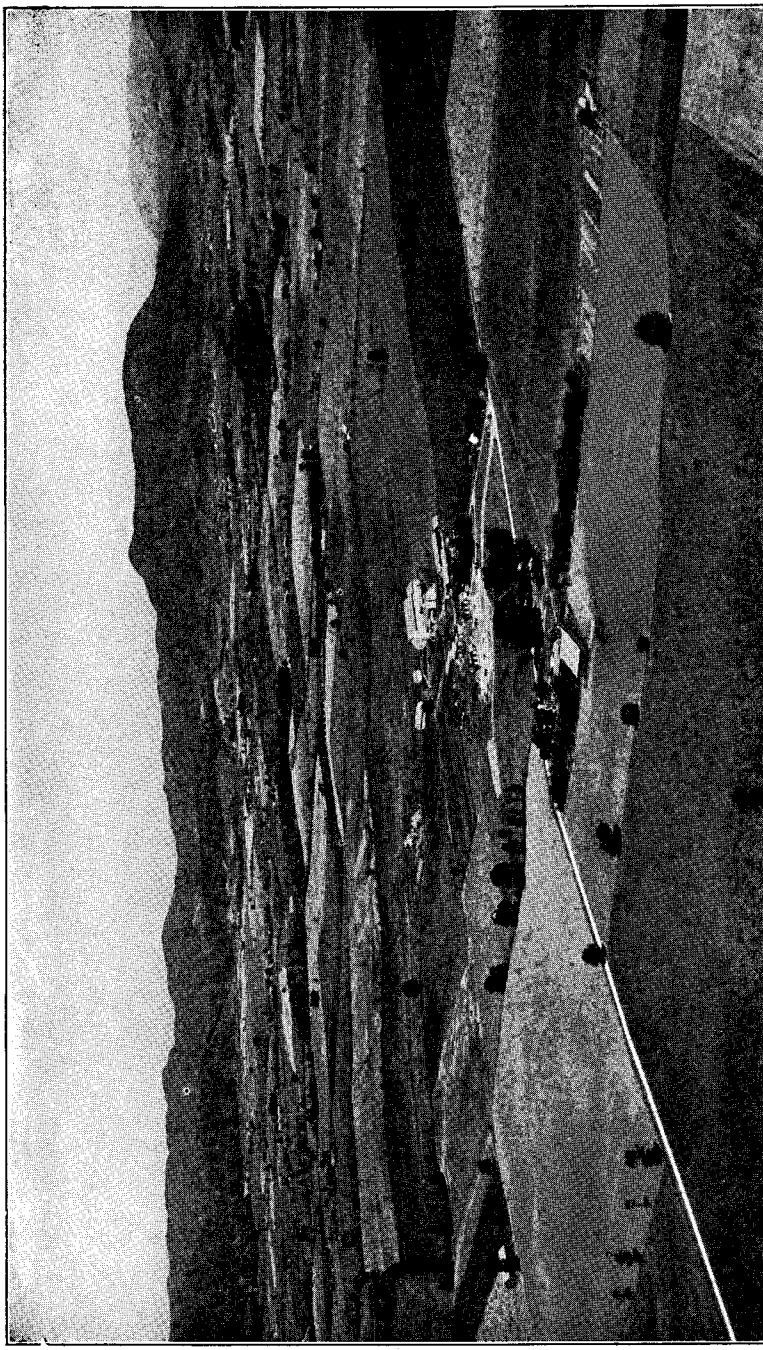
part is evaporated or is transpired by vegeation from the surface of the



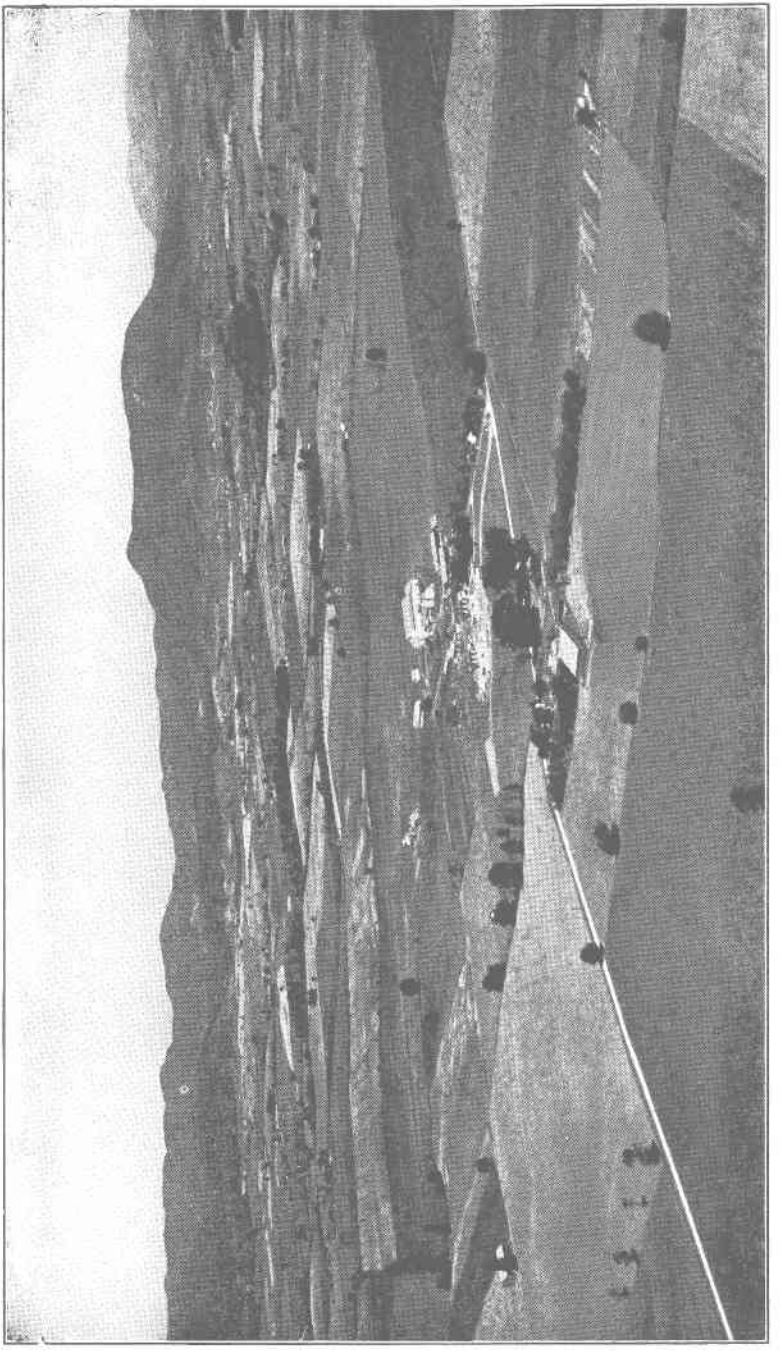
View looking southeast across the southern part of Roanoke. Mill Mountain is in the center and the Blue Ridge is in the distant background. Aerial photograph by Underwood and Underwood, courtesy of Roanoke Chamber of Commerce. *(From Virginia Geological Survey Bulletin 34.)*



View looking southeast across the southern part of Roanoke. Mill Mountain is in the center and the Blue Ridge is in the distant background. Aerial photograph by Underwood and Underwood, courtesy of Roanoke Chamber of Commerce. *(From Virginia Geological Survey Bulletin 34.)*



View looking northwest across Roanoke Valley toward the northeastern end and showing the southeastern limb of the Catawba syncline. Aerial photograph by Underwood and Underwood taken from a point just north of Roanoke, courtesy of Roanoke Chamber of Commerce. *(From Virginia Geological Survey Bulletin 34.)*



View looking northwest across Roanoke Valley toward the northeastern end and showing the southeastern limb of the Catawba syncline. Aerial photograph by Underwood and Underwood taken from a point just north of Roanoke, courtesy of Roanoke Chamber of Commerce. *(From Virginia Geological Survey Bulletin 34.)*

The principal openings in the limestones consist of joints, that originated during the severe folding of the strata, and bedding planes. The joints and bedding planes have been enlarged by solution by circulating water charged with carbon dioxide to form intricate networks of underground solution channels. Where the solution channels have become sufficiently widened, the ground water in them behaves much like that in a surface stream. Some of these underground streams, laden with suspended matter, probably have further enlarged their channels by corrosion. (See Figure 3.) That such a system of underground drainage has been developed in this district is indicated by the relatively large yields of some of the wells and by the presence of large springs (see pages 15-17), caverns, and sinks.

Caverns are exceptionally large solution openings and are probably formed above the water table where the circulation of water is fairly rapid. Several small caverns or caves occur in the Roanoke-Salem district. In other places in the Valley of Virginia large caverns have been formed and a number are now open to the general public as scenic attractions. Dixie Caverns, seven miles southwest of Salem, is one example. These caverns are in the Elbrook formation.

Sinks are enlarged vertical holes that connect the caverns with the surface. They originate along a vertical joint or at the intersection of two such joints, or may form when the roof of an underground channel collapses. Sinks are numerous north of Roanoke in the area underlain by the Elbrook formation.

Wells that tap limestone differ widely in the amount of water they yield. A discussion of the variation in the yield of limestone wells is given on pages 18-19.

WATER IN OTHER TYPES OF CONSOLIDATED ROCKS

Beds of shale occur in nearly all of the Paleozoic formations in this district and shale is the principal rock type of the Rome formation (Cambrian), Athens shale (Ordovician), and the Romney shale (Devonian). It is one of the poorest types of rock from which to get water, however. The rock itself is too dense to yield water, so the only available water is that found in joints and along bedding planes. None of the industrial or public-supply wells in the Roanoke-Salem district is known to obtain water from shale.

Tightly cemented siliceous sandstone and conglomerate and quartzite are the principal rock types in the lower 2,500 to 3,000 feet of the Cambrian system in this district. These rocks are hard and relatively impermeable except where they have been fractured. Drilling in them is difficult and expensive, and only meager yields are likely to be obtained. Records of only one well (No. 66, Table 5) and one spring (No. 67) that derive water from these rocks are available. They each yield about five gallons a minute from fractures in hard, coarse conglomerate.

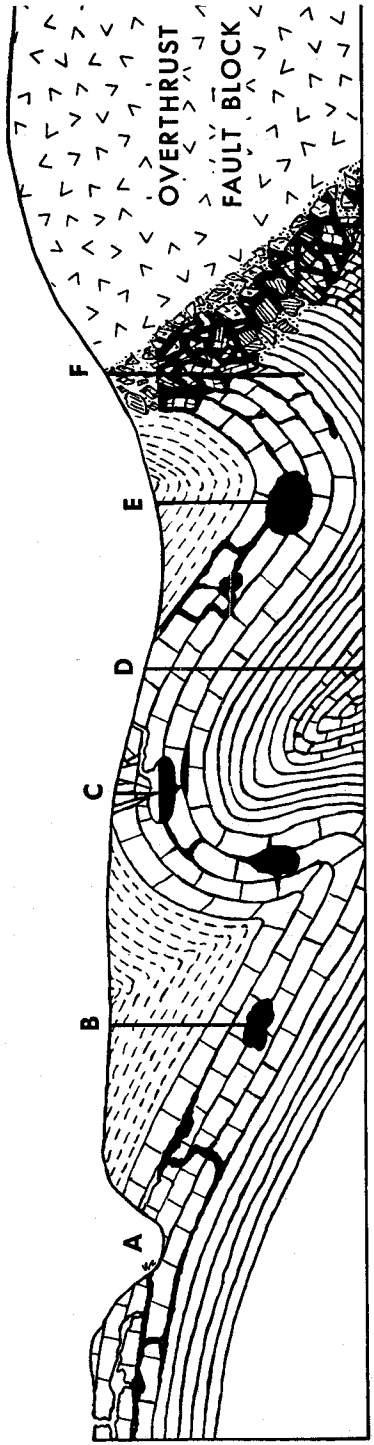


FIGURE 3.—Diagram showing a tubular spring and different conditions that may be encountered by wells in limestone. A, tubular spring; B, C, and E, wells that encountered water-bearing solution channels; D, well that encountered no openings; F, well that encountered water-bearing openings in a faulted zone.

RELATION TO GEOLOGIC STRUCTURE

The effect of the small folds in the Paleozoic rocks on the occurrence of ground water in this district is not known with certainty, but the folds are believed to be the controlling factors causing several of the wells to flow. Water falling on the outcrop area of a permeable limestone stratum moves down the limb of a fold between less permeable beds of shale and saturates the permeable stratum nearly to the surface. Wells drilled to the water-bearing bed will, under these conditions, encounter water that is under artesian pressure—that is, the water will rise in the wells above the bottom of the shale stratum that serves as a confining bed. If the altitude of the land surface at the well is lower than the altitude of the outcrop of the water-bearing bed, the water may rise high enough to flow at the surface. Six of the wells (Nos. 7, 37, 49-51, and 55, Table 5), visited in the Roanoke-Salem district are flowing wells under non-pumping conditions, and it is thought that the flows in these wells are the result of conditions like or similar to those described above.

Faulting has had an important effect on the occurrence of ground water along the Blue Ridge fault by shattering and breaking the rocks along which the movement took place, thereby increasing the amount of open space in the rocks. This fault zone is locally important as a ground-water reservoir and wells that end in it are capable of supplying large quantities of water (Figure 3). Well 57, at the American Viscose Company, which taps this shattered zone, has the largest yield of any of the wells visited in the district. It is 135 feet deep and was reported to yield 1,000 gallons per minute with a drawdown of 60 feet. The extent of this shattered zone along the Blue Ridge fault and the presence of zones along other faults are not known.

SPRINGS

Fifteen springs or groups of springs in the district, that are being used or have been used in recent years as sources of industrial or public water supply were visited. Of the fifteen, two (Nos. 48 and 70, Table 5), supply an average of about 25,000 gallons of water per day for industrial use, eleven (Nos. 6, 12, 43, 44, 47, 58, 59, 60, 67, 68, and 69) supply an average of about 7,000,000 gallons of water per day to public supplies, and two (Nos. 45 and 46) were not in use.

All of the springs observed in this district are gravity springs, that is, the water does not issue under artesian pressure but discharges by gravity at a point of outcrop of the water table. According to Meinzer (1923, p. 51) the water of a gravity spring percolates from permeable material or flows from large openings in a rock formation under the action of gravity, as a surface stream flows down its channel. Gravity springs may be further classified as seepage springs, in which the water percolates from numerous small openings in permeable material; fracture springs, in

which the water flows from joints or other fractures in the rocks; or tubular springs (Figure 3), in which the water flows freely from large channels in soluble rocks. Different types of springs may be related. The springs observed in the Roanoke-Salem district are either fracture or tubular springs. They occur on the slopes and bottoms of valleys where water-bearing fractures or solution openings have been exposed at the surface by erosion. It is difficult to determine the exact nature of the openings at many of the springs because they are obscured by overlying debris or soil and the openings of a few of the springs, such as Lake Spring at Salem, are concealed in the bottoms of large pools. Moran Spring (No. 67, Table 5), which issues from small fractures in a siliceous conglomerate, is a good example of a fracture spring, and Cave Spring (No. 70), which issues from a large solution opening in limestone, is a good example of a tubular spring. The visible part of the opening at Cave Spring is roughly oval in shape and is three to four feet in diameter.

All but one (No. 67) of the springs in this district are in limestone or dolomite. Tubular springs in soluble rocks such as limestone and dolomite are developed along fractures and bedding planes, and hence such springs may be intermediate in character between fracture springs and tubular springs, their classification depending upon the amount of solution that has taken place. Many of the springs in this district probably fall into this group. Nine of the 15 springs (Nos. 12, 45, 46, 47, 48, 58, 59, 69, and 70), occur in the Rome formation, three (Nos. 6, 43, and 44) in the Elbrook formation, two (Nos. 60 and 68) in the Shady dolomite, and one (No. 67) in the Lower Cambrian basal quartzites.

The reported discharges of the springs range within wide limits. Three of the springs discharge less than 25 gallons per minute, two discharge between 25 and 100 gallons per minutes, five discharge between 200 and 500 gallons per minute, and five discharge 500 gallons per minute or more. The largest springs in the district and their discharges are: Crystal Spring (No. 60, Table 5), 2,775 gallons per minute; Muse and House Springs (No. 59, two openings about 25 feet apart), 750 gallons per minute; Nininger Springs (No. 43, three openings about 100 feet apart), 650 gallons per minute; River Spring (No. 58), 520 gallons per minute; and Blue Hill Springs (No. 44, two openings about 100 feet apart), 500 gallons per minute.

The yields given above are average, for most springs in this district have a variable discharge that depends upon the amount of precipitation. A few were reported to have a nearly uniform discharge throughout the year, but most of them are reported to have a considerably higher yield during wet seasons than during dry seasons. For example, the reported discharge of Crystal Spring (No. 60) has been as low as 3,600,000 gallons per day during extremely dry periods and as high as 7,000,000 gallons per day during extremely wet periods; likewise, the discharge of Muse and House Springs (No. 59) has reportedly been as low as 800,000 gallons

per day and as high as 1,400,000 gallons per day. Mr. C. E. Moore, Superintendent of the Roanoke City Water Supplies, reports that the fluctuation in discharge of these springs depends not only on the amount of annual precipitation, but also on the rain intensity and storm frequency.

Descriptions and yields of all the springs visited in the Roanoke-Salem district are given in the table of well and spring records at the end of this report. (See Table 5, pp. 42-49).

WELLS IN LIMESTONE

General Statement

Records were obtained of 62 wells in the Roanoke-Salem district that are being used or have been used to furnish water for industrial or public-supply use. Descriptions of wells are given in the table of well and spring records at the end of this report. (Table 5, pp. 42-49), and the location of each well is shown on Plate 1. All but two (Nos. 53 and 66) of the wells tap limestone.

Construction

All the industrial and public-supply wells in the district are drilled wells that were put down by portable cable-tool drills mounted on trucks. Aside from a few mechanical difficulties, which are described below, drilling in this district is comparatively cheap and easy. Nearly all of the wells are open-end wells, that is, the hole is cased through the unconsolidated surface material and a few feet into the consolidated rocks, but the lower part of the hole is not cased. Oil-well type steel casing is used in the wells, and in most places it is generally not necessary to case them below a depth of 40 feet. Although the wells range from two to 14 inches in diameter, most of them are either six or eight inches in diameter. The depths of the wells range from 50 to 1,250 feet and average about 320 feet.

Problems Relating to Drilling

Drilling wells in a region underlain predominantly by limestone presents certain mechanical difficulties that are often troublesome and sometimes costly to the owner and driller. Mud-filled crevices and solution channels, from a few inches to several feet wide, have been encountered in some of the wells. Where mud-filled openings are encountered it is generally necessary to ream the hole to a larger diameter and insert casing to shut out the mud, although sometimes they can be successfully cleared out by pumping, in which case they may be important contributors of ground water, provided they lie below the water table. Mud seams were reported to have been encountered in wells Nos. 8, 32, 39, 41, and 57, and, although not reported, they probably were encountered in other wells

in this area. Those in wells Nos. 32, 39, and 41 were cased off, whereas those in wells Nos. 8 and 57 were left uncased. When first pumped, the water from well No. 57 was heavily laden with mud and sand, but after pumping continuously for nearly two months the water had cleared appreciably, although it still contained some mud particles. With continued pumping, the water should clear entirely and be free of any sediment.

Deflection of the drilling bit along tilted beds of rock or sloping crevices is another source of trouble and may result in a crooked hole being drilled. A well may be ruined if the bit jams when it is deflected on a hard layer of tilted rock. A tilted bed that tends to deflect the bit is called a "slipping formation," "sloping rock," or "drifty rock" by the drillers.

Another difficulty that is sometimes encountered in drilling in a limestone area is the presence of large caverns or caves. If the height of the cavern is considerably less than the length of the drill bit, little trouble may be experienced unless the floor of the cavern is sloping, in which case the bit will tend to be deflected as described above. If, however, the height of the cavern is nearly as great or greater than the length of the bit, the bit may drop and become caught, thereby ruining the well. Where it is necessary to drill through a large cavern, casing may be inserted to the floor of the cavern to act as a guide for the bit.

DIFFERENCES IN THE YIELD OF WELLS

Wells in limestone have a wide range in yield—the yield depending upon the number, size, and water-bearing capacity of the fractures and solution channels encountered. Different conditions that may be encountered by wells in limestone are illustrated diagrammatically in Figure 3. The black areas represent water-filled openings and the open areas represent channelways along which water moves from the surface to the water table. A well (D) that encounters no openings in the limestone will yield little or no water, but one (E) that encounters a large water-filled cavern that is fed by large tributary channels will have a very high yield. A well (B) that encounters a large water-filled cavern that is not fed by any large tributary channels may have a relatively high yield when pumping first starts, but after the cavern is drained the yield may decrease and will then be controlled by the rate at which water enters the cavern. A good example of this was encountered during the drilling of the Lee Theater well (No. 41, Table 5). When a large water-filled cavern was encountered by this well, at a depth of 502 feet, the drilling was stopped and a test pump installed. The well yielded 60 gallons per minute during the first four hours of the pumping test, after which time the yield decreased to two gallons per minute. The well was then deepened to 697 feet and a satisfactory supply of water obtained. Caverns and channels at the water table may be only partially filled with water.

Wells (C) that tap them may be capable of yielding large quantities of water during wet periods when the water table is high, but if there is a general lowering of the water table as a result of an extended dry period, these will be the first wells to diminish in yield. They may even dry up if they do not penetrate lower openings. Wells (F) that encounter limestone along or near a fault where the rock has been crushed and broken can be expected to have large yields. Well No. 57 at the American Viscose Company, which yields 1,000 gallons per minute with a drawdown of 60 feet, is a good example of this type of well. Most wells in the Roanoke-Salem district penetrate one or more channels from which they obtain moderate amounts of water.

As it is rarely possible to predict underground conditions from surface conditions, there is always some uncertainty as to the success of a new well. Two wells not far apart may encounter entirely different conditions and one may obtain a large supply of water while the other may obtain only a meager supply. For example, well No. 3 at the Leas and McVitty tannery in Salem is 325 feet deep and yields 200 gallons per minute with a small drawdown, whereas well No. 4, which is only about 150 feet from well No. 3, was drilled to a depth of 500 feet without obtaining an adequate supply of water. Well No. 35 at the Peoples Ice and Storage Company in Roanoke is 700 feet deep and is reported to be capable of pumping only about 50 gallons per minute for about ten minutes, after which time the pump must be shut off to let the well recover. Well No. 36, at the Clover Creamery Company and about 350 feet north of well No. 35, is only 99 feet deep and is reported to yield about 125 gallons per minute continuously. The rocks in the district have been severely folded and jointed and for this reason no wells have been reported as absolute failures, although two (Nos. 4 and 29) have been abandoned because of their insufficient yield, and a few (Nos. 34, 54-56) have been abandoned because of the poor quality of water obtained in them.

PUBLIC WATER SUPPLIES

General Statement

The City of Roanoke and the Town of Salem have public water systems supplied in part by ground water, and ten unincorporated communities or suburban communities in the district have publicly or privately owned water systems supplied entirely by ground water. In addition, a tourist camp, a furniture factory, and a golf club obtain their public supplies from wells, and an orphanage is supplied by both surface and ground water. In all, 29 wells and 13 springs have been developed in this district to supply water for public use. Vinton owns its distribution system but purchases water from the City of Roanoke.

Descriptions of the public water supplies follow. Data regarding the distribution systems in Roanoke, Vinton, and Salem were taken largely

from a report by the Virginia State Department of Health (1939, pp. 102-4, 108-9).

City of Roanoke.—Roanoke obtains its water supply from one spring and three surface-water reservoirs. Crystal Spring (No. 60), which issues from the Shady dolomite on the western slope of Mill Mountain in the southern part of the city (Plate 5), is the spring source and supplies an average of 4,000,000 gallons of water per day. The spring is enclosed by a concrete wall, and the water is conveyed through an open-masonry conduit to a suction well at the Crystal Spring pumping station and to an open-masonry storage basin having a capacity of 3,000,000 gallons.

River Spring (No. 58) on the south bank of Roanoke River north of Muse and House Springs is used as an auxiliary supply when needed. Its normal yeld is reported to be about 700,000 gallons per day, but when well No. 57 at the American Viscose Company plant is pumped at the rate of 1,000 gallons per minute the flow of River Spring ceases. Well No. 57 is about 600 feet west of River Spring on the opposite side of the river. It was completed and put into use in April 1945. River, Muse and House Springs all issue from limestone in the Rome formation.

Surface water that is used by the city is obtained from impounding reservoirs on Beaver Dam Creek and Falling Creek, located about 4.5 miles northeast of the city. The water passes through a filter plant near the Falling Creek reservoir where it is treated with aluminum, lime, and chlorine. From here it is delivered by gravity through a pipe-line to the distribution system in the eastern side of the city. The Roanoke city distribution system also includes five booster-pump stations located in different parts of the city.

The third surface water supply is Carvins Cove reservoir in Botetourt County, just north of the Roanoke County line. This reservoir was started about 1926, when the construction of a concrete impounding dam was begun on Carvins Creek at the south end of Carvins Cove. The dam was completed in 1947. A modern treatment plant is located just below the dam and water is transmitted to Roanoke by a 36-inch concrete main.

Town of Salem.—The public supply of Salem is owned by the town and is obtained from Lake Spring (No. 6), well No. 7, and from Roanoke River. Lake Spring issues from limestone of the Elbrook formation in the western part of town and has an average discharge of about 700,000 gallons per day. The discharge fluctuates considerably, however, and during the dry period in 1930 it was reported to be as low as 320,000 gallons per day. The water from the spring is of good chemical quality, as indicated by an analysis (see pages 30-31), which shows it to be a reltaively soft bicarbonate water containing 66 parts per million of hardness. The water is chlorinated at the spring. Well No. 7 is located just south of Lake Spring and supplies an average of 125,000 gallons a day to the Salem supply. It is a 10-inch well, 785 feet deep, that derives water from limestone in the

Elbrook formation. Equipped with an air-lift pump, the well yields about 415 gallons per minute with a drawdown of 110 feet. When not pumping the well flows at the surface. The water from the well is reported to have a higher alkalinity than the Lake Spring water, but otherwise is of good chemical quality. It is chlorinated but receives no other treatment.

The surface water used by Salem is taken from Roanoke River at an intake near the western city limits. Here, two centrifugal pumps having capacities of 750 and 1,100 gallons per minute deliver the water to a modern filtration plant located across the street from Lake Spring. The raw water is treated in the filtration plant with aluminum sulfate, chlorine, and activated carbon, and the filtered water is again treated with chlorine before being discharged to a clear-well reservoir.

Distribution of water in Salem is accomplished by two systems—a high-level system and a low-level system. The high-level system is supplied by a 150,000-gallon elevated storage tank on a hill just northeast of the filtration plant. The low-level system is supplied by a 400,000-gallon steel standpipe near the elevated tank. Pumps for both services are located at the filtration plant and include two high-service pumps having capacities of 500 and 750 gallons per minute and one low-service pump having a capacity of 750 gallons per minute.

South Salem.—South Salem is a small unincorporated community on the south side of Roanoke River opposite the Town of Salem. The waterworks system is owned by the Town of Salem and the supply is obtained from two springs, known as Mowles Springs (No. 12, Table 5), which are in the Rome formation about one mile south of this community. The springs are protected by concrete shelters, and together discharge an average of about 80,000 gallons per day. Water from the upper spring flows into the lower spring, where the water is chlorinated. The greater part of the water then flows by gravity through a pipe-line to the distribution system in South Salem, and the excess goes to a 60,000-gallon steel storage tank on a hill above the Town of Salem. About one-fourth of the water from the springs is pumped to a 16,000-gallon reservoir which supplies that part of the community that is too high to be supplied from the main distribution system.

The average monthly consumption of water at South Salem is about 1,000,000 gallons, or a little more than one-third of the average discharge of the springs.

Suburban area north and northeast of Roanoke.—A waterworks system owned by J. N. Phelps supplies water to about 1,500 families and a few small industries in the suburban area north and northeast of the City of Roanoke. This area extends about one mile out along the Lynchburg Highway (U. S. Route 460), and about two miles out along Hollins Road (State Highway 115) and Williamson Road (U. S. Route 11).

The main supply is obtained from Blue Hill Springs (No. 44), which

consists of two springs about 100 feet apart on the east side of Tinker Creek, about 0.8 mile north of the Roanoke City limits. The springs are in the Elbrook formation and have an average combined discharge of 500 to 600 gallons per minute. One spring is completely sealed with concrete and covered, the water being piped to a small underground concrete reservoir a short distance below the spring. Water from the other spring collects in a 12-inch buried vertical pipe that has a smaller horizontal discharge pipe near the top. The water from Blue Hill Springs flows by gravity to the Phelps No. 1 pumping station located about 3,000 feet downstream. At the pumping station the water is chlorinated, then delivered to the distribution system and storage tanks by a 300-gallon per minute high-service pump. All power for pumping is supplied by a 100-horsepower overshot waterwheel operated by water supplied through a concrete race from a dam on Tinker Creek. This plant pumps an average of 300 gallons per minute continuously into the mains, the excess going to several storage reservoirs. Water that is not used is discharged from the reservoirs by overflow. Storage is provided by a 10,000-gallon elevated steel tank at Franklin Court north of the pumping station, 50,000-gallon and 210,000-gallon concrete reservoirs on Round Hill, and by a 200,000-gallon steel standpipe at the north end of Williamson Road.

A second pumping plant (Phelps No. 2) is located on the west side of Tinker Creek about one mile upstream from the No. 1 plant. This plant is supplied by Nininger Springs (No. 43)—three individual springs about 100 feet apart in the Elbrook formation. These springs have average discharges of 50, 200, and 400 gallons per minute, respectively. Concrete shelters have been constructed over each spring. Water from the two larger springs flows to the pumping plant by gravity. The smaller spring, which is used as a standby supply, is lower than the pumping plant, and therefore the water must be pumped to the plant. The No. 2 plant has a 60-horsepower overshot waterwheel for power; otherwise the equipment is similar to that at the No. 1 pumping plant. Water is delivered to the distribution system by high-service pumps. The No. 2 plant is operated only during hot months in the summer when water is furnished to the City of Roanoke. Mr. Phelps reports that during the summer of 1944 he supplied about 500,000 gallons of water a day to the city from Nininger Springs.

A third group of springs has been developed along the east side of Tinker Creek just below the No. 1 pumping plant. These are known as Masons Mill Springs (No. 45) and consist of two separate springs, about 100 feet apart, in limestone of the Rome formation. Both springs are encased in concrete enclosures. The northernmost one is reported to have a very small yield and is not connected to the water system. The south spring yields about 200 gallons per minute and is connected to the No. 1 pumping plant by a pipe-line. It serves only as a standby supply. An

analysis of the water from the south spring is given on pages 30-31 (see No. 45, Table 5). The water is hard; otherwise it is of good chemical quality.

Although now unused, East Gate Spring (No. 46) formerly supplied water to the Phelps water system. It is on the east side of Tinker Creek about 0.2 mile north of U. S. Route 460. The spring is encased in a concrete structure over which a small brick pump house has been built. It yields about 200 gallons per minute from a limestone bed of the Rome formation.

Edgewood.—Edgewood is a small unincorporated community about midway between Roanoke and Salem on the south side of State Highway 24. About 250 families in Edgewood are supplied with water through a waterworks system owned by the Edgewood Water Company. The supply is obtained from one drilled well (No. 13) in the Elbrook formation and two drilled wells (Nos. 19 and 20) in the Rome formation. Well No. 13 is 5⅝ inches in diameter, is 90 feet deep, and is equipped with a centrifugal pump and electric motor. The static water level stands about 10 feet below the surface. The well yields 1,500 gallons per hour with a drawdown of 5 feet, but is reported to be capable of supplying as much as 3,000 gallons per hour if needed. It supplies an average of about 18,000 gallons per day to the system. Wells Nos. 19 and 20 are 5⅝ inches in diameter and are 320 and 210 feet deep, respectively. Each well is equipped with a plunger pump powered by an electric motor, and yields 1,000 gallons per hour. The water level is about 100 feet below the surface in well No. 19 and about 30 feet below the surface in well No. 20. From 5,000 to 6,000 gallons per day is supplied by well No. 19 and about 10,000 gallons per day is supplied by well No. 20.

Water is pumped from each of the three wells into the pipe-line system and the excess goes to three wood-stave tanks having a combined storage capacity of 16,400 gallons. The water is not treated.

The Edgewood Water Company also has a standby well (No. 14) that is not equipped with a pump. It is a 5⅝ inch diameter well, 70 feet deep, and taps the Elbrook formation. The water level in the well stands 10 feet below the surface. During a pumping test at the time the well was drilled in 1932, it yielded 50 gallons per minute with a drawdown of five feet.

South Edgewood.—Eighteen families in a small community south of Edgewood, known locally as South Edgewood, are supplied by a drilled well (No. 18) owned by the Dixie Finance and Loan Corporation of Roanoke. The well is 5⅝ inches in diameter, 160 feet deep, and derives water from the Rome formation. The water level in the well stands about 70 feet below the surface. It is equipped with an electrically powered plunger pump having a capacity of 1,000 gallons per hour. The well is reported to be capable of yielding 1,500 gallons per hour with a 30-foot drawdown, however. The water, which is not treated, is pumped into a 1,000-gallon pressure tank from which it is distributed by pipe-line to the users.

A second well (No. 17) is maintained as a standby well. It is four inches in diameter, 157 feet deep, and also taps the Rome formation. The well is equipped with a plunger pump and is being used intermittently to irrigate an orchard.

Conehurst.—Conehurst is a small residential addition west of Edgewood. One drilled well (No. 16) owned by the Conehurst Mutual Citizens supplies an average of 3,600 gallons of water daily to 43 families in this community. The well is six inches in diameter, 300 feet deep, and taps the Rome formation. An electrically powered lift-pump delivers about 450 gallons per hour to an underground concrete reservoir located on top of a hill near the well. The water is chlorinated and distributed by a gravity pipe-line to the users.

Sunset Village.—Well No. 15, owned by Mr. Charles Duffy, supplies water to 26 families at Sunset Village, a small unincorporated community north of State Highway 24 and east of Mason Creek. The well is six inches in diameter, 180 feet deep, and taps the Elbrook formation. The static water level is about 20 feet below the surface. An electrically driven plunger pump having a capacity of 700 gallons per hour lifts the water to a 1,000-gallon pressure tank that is connected to the distribution system. The water from this well is of good chemical quality and is relatively soft as indicated by the analysis given in Table 2. It is not treated.

Washington Heights.—Washington Heights is a small unincorporated community about 0.6 mile northwest of the Roanoke city limits. G. L. Whitlow supplies water to 44 families in this community from wells Nos. 21 and 22. The wells are 5⅝ inches in diameter, 120 and 250 feet deep, respectively, and obtain water from the Rome formation. The water level stands about 16 feet below the surface in well No. 21 and about 60 feet below the surface in well No. 22. The wells are equipped with electrically driven plunger pumps having capacities of 440 and 460 gallons per hour, respectively. The water is pumped into a 1,100-gallon underground pressure tank that is connected with the distribution system. The water is sometimes treated with chlorine.

Hershberger Road.—Wells Nos. 23 and 24 supply water to several families living on Hershberger Road north of Washington Heights. Both wells are in the Elbrook formation. Well No. 23, which is owned by A. L. Crantz, is two inches in diameter and 140 feet deep. It is equipped with a lift pump and electric motor. The water is chlorinated and distributed to six families.

Frank Gilbert owns well No. 24 from which he supplies water to 11 families. The well is six inches in diameter, 104 feet deep, and the water level stands about 64 feet below the surface. A small plunger pump powered by an electric motor lifts the water to a 475-gallon elevated storage tank from which the water is distributed by gravity to the users. The water receives no treatment.

Westwood Annex.—This is a small suburban community adjacent to the western city limits of Roanoke. E. E. Engleman furnishes water to 32 families in Westwood Annex from wells Nos. 27 and 28 that tap the Elbrook formation. They are both six-inch wells, are 210 and 132 feet deep, respectively, and are equipped with cylinder pumps powered by electric motors. The water is pumped into the mains and the excess goes to a 1,000-gallon storage tank near well No. 27 and to a smaller tank at well No. 28. Well No. 28 supplies most of the water. When the consumption is high and the pressure drops below a certain point well No. 27 automatically starts pumping. The water receives no regular treatment but has been chlorinated at different times.

Garden City.—The residential district southeast of Roanoke known as Garden City has three separate public-water systems.

A water-supply system owned by J. W. Moran supplies water to 70 families in this district. The supply is obtained from spring No. 67 and well No. 66, both of which derive water from fractures in a coarse conglomerate of the basal Cambrian quartzites. The spring discharges about five gallons per minute and is protected by a concrete structure. The water flows into a 13,000-gallon, covered, concrete collecting basin just below the spring and thence to the distribution system. Well No. 66 is six inches in diameter and 67 feet deep. An electrically powered plunger pump delivers five gallons of water per minute to the collecting basin described above. Chlorinated lime is applied to the water occasionally; otherwise the water receives no treatment. Waters from the spring and well are reported to be very soft.

A system owned by J. O. Plunkett distributes the water from spring No. 68 to 75 families in the Garden City area. The spring is in the Shady dolomite and is reported to have a rather small discharge. It is encased in a galvanized-iron pipe that is about 60 inches in diameter. Water from the spring is delivered untreated to a 500-gallon pressure tank and the pipe-line system by an electrically driven pump.

A third system is owned by C. R. Clark. Water from this system is obtained from wells Nos. 64 and 65 and is supplied to 16 families in the Garden City area. Both wells are in the Shady dolomite, are six inches in diameter, 132 feet deep, and are equipped with small-capacity plunger pumps driven by electric motors. The water, which is not treated, is pumped into small pressure tanks at each well and thence into the pipe system.

Cave Spring.—A waterworks system owned by the Cave Spring Water Company furnishes water to 65 families in the Cave Spring community. The supply is obtained from a concrete-enclosed spring (No. 69) that issues from limestone in the Rome formation. The spring has a discharge of approximately 2,000 gallons per hour. An electrically driven piston pump delivers about 1,500 gallons of water per hour to a reservoir

on a hill above the spring and from here the water is distributed by gravity to the users. The system includes an automatic chlorinator.

The water supply at the Baptist Orphanage north of Salem is obtained in part from well No. 1, which is 1,250 feet deep and is thought to tap the Nittany dolomite. It is an eight-inch well in which the water level stands about 65 feet below the surface. Equipped with an electrically driven turbine pump the well yields 30 gallons per minute with a drawdown of 16 feet. An analysis of the water shows it to be relatively soft, water that contains 81 parts per million of hardness. (See analysis 1, Table 2.) The main supply at the orphanage is obtained from a surface-water reservoir in an unnamed watershed on Lewis Mountain about 1.5 miles northwest of the orphanage. Both sources of supply are chlorinated. For emergency use there is a two-inch, cross-connected line from the Town of Salem.

The Fort Lewis Tourist Court, which is one mile west of Salem on U. S. Route 11, maintains a small water system supplied by well No. 2. This well is in the Elbrook formation and is six inches in diameter and 50 feet deep. The water level in the well stands only about one foot below the surface. A small turbine pump driven by an electric motor delivers 1,300 gallons per hour to a pressure tank that is connected to the pipe-line system.

The Roanoke Country Club in the northwest section of Roanoke has two wells (Nos. 25 and 26) that are used to supply water to the club house and for irrigating the grass on the golf course. Both wells are eight inches in diameter and obtain water from the Elbrook formation. Well No. 25 is 285 feet deep and the water level stands about 30 feet below the surface. It is equipped with a plunger pump and electric motor and yields 56 gallons per minute. Well No. 26 is 168 feet deep and the water level is about 138 feet below the surface. Equipped with an electrically driven turbine pump, it yields 63 gallons per minute. It is reported that the water from this well becomes turbid in extremely dry weather. Only one of the above wells is pumped at a time and the water that is used for drinking is chlorinated. An analysis of a sample of water collected from well No. 26 shows it to be a moderately hard bicarbonate water that contains 129 parts per million of hardness and 164 parts per million of bicarbonate. (See analysis 26, Table 2.)

The Johnson-Carper Furniture Company, located about one mile north of Roanoke, has one well (No. 42) that supplies water for drinking, washing, sanitary uses, and for use in their boilers. It is an eight-inch well, 58 feet deep, that taps the Elbrook formation. A steam-driven turbine pump delivers 43 gallons per minute directly to the pipe-line system. An automatic feeder chlorinates the water at the pump discharge.

Based upon reports and estimates, the amount of water derived from public-supply wells and springs in the Roanoke-Salem district during the year 1944 was about 2,615,000,000 gallons or an average of about 7,000,000 gallons per day.

INDUSTRIAL WATER SUPPLIES

GENERAL STATEMENT

Records were obtained of 30 drilled wells and two springs that were developed in the Roanoke-Salem district to supply water for industrial use. Eight of the 30 wells are not in use, either because the yield was inadequate or because the quality of the water was not satisfactory. In general, most industries in this area have been able to obtain adequate supplies of satisfactory water for their needs. In some cases it was necessary to drill more than one well before a satisfactory supply was obtained, however. The industrial uses of water from wells and springs include cooling, manufacture of soft drinks, boiler water, laundry water, and in the processing of leather.

Cooling.—Cooling is the principal industrial use for ground water in the district. All or a part of the water pumped from the 22 active industrial wells is used for this purpose by theaters, dairies, markets, and other business and industrial establishments. The advantage of using ground water for cooling is its relatively low uniform temperature throughout the year. The temperature of the water in 12 representative wells and three springs in this area was found to range from 56° to 67°F. and to average about 59.6°F. In general, the quality of the ground waters in this area is entirely satisfactory for cooling, although the waters from a few wells have been unsatisfactory. The water from well No. 38 at the Roanoke City Market is reported to be excessively hard and to form a crust on the inside of the condenser pipes which must be cleaned out at periodic intervals. Well No. 34 at the Patrick Henry Hotel in Roanoke is not used because the quality of the water was considered unsatisfactory for cooling. Both of the above wells are in the Rome formation. Three deep wells (Nos. 54-56) in the Shady dolomite, drilled for the American Viscose Company, were also abandoned because the water was too highly mineralized for cooling. The American Viscose Company now obtains its water from a well (No. 57) 135 feet deep, in the Rome formation, well No. 53, 21.7 feet deep, in Quaternary deposits, and from the Roanoke River.

Bottling.—The waters from one well and two springs are being used in bottling soft drinks. The Dr. Pepper Bottling Company in Roanoke obtains water from well No. 63 that is used for all purposes at the bottling works including cooling, washing, and the preparation of soft drinks. The well is six inches in diameter, 377 feet deep, and taps the Shady dolomite. An electrically driven turbine pump delivers 50 gallons of water per minute to a 3,000-gallon buried pressure tank. The water is chlorinated and passes through a baffle tank and an activated carbon filter before being used. An analysis of a sample of water from this well is given in Table 2.

The water from two so-called mineral-water springs (No. 48) at the Virginia Etna Springs Company in Vinton is bottled straight and in soft drinks. The water is reported to be high in calcium sulfate. The two springs, located adjacent to the bottling works, are about 25 feet apart and issue from limestone in the Rome formation. Their aggregate discharge is about 17,000 gallons per day. Both springs are encased in covered concrete pits and their water flows by gravity the short distance to the bottling works.

Boiler water.—Only a very small amount of ground water is used in boilers in the Roanoke-Salem district, for in much of the district the ground water is not of suitable chemical character for boiler use. (See pages 29-31.) Most of the industrial establishments having boilers use city water for this purpose. Part of the water from well No. 42 is used as boiler water at the Johnson-Carper Furniture Company. A description of this well is given on pages 46-47.

Laundry water.—Most of the laundries in the Roanoke-Salem district are supplied with city water by Roanoke or Salem. Water that is used in laundries should be clear, soft, and free of iron. Ground water in parts of the district would be suited to this purpose, but in most places it would be necessary to treat the water for reduction of hardness. The Nu-Way Laundry on U. S. Route 221 between Roanoke and Cave Spring is the only laundry in the district having its own water supply. The supply is obtained from Cave Spring (No. 70) located about 0.5 mile southwest of the laundry. The spring discharges about 230 gallons per minute from steeply dipping limestone of the Rome formation. A concrete retaining wall has been constructed at the spring and the water is pumped to a reservoir on a hill, from which it flows by gravity to the laundry. About 25,000 gallons per day are used at the laundry. The water is clear and an analysis shows it to have a hardness of 105 parts per million and to contain 0.03 part per million of iron. It is softened by a zeolite process before being used at the laundry.

Leather processing.—The Leas and McVitty tannery at Salem uses ground water in the processing of leather. Their supply is obtained from well No. 3, which is an eight-inch well, 325 feet deep, and taps the Elbrook formation. A steam-driven plunger pump delivers 200 gallons per minute to the plant, part of which is used in condensers. Two other wells at the tannery, one (No. 4) 500 feet deep and the other (No. 5) 275 feet deep, are not used because their yields were inadequate. The tannery uses from 75,000 to 100,000 gallons of water per day, of which 50,000 to 60,000 gallons is supplied by well No. 3 and the rest is supplied by the Town of Salem from Lake Spring (No. 6). The water from well No. 3 is a hard calcium bicarbonate water containing 220 parts per million of hardness (analysis 3, Table 2).

Based on consumption figures supplied by the different industrial users of ground water, it is estimated that nearly 1,100,000,000 gallons of ground water was used for industrial purposes in the Roanoke-Salem district in 1944, or an average of more than 3,000,000 gallons per day.

QUALITY OF WATER

The chemical character of the well and spring waters in the Roanoke-Salem district is shown by the analyses of water from 15 wells and springs given in Table 2 (pp. 30-31). Partial analyses of samples of water from eight wells and three springs were made by G. W. Whetstone and complete analyses of samples from four wells were made by Evelyn Holloman in the Water Resources laboratory of the United States Geological Survey at Raleigh, North Carolina. The analyses show only the dissolved mineral content of the waters and do not in general indicate their sanitary condition.

Most of the waters analyzed were slightly hard to hard bicarbonate waters, but two (analyses 39 and 49) were very hard sulfate waters in which the content of sulfate was greater than 1,000 parts per million. The bicarbonate waters contained from 90 to 299 parts per million of bicarbonate.

TABLE 2.—*Analyses of ground waters*
(Analysts, G. W. Whetstone and

Well or spring No.	Depth of well (feet)	Geologic source	Date of collection, 1945	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)
1	1,250	Nittany(?)	May 24	58	.....	0.03	.....
3	325	Elbrook	May 25	57	8.7	.03	55
6	Spring	Elbrook	May 24	64	.....	.07	.....
9	183	Elbrook	May 24	61	.....	.03	.....
15	180	Elbrook	May 25	58	.....	.08	.....
26	168	Elbrook	May 25	57	.....	.02	.....
36	99	Rome	May 23	59	11	2.5	86
39	1,230	Shady	May 24	62	13	.07	301
40	182	Rome	May 24	61	.....	[a]11	.....
41	697	Elbrook	May 25	60	.....	.27	.....
45	Spring	Rome	May 25	57	.....	.03	.....
49	205	Rome	May 24	67	.....	1.2	.....
52	130	Rome	May 24	59	.....	.04	.....
63	377	Shady	May 23	59	10	.05	53
70	Spring	Rome	May 24	56	.....	.03	.....

[a]Includes iron in sediment present at time of collection. [b]Approximate.

from the Roanoke-Salem district, Virginia
Evelyn Holloman. Parts per million)

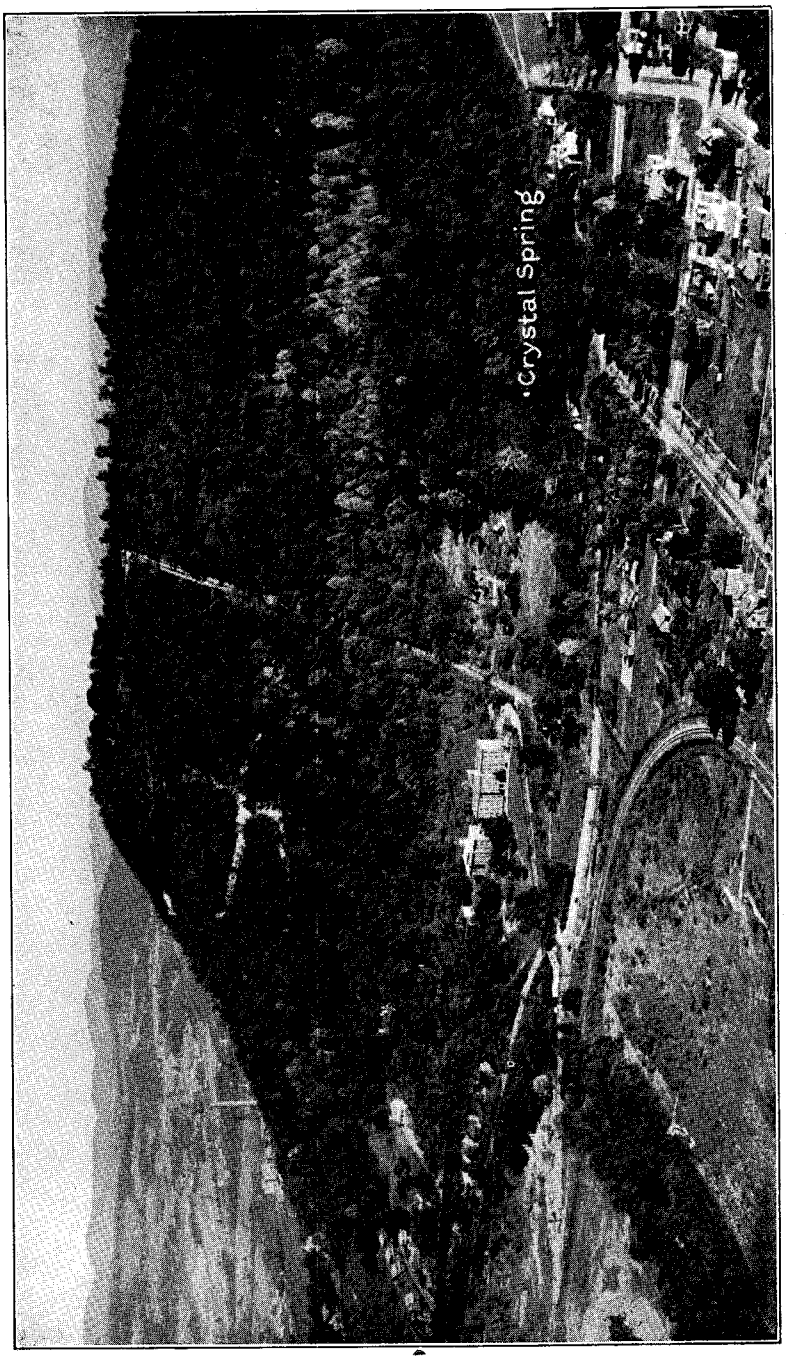
Magnesium (Mg)	Sodium and Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness (as $CaCO_3$)
.....	.....	104	6	1	.....	0.2	.....	81
20	19	203	46	28	0	7.5	301	220
.....	.....	91	5	3	.....	.8	.....	66
.....	.....	257	7	21	.....	37	.....	246
.....	.....	90	2	4	.....	1.4	.....	75
.....	.....	164	4	6	.....	3.3	.....	129
39	32	262	126	57	.2	22	537	375
105	330	208	1,020	470	1.8	2.0	2,350	1,180
.....	.....	299	[b]270	58	.....	14	.....	354
.....	.....	264	5	6	.....	14	.....	222
.....	.....	218	22	4	.....	12	.....	204
.....	.....	97	1,540	5	.....	.1	.....	1,410
.....	.....	243	[b]180	240	.....	15	.....	348
19	12	142	102	7.4	.5	3.0	293	210
.....	.....	124	14	2	.....	4.8	.....	105

Hardness is the property of water that generally receives the most attention and is commonly recognized by its effects when soap is used with the water in washing. The hardness of most ordinary waters is caused almost entirely by calcium and magnesium. These constituents with silica and iron form practically all the scale found in steam boilers. A hardness of 50 parts per million or less is scarcely noticed. Hardness between 50 and 150 parts per million slightly increases the consumption of soap and its removal by a softening process is profitable for laundries or other industries using large quantities of soap. Waters in the upper part of this range of hardness will cause considerable scale on steam boilers. All of the waters analyzed are slightly hard to very hard. Three samples (analyses 1, 6, and 15) had between 50 and 100 parts per million of hardness, ten had between 100 and 375 parts, and two (analyses 39 and 49) had more than 1,000 parts. Waters from the Rome formation are in general somewhat harder than the waters from the Elbrook formation. Six samples from the Rome formation had from 105 to 1,410 parts per million of hardness and averaged 466 parts; whereas, six samples from the Elbrook formation had from 66 to 246 parts per million and averaged about 160 parts. Two samples from the Shady dolomite had 210 and 1,180 parts per million of hardness, and one sample from the Nittany dolomite had 81 parts.

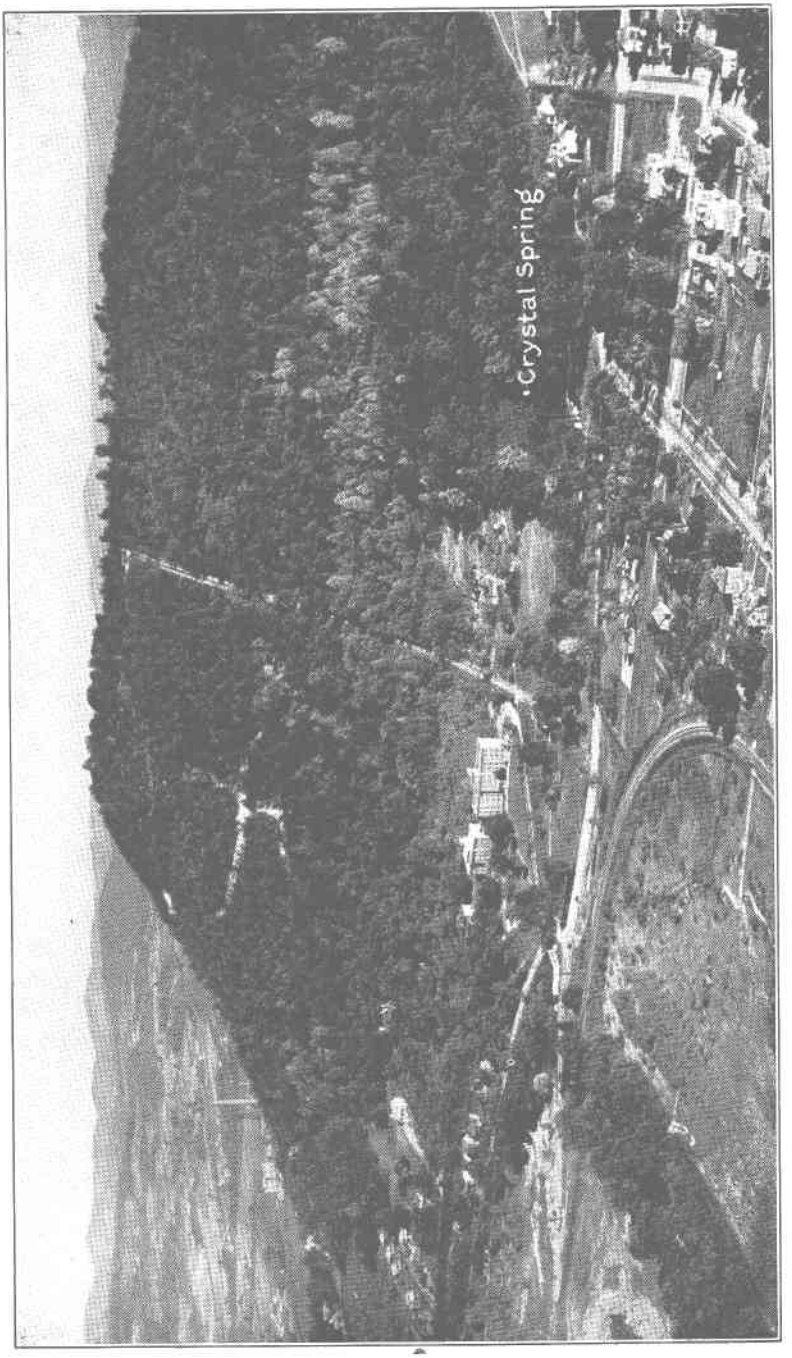
Iron is dissolved from many rock materials and may be dissolved from water pipes in quantities so large as to be objectionable. If a water contains much more than 0.1 part per million of iron, the excess may separate out and settle as a reddish sediment. A water high in iron is not suited for use by laundries or for making ice unless the excess iron has been removed. Only four (analyses 36, 40, 41, and 49) of the 15 samples analyzed contained more than 0.1 part per million of iron. The highest concentration of iron, 11 parts per million, was found in the water from well No. 40.

In the four samples for which complete analyses are available, the content of total dissolved solids ranged from 293 to 2,350 parts per million.

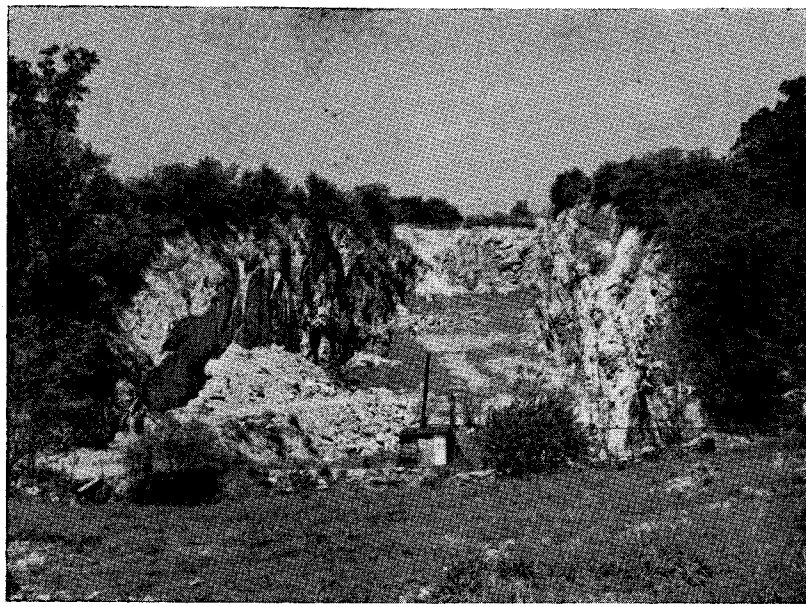
Most of the waters analyzed are entirely satisfactory for public-supply use, except for the difficulties resulting from their hardness. Many of the waters are unsuited for certain industrial uses, such as boiler water and laundry water, and would have to be treated to be used for these purposes. In general, most of the waters are satisfactory for cooling, however.



Mill Mountain in the southern part of Roanoke. View looking east toward the western slope of the mountain, and showing the location of Crystal Spring. Aerial photograph by Underwood and Underwood, courtesy of Roanoke Chamber of Commerce. *(From Virginia Geological Survey Bulletin 34.)*



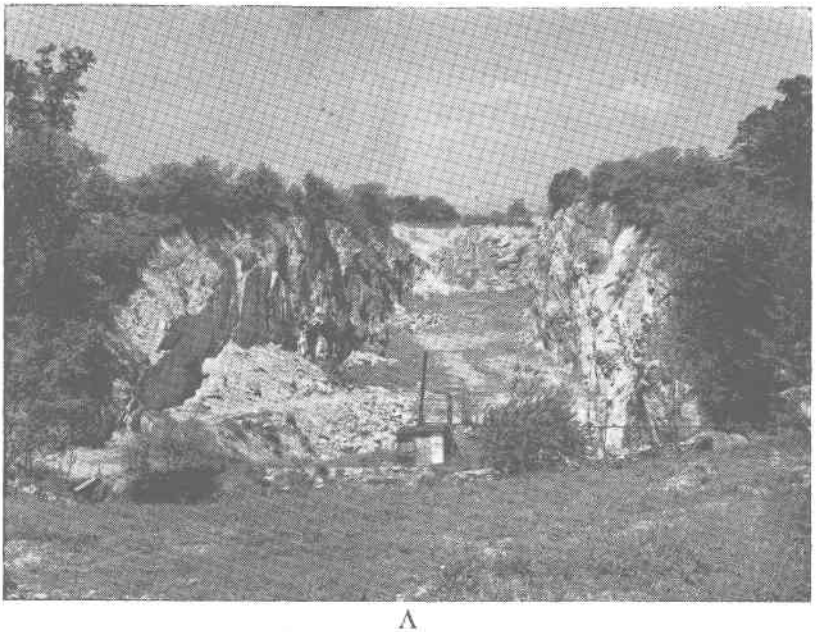
Mill Mountain in the southern part of Roanoke. View looking east toward the western slope of the mountain, and showing the location of Crystal Spring. Aerial photograph by Underwood and Underwood, courtesy of Roanoke Chamber of Commerce. *(From Virginia Geological Survey Bulletin 34.)*



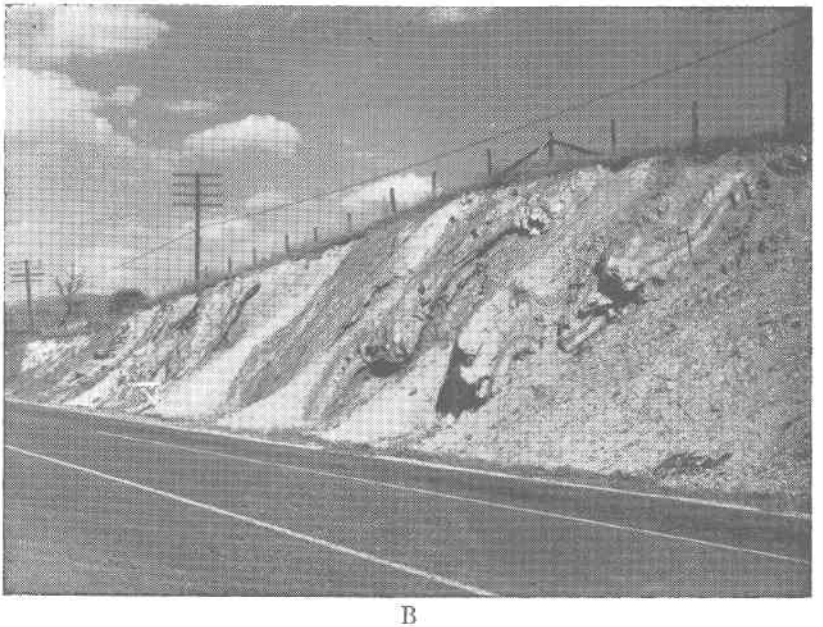
A

B

A, Rome formation in the Roanoke City quarry. A bed of dolomite about 100 feet thick is being quarried here. Beds are dipping steeply to the right. B, Contorted and steeply dipping shale beds of the Rome formation; along U. S. Route 460, about 4 miles northeast of Roanoke, Virginia.



A



B

A, Rome formation in the Roanoke City quarry. A bed of dolomite about 100 feet thick is being quarried here. Beds are dipping steeply to the right. B, Contorted and steeply dipping shale beds of the Rome formation; along U. S. Route 460, about 4 miles northeast of Roanoke, Virginia.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

PRECAMBRIAN ROCKS

Rocks of Precambrian age occur at the surface in the southeastern and southwestern parts of the Roanoke-Salem district (Plate 1). They consist of metamorphosed granite-like crystalline rocks with associated altered and recrystallized schists and slates of various types. Precambrian rocks are unimportant as a source of industrial or public-water supplies in this district. None of the wells or springs for which records were obtained derive their supply from these rocks.

CAMBRIAN SYSTEM

BASAL QUARTZITES

The basal Cambrian quartzites crop out in two belts south of Roanoke (Plate 1). Mill Mountain in the southern part of Roanoke is underlain by these rocks, as is Yellow Mountain farther south. They consist of quartzite sandstone, coarse and fine conglomerate, shale, and some slate, that have been so highly deformed as to obscure the original bedding in many places. Their thickness in this area is not known with certainty but is believed to be between 2,500 and 3,500 feet.

Records of one well (No. 66) and one spring (No. 67) that derive water from these rocks for public use are available. The well is 67 feet deep and is reported to obtain five gallons per minute from fractures in a coarse conglomerate. The spring yields five to six gallons per minute from fractured conglomerate. The waters from both sources are reported to be soft (Virginia Department of Health, 1939, pp. 142-3). The rocks of the basal Cambrian quartzites are relatively impermeable and do not contain water except in open joints and fractures. Large supplies of water are not to be expected from them.

SHADY DOLOMITE

The Shady dolomite, also known in other areas as the Tomstown dolomite, unconformably overlies the basal Cambrian quartzites in the district south of Roanoke (Plate 1). Because of the ease with which it weathers, actual exposures of bedrock are rare and generally the formation is masked by a deep soil or by float from the adjacent quartzite foothills. The formation is composed predominantly of beds of massive, coarse-grained, impure dolomite, but also contains many interbedded layers of shale and clay. The dolomite is blue to dark gray when fresh and dark gray to black when weathered. Sandy beds cemented by residual deposits of iron and manganese are also present in the formation. The formation is about 1,500 feet thick in the district.

The nine wells and two springs in the Shady dolomite for which records were obtained are all in or south of Roanoke. Four (Nos. 61, 62, 64, and 65) of the wells are public-supply wells, two (Nos. 39 and 63) are industrial wells, and two (Nos. 55 and 56) are abandoned industrial wells. Both springs (Nos. 60 and 68) furnish water to public supplies. The wells range in depth from 132 to 1,230 feet and in yield from a few gallons per minute to 382 gallons per minute. The largest yields have been obtained from the deeper wells. Two shallow wells (Nos. 64 and 65), each 132 feet deep, have small yields. Well No. 63 is 377 feet deep and yields 50 gallons per minute. Three deep wells (Nos. 39, 61, and 62) for which yields are available are 1,230, 1,003, and 656 feet deep and yield 382, 175, and 146 gallons per minute, respectively. The discharge of spring No. 68 is not known but was reported to be small. Crystal Spring (No. 60), with an average discharge of about 2,800 gallons per minute, is the largest spring in the Roanoke-Salem district and is an important contributor to the Roanoke City water supply.

According to an analysis published by the Virginia State Department of Health the water from Crystal Spring is a calcium bicarbonate water having 134 parts per million of hardness (Virginia Department of Health, 1939, pp. 152-3). An analysis of a sample of water from well No. 63 shows it to be a hard calcium bicarbonate water having 210 parts per million of hardness (Table 2). The waters from deeper wells in the Shady dolomite are of a much poorer quality. Wells Nos. 55 and 56 at the American Viscose Company are 1,100 and 600 feet deep, respectively, and were abandoned because the waters were too highly mineralized for industrial use. Wells Nos. 61 and 62 are used by the City of Roanoke only during emergencies because of the hardness and excessive amount of iron in the waters. The wells are 1,003 and 656 feet deep, respectively. The Hotel Roanoke well (No. 39), which is 1,230 feet deep, starts in the Rome formation, but is believed to end in and derive all of its water from the Shady dolomite. An analysis of a sample of water from this well shows it to be a highly mineralized sulfate water containing 2,350 parts per million of total solids and having a hardness of 1,180 parts per million (Table 2).

ROME FORMATION

The Rome formation, also called the Waynesboro formation, is the most widespread formation in the Roanoke-Salem district. It crops out in an east-west belt that is from one to 4.5 miles in width and extends across the central part of the district (Plate 1). A smaller outcrop of the Rome formation occurs just east of Salem. South and southwest of Roanoke the Rome borders the outcrop of the Shady dolomite, but east of Roanoke and south of Salem it is in contact with Precambrian rocks along the Blue Ridge fault. (See Plate 1.) The Rome is a heterogeneous formation composed of red, green, and purple shales with interbedded

limestones, dolomites, and some sandstone. The shales are very fine grained, close jointed, and generally weather yellowish gray. Distinctive features of the formation are the prominent red shale, and the greenish and gray shales having a silky luster due to a high sericite content. The sandstones are calcareous and weather to a rusty brown color. The most important feature of the formation from the standpoint of obtaining water is the widespread occurrence of beds of limestone and dolomite. The limestones and dolomites are blue gray to dark blue in color and generally not over 20 feet thick, although the dolomite bed being quarried at the Roanoke City quarry is about 100 feet thick (Plate 6B). The Rome formation is about 900 feet thick in this district.

The shale and limestone beds have been severely folded and faulted resulting in a very complex structure (Plate 6A). The general strike of the beds is N. 40°E., and the prevailing dip is to the south. Most of the folds within the formation are tightly compressed and many are overturned. Small normal faults having slight displacements are common. Also common are small thrust faults, generally strike faults, which break the overturned folds in the shales.

The importance of the Rome formation as a source of ground water in this district is indicated by the fact that 38 of the 83 industrial- and public-supply wells and springs are in this formation. This includes 29 of the 61 wells and nine of the 15 springs. The wells range in depth from 65 to 1,100 feet and in yield from seven to 1,000 gallons per minute. The limestone and dolomite beds in the Rome formation supply water to most of the wells, although fractures and bedding planes in shale may be the source of a small part of the water in some wells. A few wells, such as the Hotel Roanoke well (No. 39), did not encounter an adequate supply of water in the Rome formation and were drilled deeper into the underlying Shady dolomite. In general, however, moderate to large supplies of water can be obtained from the Rome formation by wells less than 300 feet deep, as indicated by the following table:

TABLE 3.—*Range in yield and average yield of 21 wells that end in the Rome formation, classified according to depth.*

Depth (feet)	Number of wells	Range in yield (gallons per minute)	Average yield (gallons per minute)
Less than 100	2	95, 125	110
100-200	6	7-1,000	253
201-300	7	7.5-400	126
301-500	4	17-150	76
501-700	2	50, 110	80

If a satisfactory supply is not obtainable within 300 feet, it would be a better risk to start a new well a short distance away rather than drill the well to a greater depth.

The nine springs in the Rome formation all issue from fractures or solution openings in limestone or dolomite. Their discharges range from 12 to 750 gallons per minute and the average discharge is about 244 gallons per minute. The most important of the springs and their discharges are Smith Spring (No. 47), 200 gallons per minute; River Spring (No. 58), 520 gallons per minute; Muse and House Springs (No. 59), 750 gallons per minute; and Mowles Springs (No. 12), 55 gallons per minute. Mowles Springs contribute to the Salem water supply.

Analyses were made of six samples of water from the Rome formation. Five samples were moderately hard to hard bicarbonate waters and one was a very hard sulfate water. The bicarbonate waters contained 124 to 299 parts per million of bicarbonate, 22 to 270 parts of sulfate, and had 105 to 375 parts of hardness. The one sulfate water contained 1,540 parts per million of sulfate, 97 parts of bicarbonate, and had 1,410 parts per million of hardness. The iron content in three of the samples was 0.04 part per million or less, but in the other three samples it ranged from 1.2 to 11 parts per million.

ELBROOK FORMATION

The Elbrook formation underlies most of the northern part of the Roanoke-Salem district. It crops out in a belt about two miles wide that trends roughly northeast-southwest and passes through Salem (see Plate 1). The formation consists of a thick series of blue and bluish-gray, partly argillaceous, and generally thinly bedded, limestones and alternate beds of buff and gray calcareous shale. The lower part of the formation is more shaly than the upper part. In places the shales are red and yellow and contain thin, finely laminated, interbedded limestones. The middle and upper parts are thicker bedded and contain thin beds of dolomite. The thickness of the Elbrook formation in the district ranges from about 1,000 to 1,600 feet. The general character of the formation has favored the development of abundant underground drainage as indicated by the numerous springs and sinks that occur in the outcrop area. Dixie Caverns southwest of Salem are in the Elbrook formation.

Records were obtained of 25 wells and six springs in the Roanoke-Salem district that obtain water from the Elbrook formation. The depths of the wells range from 50 to 785 feet, but more than half of them are less than 200 feet. They yield from five to 415 gallons per minute and average about 74 gallons per minute. The range in yield and average yield of 16 of these wells for which the yield is known, classified according to their depth, are given in Table 4 below.

TABLE 4.—*Range in yield and average yield of 16 wells that end in the Elbrook formation, classified according to depth.*

Depth (feet)	Number of wells	Range in yield (gallons per minute)	Average yield (gallons per minute)
Less than 100	4	22-50	35
100-200	6	5-100	41
201-300	3	15-56	37
More than 300	3	70-415	228

This table indicates that the larger yields are obtained from the deeper wells, whereas shallow wells furnish only moderate yields. The data are too scanty to make such a general statement, however. The yields given for some of the wells represent the capacities of the pumps and do not indicate the capacities of the wells. This is particularly true for some of the shallow wells from which only small or moderate supplies are demanded. For example, well No. 10, which is 179 feet deep, yields 55 gallons per minute with a drawdown of about one foot. The 55 gallons per minute is all that is demanded, but by increasing the drawdown the well would be capable of yielding considerably larger quantities. A few wells have been drilled to depths greater than 300 feet without encountering an adequate supply. Well No. 4, which is 500 feet deep, was abandoned because of its low yield. No water was reported to have been encountered in this well below a depth of 100 feet. Well No. 4 is not included in Table 4 because its yield was not known although it was reported to be very small. On the other hand, well No. 41, which is 697 feet deep, derives nearly its entire supply from openings below a depth of 502 feet (page 18).

Of the many springs that occur in the Elbrook formation in this district, three are being used to furnish water to public supplies. Lake Spring (No. 6) has an average discharge of 485 gallons per minute, all of which is used by the Town of Salem. Nininger and Blue Hill Springs are owned by the J. N. Phelps Water Company which furnishes water to a rather densely populated community north of Roanoke. Nininger Springs (No. 43) consists of three individual springs about 100 feet apart that discharge 50, 200, and 400 gallons per minute, respectively. Blue Hill Springs (No. 44) consists of two openings about 100 feet apart that discharge an aggregate of about 500 gallons per minute. The most prominent of the springs in the Elbrook formation not being used as a source of industrial or public-water supply is Moomaw Springs along the south side of Lick Creek Valley just north of Roanoke. There are two main springs here with a total discharge of about 1,600,000 gallons per day (Woodward, 1932, p. 147).

Waters from the Elbrook formation, in general, are of better quality than the waters from the Rome formation. Six samples of water from the Elbrook formation were analyzed and the results are given in Table 2. The waters were all slightly hard to hard bicarbonate waters. Two of the samples had less than 100 parts per million of hardness and four had from 129 to 246 parts per million. The bicarbonate content of the samples ranged from 90 to 264 parts per million. Only one sample contained more than 0.1 part per million of iron and this one contained 0.27 part per million.

CONOCOCHEAGUE LIMESTONE

The Conococheague limestone does not crop out in the Roanoke-Salem district, but occurs beneath younger formations in the area north of Round Hill. Where it is found at the surface north of this district it consists chiefly of light-colored magnesian limestone and dolomite and has a thickness of more than 1,000 feet. No industrial or public-supply wells penetrate the Conococheague in the district.

ORDOVICIAN SYSTEM

The lower part of the Ordovician system, comprising the Nittany dolomite and the Stones River group, consists of about 1,100 feet of limestone and dolomite. These calcareous rocks do not crop out in this district, consequently they are not shown on the geologic map (Plate 1). However, they occur beneath younger Ordovician strata in the northwestern part of the district. Well No. 1 at the Baptist Orphange north of Salem is thought to end in these rocks. It is 1,250 feet deep and yields 30 gallons per minute with a drawdown of 16 feet. The well is reported to be capable of supplying as much as 100 gallons per minute with a greater drawdown. A chemical analysis of a sample of water from this well shows a hardness of only 81 parts per million, indicating a relatively soft water for a limestone well.

Shales and sandstones with minor thin-bedded limestones overlie the Lower Ordovician limestones and dolomites. They include, in ascending order, the Athens shale, the Moccasin formation, and the Martinsburg shale. The Athens shale consists of blue to black shale containing thin beds of blue-black limestone in the lower part. It is about 970 feet thick in this district. The Moccasin formation is from 150 to 300 feet thick and consists largely of blue-gray and red-brown calcareous sandstone interbedded with thin layers of red sandy shale. The unweathered rocks of this formation are hard and resistant, but upon weathering they become porous and crumbly. The upper formation of the Ordovician system, the Martinsburg shale, consists of gray-brown calcareous shale, thin beds of sandstone, and thinly bedded crystalline limestone and is about 1,000 feet thick. Rocks of the Athens, Moccasin, and Martinsburg

formations crop out in narrow belts in the northwestern part of the district, where they have been severely folded and faulted. (See Plate 1 and Figure 2.) No records are available of wells in this district that derive water from these rocks.

SILURIAN AND DEVONIAN SYSTEMS

The Silurian system is represented in this district by the Clinch and Clinton formations which consist dominantly of red and white friable sandstone, coarse-grained, cross-bedded, gray sandstone, and buff and red shale. These rocks as a whole are highly indurated and very resistant to erosion, and for this reason are prominent ridge makers. The combined thickness of the Clinch and Clinton formations in this district is about 400 feet. They crop out in a very narrow belt northwest of Salem, where they form the ridges of Little Brushy Mountain. The Clinch sandstone caps Round Hill noth of Roanoke (Plate 1).

The extreme northwestern corner of the Roanoke-Salem district is underlain by rocks belonging to the Devonian system (Plate 1). Approximately the lower 25 feet consists of white to gray and brown, partly ferruginous, cross-bedded sandstone that is believed to belong to the Helderberg group. Above this is the Romney shale consisting of about 600 feet of dark-gray to black, fissile, carbonaceous shale.

Because of their topographic and geographic position the rocks of the Silurian and Devonian systems are unimportant as sources of water. No industrial or public-supply wells tap these rocks in this district; therefore they are not described in any detail in this report.

QUATERNARY SYSTEM

Overlying the Romney shale of Devonian age, which is the youngest formation of consolidated rocks in the district, are unconsolidated deposits of Quaternary age. They consist of alluvial clay, silt, sand, and gravel that occur along the present stream valleys and in terrace remnants scattered irregularly along the larger valleys. They are generally thin, although in places they may be 50 feet or more in thickness. They are the products resulting from the weathering and erosion of older bedded rocks. The gravels are composed chiefly of resistant materials such as chert, quartzite, and igneous rocks and the sands are composed largely of quartz grains. In general the Quaternary deposits are very poorly sorted.

Small to moderate supplies of water may be obtained from these deposits in places, but they are unimportant as a source of large supplies. The gravels generally contain much fine-grained material causing them to have rather low permeabilities. Furthermore, the gravels are best developed in terrace remnants on the stream divides and hence in many places they are lacking in ground water. Along Roanoke River the allu-

vial deposits are from a few feet to about 30 feet in thickness. Wells put down in the alluvium to the underlying bedrock are limited in yield by the small drawdown that is possible.

About 1918 the American Viscose Company attempted to develop a large supply of water from the alluvium along Roanoke River. Six wells were put down that ranged in depth from 20.9 to 22.8 feet and were spaced from 75 to 100 feet apart. The yields when the wells were pumped individually ranged from 25 to 75 gallons per minute and averaged about 50 gallons per minute. However, when the wells were pumped simultaneously the individual yield of each well decreased markedly due to the interference between the wells. It was found that nearly as much water could be obtained by pumping only one well, and for this reason all the wells but one have been abandoned. The remaining well (No. 53) is the only well in the Roanoke-Salem district that obtains water from Quaternary deposits for industrial or public use. It is 21.7 feet deep and yields 60 gallons per minute. The static water level in the well stands 12 feet below the land surface.

RECORDS OF WELLS AND SPRINGS

Descriptions of the public and industrial wells and springs in the Roanoke-Salem district studied by the writer are given in Table 5. The data in this table were reported by the owners, operators, or drillers of the wells and springs listed. Some of the reports were given from memory, so that part of the information may be inaccurate in some respects. The yield of each well as given in the table is the rate at which the well is ordinarily pumped and does not necessarily represent the capacity of the well. Where the capacity of a well is known, it is given in the "Remarks" column. The yield given for each spring is the average or normal natural discharge of the spring.

REFERENCES

1. Meinzer, O. E., 1923, Outline of ground-water hydrology, with definitions: U. S. Geol. Survey Water-Supply Paper 494, 71 pp.

2. Virginia Department of Health, Bureau of Sanitary Engineering, 1939, Public water supplies in Virginia, descriptions and chemical analyses: 159 pp.

3. Woodward, H. P., 1932, Geology and mineral resources of the Roanoke area, Virginia: Virginia Geol. Survey Bull. 34, 172 pp.

TABLE 5.—*Records of drilled wells and springs*
[Springs are indicated by an asterisk (*) beside number; wells

No. on Pl. 1	Location	Owner	Driller	Date completed	Topographic situation	Depth of well (feet)	Diameter of well (inches)
1	0.8 mile north of Salem	Baptist Orphanage	Mr. Thompson	1930	Slope	1,250	8
2	1 mile west of Salem	Ft. Lewis Tourist Court	Mr. Bishop	1931	Valley	50	6
3	Salem	Leas and McVitty, Inc.	.....	1895	Valley	325	8
4	Salem	Leas and McVitty, Inc.	.....	1926	Valley	500	.....
5	Salem	Leas and McVitty, Inc.	.....	.....	Valley	275	8
*6	Salem	Town of Salem	.....	.....	Base of hill	.....	.....
7	Salem	Town of Salem	.....	1905	Valley	785	10
8	Salem	Colonial Theater	Southern Drilling Co.	1941	Valley	100	8
9	Salem	Salem Creamery Co.	St. Clair Well Drilling Co.	1928	Slope	183	6
10	Salem	Jeffreys Laboratories, Inc.	Southern Drilling Co.	1945	Valley	179	8
11	Salem	Nuehoff, Inc., Packers	.....	.....	Valley	.....	.....
*12	1.5 miles south-southeast of Salem	Town of Salem	.....	.....	Valley	.....	.....
13	1.4 miles east-northeast of Salem	Edgewood Water Co.	St. Clair Well Drilling Co.	1928	Valley	90	5⅝
14	1.4 miles east-northeast of Salem	Edgewood Water Co.	St. Clair Well Drilling Co.	1932	Valley	70	5⅝
15	1.7 miles east-northeast of Salem	Charles Duffy	.....	1936	Hillside	180	6
16	1.5 miles east of Salem	Conehurst Mutual Citizens	St. Clair Well Drilling Co.	1915	Hillside	300	6
17	1.7 miles east of Salem	Dixie Finance and Loan Corp.	St. Clair Well Drilling Co.	1936	Hilltop	157	4
18	1.7 miles east of Salem	Dixie Finance and Loan Corp.	St. Clair Well Drilling Co.	1939	Hillside	160	5⅝
19	1.5 miles west-northwest of Roanoke	Edgewood Water Co.	St. Clair Well Drilling Co.	1927	Hillside	320	5⅝
20	1.5 miles west-northwest of Roanoke	Edgewood Water Co.	St. Clair Well Drilling Co.	1930	Valley	210	5⅝
21	1 mile west-northwest of Roanoke	G. L. Whitlow	.....	1941	Hillside	120	5⅝
22	1 mile west-northwest of Roanoke	G. L. Whitlow	St. Clair Well Drilling Co.	1925	Hilltop	250	5⅝

in the Roanoke-Salem district, Virginia
not shown on Geologic map, Plate 1, are indicated by (†)]

Depth to which well is cased (feet)	Principal water-bearing bed		Depth to water level below land-surface (feet)	Method of lift[1]	Yield (gallons a minute)	Draw-down (feet)	Use of water[2]	Remarks	No. on Pl. 1
	Character of material	Geologic horizon							
.....	Limestone	Nittany(?)	65	T, E	30	16	P	Well reported capable of yielding 100 gallons a minute with reasonable drawdown. See analysis.	1
15	Limestone	Elbrook	1	T, E	22	Small	P	Water-bearing crevice in limestone at 50 feet.	2
.....	Limestone	Elbrook	22	P, S	200	Small	I, C	Water used in general processing of leather. City water also used. See analysis.	3
.....	Limestone	Elbrook	.....	N	.....	.....	N	Well is 150 feet from well 3. Small yield obtained at 100 feet; no water below 100 feet. Abandoned because of low yield.	4
.....	.....	Elbrook	.....	N	42	.....	N	Not used since 1936 because of insufficient yield.	5
.....	Limestone	Elbrook	.....	F	485	.....	P	Lake Spring. Yield fluctuates with rainfall and has been as low as about 220 gallons a minute. Turbidity increases after long period of rainfall. See analysis.	*6
.....	Limestone	Elbrook	Flows	A	415	110	P	.....	7
18	Limestone	Elbrook	20	T, E	100	20	C	Driller reports that 4 water-bearing openings from less than ½ foot to 3 feet high were encountered. Mud seam encountered between 42 and 43 feet.	8
.....	Limestone	Elbrook	60	P, E	8	.....	C	.....	9
.....	Limestone	Elbrook	16	N	55	1	C	Driller reports 55 gallons a minute pumped for 9 hours; after which 96 gallons a minute was pumped for 1 hour with only a small increase in drawdown. Permanent pump not yet installed.	10
.....	Limestone	Elbrook	.....	T, E	27	.....	C	City water used for drinking, washing meats, etc.	11
.....	Limestone	Rome	.....	F	55	.....	P	Mowles Springs. 2 springs encased in concrete shelters.	*12
50	Limestone	Elbrook	10	C, E	25	5	P	Driller reports 50 gallons a minute available. Wells 13, 19, and 20 supply water to 250 families in Edgewood district.	13
40	Limestone	Elbrook	10	N	50	5	N	Tested when drilled. Standby well.	14
.....	Limestone	Elbrook	20	P, E	12	.....	P	Supplies water to 26 families at Sunset Village. See analysis.	15
.....	Limestone	Rome	30	Cy, E	7.5	.....	P	Supplies water to 43 families in Conehurst district.	16
.....	Limestone	Rome(?)	Shallow	P, E	.....	.....	N	Standby well. See well 18.	17
.....	Limestone	Rome(?)	70	P, E	17	.....	P	Tested when drilled, 25 gallons a minute with drawdown of 30 feet. Supplies water to 18 families in South Edgewood.	18
60	Limestone	Rome	100	P, E	17	.....	P	See well 13.	19
40	Limestone	Rome	30	P, E	17	.....	P	Water level lowers to bottom of intake pipe, 175 feet, after pumping 17 gallons a minute for 5 hours. See well 13.	20
16	Limestone	Rome	16	P, E	7	.....	P	Wells 21 and 22 supply water to 44 families in Washington Heights.	21
40	Limestone	Rome	60	P, E	8	.....	P	Drawdown 100 feet pumping 27 gallons a minute.	22

TABLE 5.—*Records of drilled wells and springs in*
[Springs are indicated by an asterisk (*) beside number; wells

No. on Pl. 1	Location	Owner	Driller	Date completed	Topographic situation	Depth of well (feet)	Diameter of well (inches)
23	1 mile northwest of Roanoke	A. L. Crantz	.....	.....	Slope	140(?)	2
24	0.9 mile northwest of Roanoke	Frank Gilbert	Mr. Thomas	1914	Slope	104	6
25	Northwest edge of Roanoke	Roanoke Country Club	Mr. Thomas	1932	Slope	285	8
26	Northwest edge of Roanoke	Roanoke Country Club	Mr. Thomas	1922	Hilltop	168	8
27	West edge of Roanoke	E. E. Engleman	Mr. Bishop	1937	Slope	210	6
28	West edge of Roanoke	E. E. Engleman	.....	1915	Hillside	132	6
29	12th Street, SW., Roanoke	Virginia Brewing Co.	.....	1915	Slope	400	12
30	720 Fairfax Ave., NW., Roanoke	Roanoke Dairy and Ice Cream Co.	Southern Drilling Co.	1939	Slope	82	8
31	318 Church Ave., SW., Roanoke	John M. Oakey, Inc.	St. Clair Well Drilling Co.	1937	Slope	400	5⅝
32	2nd and Luck Streets, Roanoke	Roanoke Photo Finishing Co.	Sydnor Pump and Well Co.	1938	Slope	500	6
33	211 Jefferson St., S., Roanoke	American Theater	Mr. Thomas	1927	Slope	300	8
34	613 Jefferson St., S., Roanoke	Patrick Henry Hotel	St. Clair Well Drilling Co.	1940	Slope	601.5	8
35	526 First St., SE., Roanoke	Peoples Ice and Storage Co.	Mr. Thomas	1928	Slope	700	8
36	502 First St., SE., Roanoke	Clover Creamery Co., Inc.	.....	1914	Slope	99	8
37	24 Campbell Ave., E., Roanoke	Minton Meat Market	.....	.....	Flat	65	6
38	Campbell and First St., E., Roanoke	Roanoke City Market	Mr. Thomas	1921	Flat	152(?)	8
39	Jefferson and Wells Aves., Roanoke	Hotel Roanoke	Virginia Machinery & Well Co.	1938	Slope	1,230	12
40	1218 Wise Ave., SE., Roanoke	Virginia Brewing Co.	Mr. Bishop	1915	Slope	182	12

the Roanoke-Salem district, Virginia—Continued
not shown on Geologic map, Plate 1, are indicated by (†)]

Depth to which well is cased (feet)	Principal water-bearing bed		Depth to water level below land-surface (feet)	Method of lift[1]	Yield (gallons a minute)	Draw-down (feet)	Use of water[2]	Remarks	No. on Pl. 1
	Character of material	Geologic horizon							
.....	.....	Elbrook	.....	Cy, E	.....	.....	P	Supplies 6 families.	23
.....	Limestone	Elbrook	64	P, E	.....	.....	P	Supplies 11 families.	24
.....	.....	Elbrook	30	P, E	56	.....	P, Ir	70 gallons a minute reported to be available.	25
.....	.....	Elbrook	138	T, E	63	.....	P, Ir	Water becomes muddy after prolonged dry period. See analysis.	26
.....	Limestone and shale	Elbrook	60	Cy, E	15	.....	P	Tested 20 gallons a minute when drilled. Wells 27 and 28 supply water to 32 families in Westwood Annex.	27
125	Limestone	Elbrook	122	Cy, E	5	.....	P	5 gallons a minute reported to be maximum yield of well.	28
.....	Limestone	Rome	.....	N	50-60	.....	N	Abandoned because of low yield.	29
.....	Limestone	Rome	8	T, E	95	11.5	C	.....	30
.....	Limestone	Rome	40	T, E	85	40	C	City water used in boiler because of excessive hardness of well water.	31
190	Limestone	Rome	11	T, E	150	94	C	Mud-filled cavern between 155 and 166.5 feet cased off.	32
.....	.....	Rome	15±	T, E	400	.....	C	.....	33
.....	Limestone	Rome	.....	T, E	110	.....	N	Shale encountered from 45 to 500 feet and hard limestone from 500 to 601.5 feet. Only 55 gallons a minute obtained at 500 feet; driller believes most of water came in at contact of shale and limestone. Drilled for cooling water. Abandoned because of excessive hardness, which was reported to be 109 parts per million.	34
40	.....	Rome	.....	T, E	50-60	.....	C	Used only during extremely hot weather. Large drawdown; after pumping 50-60 gallons a minute for about 10 minutes pump stops to let well recover.	35
.....	.....	Rome	20	T, E	125	.....	C	See analysis.	36
.....	.....	Rome	Flows	T	.....	.....	N	Formerly used for cooling. Discontinued in favor of public supply.	37
.....	.....	Rome	5	T, E	112	.....	C	Water hard; forms incrustation in pipes. Yield decreased appreciably during summer of 1943 and water became muddy.	38
60	Limestone	Shady	37	T, E	300	66	I, C	Capacity of well at 1,000 feet was 115 gallons a minute. After deepening to 1,230 feet well yielded 382 gallons a minute with a drawdown of 80 feet. Noticeable odor of hydogen sulphide when water is fresh. See analysis.	39
40	Limestone	Rome	12	T, E	360	21	I, C	Pumped 500 gallons a minute during test when well was drilled; drawdown unknown. Water comes from opening in limestone between 180-182 feet. See analysis.	40

TABLE 5.—*Records of drilled wells and springs in*
[Springs are indicated by an asterisk (*) beside number; wells

No. on Pl. 1	Location	Owner	Driller	Date completed	Topographic situation	Depth of well (feet)	Diameter of well (inches)
41	Williamson Road and Lee Ave., Roanoke County	Lee Theater	Virginia Machinery & Well Co.	.....	Slope	697	10-6
42	Hollins Road, Roanoke County	Johnson-Carper Furniture Co.	Mr. Bishop	.....	Slope	58	.....
*43	Tinker Creek, 1.5 miles north of Roanoke	J. N. Phelps	.....	.....	Slope	.....	.....
*44	Tinker Creek, 0.8 mile north of Roanoke	J. N. Phelps	.....	.....	Slope	.....	.....
*45	Tinker Creek, 0.3 mile north of Roanoke	J. N. Phelps	.....	.....	Base of cliff	.....	.....
*46	Tinker Creek, at northeast edge of Roanoke city limits	J. N. Phelps	.....	.....	Base of cliff	.....	.....
*47	Vinton	City of Roanoke	.....	.....	Draw	.....	.....
*48	Vinton	Virginia Etna Springs Co.	.....	.....	Hillside	.....	.....
49	Waverly Place, SE., Roanoke	Stauffer Chemical Co., Inc.	Sydnor Pump and Well Co.	1939	Valley	205	4
50	Waverly Place, SE., Roanoke	Stauffer Chemical Co., Inc.	Sydnor Pump and Well Co	1935	Valley	205	6
51	Waverly Place, SE., Roanoke	Stauffer Chemical Co., Inc.	Sydnor Pump and Well Co.	1941	Valley	205	8
52	Walnut Ave., SE., Roanoke	Roanoke Iron and Bridge Works	.....	1906	Valley	130	6
53	Southeast edge of Roanoke	American Viscose Co.	.....	1918	Valley	21.7	.....
54	Southeast edge of Roanoke	American Viscose Co.	.....	.....	Valley	Deep	.....
55	Southeast edge of Roanoke	American Viscose Co.	.....	.....	Valley	1,100	.....
56	Southeast edge of Roanoke	American Viscose Co.	.....	.....	Base of hill	600	.....
57	Southeast edge of Roanoke	American Viscose Co.	Sydnor Pump and Well Co.	1945	Valley	135	14
*58	0.3 mile southeast of Roanoke	City of Roanoke	.....	.....	Flood plain	.....	.....
*59	0.5 mile southeast of Roanoke	City of Roanoke	.....	.....	Side of draw	.....	.....

the Roanoke-Salem district, Virginia—Continued
not shown on Geologic map, Plate 1, are indicated by (†)]

Depth to which well is cased (feet)	Principal water-bearing bed		Depth to water level below land-surface (feet)	Method of lift[1]	Yield (gallons a minute)	Draw-down (feet)	Use of water[2]	Remarks	No. on Pl. 1
	Character of material	Geologic horizon							
.....	Limestone	Elbrook	45	T, E	70-80	Very small	C	When drilled, pumped 115 gallons a minute for 26 hours with very small drawdown. When well was 502 feet deep, pumped 60 gallons a minute for 4 hours, then yield decreased to 2 gallons a minute with drawdown of 115 feet. See analysis.	41
.....	Limestone	Elbrook	.....	T, S	43	.....	I, P	.....	42
.....	Limestone	Elbrook	.....	F	650	.....	P	Nininger Springs. 3 individual springs about 100 feet apart that yield 50, 200, and 400 gallons a minute.	*43
.....	Limestone	Elbrook	.....	F	500	.....	P	Blue Hill Springs. 2 springs about 100 feet apart.	*44
.....	Limestone	Rome	.....	F	200±	.....	N	Masons Mill Springs. 2 springs about 100 feet apart. Formerly used as public supply. See analysis.	*45
.....	Limestone	Rome	.....	F	200	.....	N	East Gate Spring. Formerly used as public supply.	*46
.....	Limestone	Rome	.....	F	200	.....	P	Smith Spring. Yield fluctuates with percipitation.	*47
.....	Limestone	Rome	.....	F	12	.....	I	2 springs about 30 feet apart. Water is bottled straight and in soft drinks.	*48
40	Limestone	Rome	Flows	T, E	50	75	C	Use city water for boilers and uses other than cooling. See analysis.	49
40	Limestone	Rome	Flows	T, E	150	75	C	See well 49.	50
40	Limestone	Rome	Flows	T, E	250	75	C	See well 49.	51
.....	Limestone	Rome	20	Cy, E	25	5	C	See analysis.	52
.....	Sand & gravel	Quaternary	12	C, E	60	.....	C	Were originally 6 shallow wells. See page .	53
.....	.....	.....	.....	N	.....	.....	N	Well abandoned. Water reported too highly mineralized for industrial use.	54
.....	Limestone	Shady	Flowed	N	.....	.....	N	Well abandoned. Water reported too highly mineralized for industrial use.	55
.....	Limestone	Shady	.....	N	200	.....	N	Well abandoned. Water reported too highly mineralized for industrial use.	56
22	Limestone	Rome	12	T, E	1,000	60	C	Pumped 900 gallons a minute with drawdown of 55 feet during test. Water reported to contain 180 parts per million of total solids and 134 parts of soap hardness. Temp. 62°F.	57
.....	Limestone	Rome	.....	F	520	.....	P	River Spring. Water reported to issue from crevices in limestone. Shale (Rome) exposed in bank about 50 feet south of spring.	*58
.....	Limestone	Rome	.....	F	750	.....	P	Muse and House Springs. 2 springs about 25 feet apart. Yield has fluctuated from about 550 gallons a minute during dry periods to 1,000 gallons a minute during prolonged rainy periods.	*59

TABLE 5.—*Records of drilled wells and springs in*
[Springs are indicated by an asterisk (*) beside number; wells

No. on Pl. 1	Location	Owner	Driller	Date completed	Topographic situation	Depth of well (feet)	Diameter of well (inches)
*60	McClanahan St. and Stanley Ave., Roanoke	City of Roanoke	.....	.....	Slope	.....	.....
61	Near Wellington Ave. bridge, Roanoke	City of Roanoke	.....	1908	Slope	1,003	12-8
62	Near Wellington Ave. bridge, Roanoke	City of Roanoke	.....	1908	Slope	656	12-8
63	McClanahan Place, Roanoke	Dr. Pepper Bottling Co.	.....	1941	Slope	377	6
64	Garden City, Roanoke County	C. R. Clark	.....	1942	Slope	132	6
65	Garden City, Roanoke County	C. R. Clark	.....	1940	Ridge	132	6
66	Garden City, Roanoke County	J. W. Moran	Mr. Waldron	1937	Hillside	67	6
*67	Garden City, Roanoke County	J. W. Moran	.....	.....	Side of draw	.....	.....
*68	Garden City, Roanoke County	J. O. Plunkett	.....	.....	Hillside	.....	.....
*69	0.6 mile north-northeast of Cave Spring	Cave Spring Water Co.	.....	.....	Valley	.....	.....
*70	Cave Spring	W. B. Rasnake	.....	.....	Base of cliff	.....	.....
71	West edge of Roanoke	Southern Drilling Co.	Southern Drilling Co.	1949	Valley	164	8
72	Roanoke	Roanoke Fruit and Produce Company	Southern Drilling Co.	1946	Slope	1,100	10
73	Approximately 3 miles east of Salem	Thaden Engineering Co.	Southern Drilling Co.	1946	Valley	350	.....
74	1 mile west of Salem, on Route 11	Frank Jones	Southern Drilling Co.	1949	Valley	345	8
75	Roanoke	Densmore Poultry Farm	Southern Drilling Co.	1946	Hilltop	590	8
†76	Highest point on Poor Mountain southwest of Salem	WSLS Radio Station	Southern Drilling Co.	1947	Hilltop	204	.....
77	1 mile west of Salem on Route 11	Chapman Rice, Inc.	Southern Drilling Co.	1948	Valley	297	8
78	1 mile west of Roanoke on Route 11	Public Entertainment, Inc.	Southern Drilling Co.	1948	Valley	232	.....
79	1 mile southwest of Roanoke	Southern Drilling Co.	Booth	1947	Slope	500	8
†80	4 miles southwest of Roanoke	Steel Service, Inc.	Southern Drilling Co.	1952	Valley	169	6
†81	Dixie Caverns	Dixie Caverns, Inc	Southern Drilling Co.	1951	Valley	171	.....
†82	¾ mile north of Route 460 near Lakeside	Charles Duffy	S. W. St. Clair	1949	.....	202	6
83	1 mile west of Route 220, and ½ mile north of Route 119.	Ogden School	R. L. Obenchain	1950	.....	252	6

[1]A, air lift; C, centrifugal pump; Cy, cylinder pump; F, natural flow; N, none; P, plunger pump; T, turbine pump; E, electric motor; S, steam power.
[2]C, condensing or cooling; I, industrial; Ir, irrigation; N, none; P, public supply.

the Roanoke-Salem district, Virginia—Continued
not shown on Geologic map, Plate 1, are indicated by (†)]

Depth to which well is cased (feet)	Principal water-bearing bed		Depth to water level below land-surface (feet)	Method of lift[1]	Yield (gallons a minute)	Draw-down (feet)	Use of water[2]	Remarks	No. on Pl. 1
	Character of material	Geologic horizon							
.....	Limestone	Shady	.....	F	2,775	.....	P	Crystal Spring. Yield decreases to about 2,500 gallons a minute during dry periods.	*60
652	Limestone	Shady	5	A	175	90	P	New casing installed in 1939. Water reported to be hard and to contain excessive iron. Because of poor quality of water, well is used only in emergency.	61
535	Limestone	Shady	5	A	146	122	P	New casing installed in 1939. Water reported to be hard and to contain excessive iron. Because of poor quality of water well is used only in emergency.	62
40	Limestone	Shady	15	T, E	50	10	I, C	See analysis.	63
.....	Limestone	Shady	.....	P, E	.....	.....	P	Wells 64 and 65 supply water to 16 families in Garden City district.	64
80	Limestone	Shady	.....	P, E	.....	.....	P	See well 64.	65
20	Coarse conglomerate	Basal quartzites	Shallow	P, E	5	.....	P	Well 66 and spring 67 supply water to about 70 families in Garden City district.	66
.....	Coarse conglomerate	Basal quartzites	.....	F	5	.....	P	Water issues from fractures in hard conglomerate. No apparent fluctuation in yield. See well 66.	*67
.....	Limestone	Shady	.....	F	Small	.....	P	Spring; 5-foot galvanized iron pipe sunk in ground. Water pumped to pressure tank. Supplies water to 75 families in Garden City district.	*68
.....	Limestone	Rome	.....	F	30	.....	P	Spring; supplies water to 65 families in Cave Spring area.	*69
.....	Limestone	Rome	.....	F	230	.....	I	Water issues from large solution opening in limestone. Supplies water to Nu-Way Laundry. Softened by zeolite process. See analysis.	*70
.....	Shale and limestone	Rome	70	C	68	.....	P		71
.....	Limestone	Rome	10	P	87	C	C		72
.....	Limestone	Elbrook	3	C	24½	54	.....		73
173	Limestone	Elbrook	15	.....	15	70	C, P		74
.....	Limestone	Rome	59	P	94	51	.....		75
.....	Limestone	Elbrook	30	.....	10½	.....	.....		†76
.....	Limestone	Elbrook	107	P	88	20	P		77
.....	Limestone	Rome	28.5	C	20	72	P		78
.....	Shale and limestone	Rome	250	T	18	.....	P		79
111	Limestone	Shady	58	.....	25	.....	.....		†80
.....	Limestone	Elbrook	16	.....	75	.....	.....		†81
170	.....	.....	75	C	20	15	P		†82
.....	.....	Rome	65	.....	40	110	.....		83

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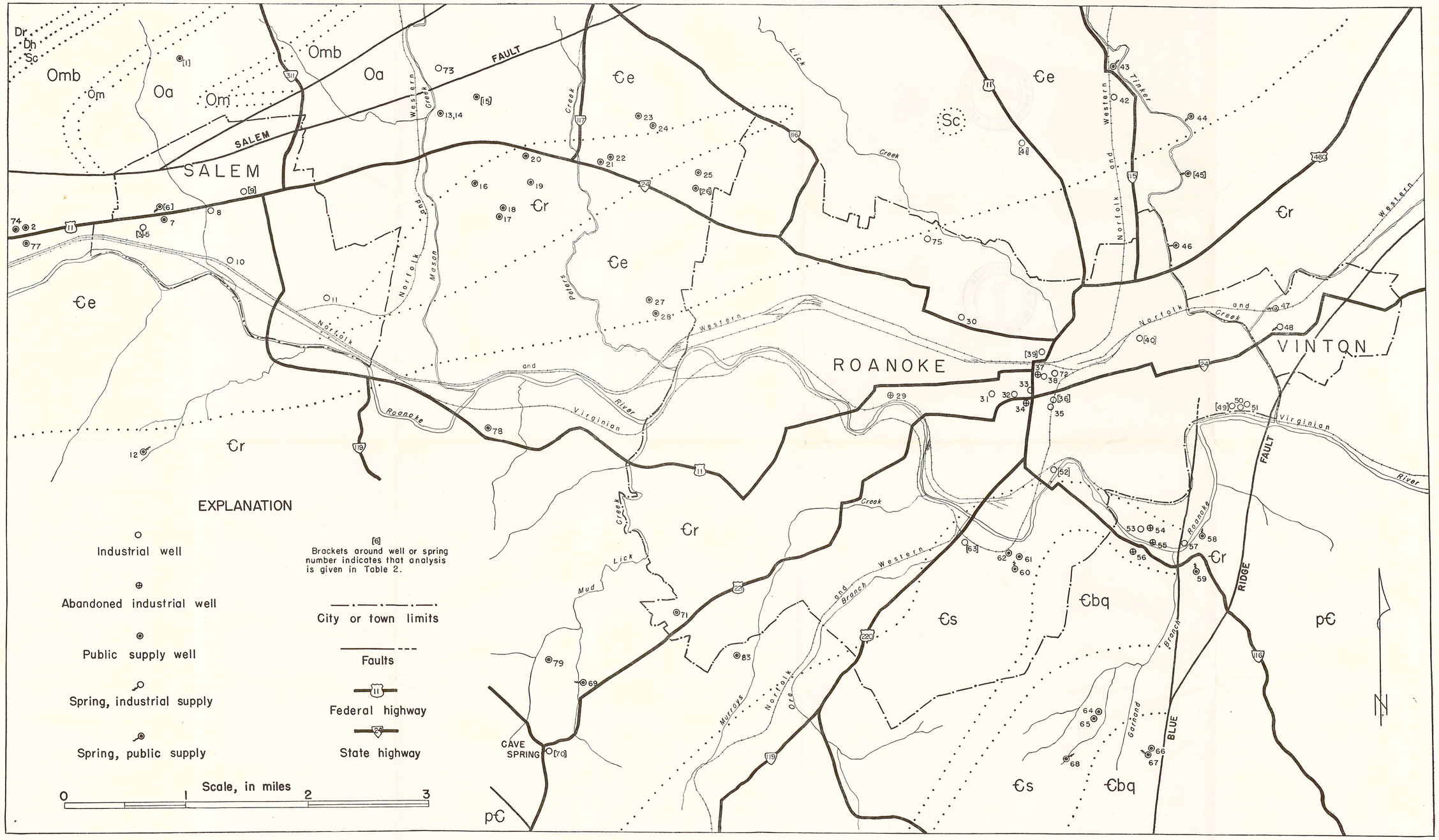

EXPLANATION

DEVONIAN

Dr — Romney shale
(Dark gray to black carbonaceous shale.)

Dh — Helderberg group
(Gray-brown friable sandstone.)

SILURIAN

Sc — Clinton formation and Clinch sandstone
(Red, white, and gray sandstone and buff and red shale.)

ORDOVICIAN

Omb — Martinsburg shale
(Gray-brown shale, thin sandstones, and thinly bedded crystalline limestone.)

Om — Mocassin formation
(Reddish sandstone and shale.)

Oa — Athens shale
(Black shale containing thin beds of black limestone in lower part.)

CAMBRIAN

Ꞓe — Elbrook formation
(Blue and bluish-gray thinly bedded limestone, buff and gray calcareous shale, and a few thin beds of dolomite. Twenty wells have average yield of about 74 gallons a minute and three springs discharge 465 to 650 gallons a minute. Water is slightly hard to hard.)

Ꞓr — Rome formation
(Red, rusty-brown, and purple shale, containing prominent beds of bluish-gray to dark-blue limestone and dolomite. Limestone and dolomite beds are important sources of water in this area and supply water to nearly half of the recorded wells. Wells yield from 7 to 1,000 gallons a minute and springs discharge from 12 to 750 gallons a minute. Water is moderately hard to hard.)

Ꞓs — Shady dolomite
(Blue to dark-gray impure dolomite containing some shale and clay. Two shallow wells have small yields. Three deep wells yield 146 to 382 gallons a minute. Waters from springs and shallow to moderately deep wells are hard but otherwise of good quality. Waters from deep wells generally are highly mineralized.)

Ꞓbq — Basal quartzites
(Sandstone, quartzite, conglomerate, shale, and some slate. One well and one spring derive small supplies of soft water from these rocks. They are hard and difficult to drill and probably are capable of furnishing only small supplies.)

PRE-CAMBRIAN

p€ — Precambrian crystalline rocks
(No record of wells in these rocks.)

No record of wells in these rocks.

Base modified from map by J. L. Wentworth, City Engineer of Roanoke, Virginia

GEOLOGIC MAP OF THE ROANOKE-SALEM DISTRICT, VIRGINIA, SHOWING THE LOCATION OF WELLS AND SPRINGS

Geology taken mainly from Geologic Map of the Roanoke Area, Virginia, by Herbert P. Woodward, Virginia Geological Survey Bulletin, 34, Plate 1, 1932. Data on wells and springs by Bruce F. Latta with additions by Alfred C. Walker.