Please return this publication to the Virginia Geological Survey when you have no further use for it. Postage will be refunded.

COMMONWEALTH OF VIRGINIA

STATE COMMISSION ON CONSERVATION AND DEVELOPMENT

VIRGINIA GEOLOGICAL SURVEY

ARTHUR BEVAN, *State Geologist*

Bulletin 34

Geology and Mineral Resources of the Roanoke Area, Virginia

BY

HERBERT P. WOODWARD

UNIVERSITY, VIRGINIA

1932

COMMONWEALTH OF VIRGINIA
STATE COMMISSION ON CONSERVATION AND DEVELOPMENT
VIRGINIA GEOLOGICAL SURVEY
ARTHUR BEVAN, *State Geologist*

Bulletin 34

Geology and Mineral Resources of the Roanoke Area, Virginia

BY
HERBERT P. WOODWARD

UNIVERSITY, VIRGINIA
1932

RICHMOND:
DIVISION OF PURCHASE AND PRINTING
1932

Gorge of Carvins Creek looking north into Carvins Cove. The rock is vertical Silurian (Clinch) sandstone. The dam of the Roanoke Water Works Company has been built in this gorge. (See pp. 24 and 55.) Photograph by Davis Photo Co. (Courtesy of Roanoke Chamber of Commerce.)

Gorge of Carvins Creek looking north into Carvins Cove. The rock is vertical Silurian (Clinch) sandstone. The dam of the Roanoke Water Works Company has been built in this gorge. (See pp. 24 and 55.) Photograph by Davis Photo Co. (Courtesy of Roanoke Chamber of Commerce.)

Charles E. Reville - U. Va. 1 + 9.

STATE COMMISSION ON CONSERVATION AND DEVELOPMENT

William E. Carson, *Chairman,* Riverton

Coleman Wortham, *Vice-Chairman,* Richmond

E. Griffith Dodson, Norfolk

Thomas L. Farrar, Charlottesville

Junius P. Fishburn, Roanoke

Lee Long, Dante

Rufus G. Roberts, Culpeper

Richard A. Gilliam,
Executive Secretary and Treasurer, Richmond

LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA
VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., February 28, 1930.

To the State Commission on Conservation and Development:

GENTLEMEN:

I have the honor to transmit and to recommend for publication as Bulletin 34 of the Virginia Geological Survey series of reports a manuscript and illustrations of a report on the *Geology and Mineral Resources of the Roanoke Area, Virginia,* by Dr. Herbert P. Woodward, Professor of Geology, Dana College, Newark, N. J.

This report is a rather comprehensive discussion of the surface features, rock formations, structure, geologic history, and mineral resources of Roanoke County and adjoining parts of Botetourt, Bedford, Franklin, Floyd, Montgomery, and Craig counties. It contains a description of the sedimentary formations of this part of the Blue Ridge and the adjacent part of the Appalachian Valley in Virginia, according to modern interpretations of the stratigraphy. It is accompanied by a geologic map in colors and contains several excellent aeroplane photographs of the area.

This report will be of especial interest to geologists and to the residents of the area. It will aid in understanding the interesting and complex geologic history of the area, and thus should be a guide to intelligent prospecting and utilization of its diverse mineral resources. It should give the layman a better understanding of the geologic processes and events which have been responsible for the accumulation of the mineral deposits and for the present topography of the region which has had a controlling influence on human activities.

A glossary of technical terms is given at the end of the report.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
State Commission on Conservation and Development,
Richmond, Virginia, February 28, 1930.
E. O. FIPPIN, *Executive Secretary.*

CONTENTS

ILLUSTRATIONS

TABLES

ABSTRACT

The area described in this report comprises Roanoke County, Virginia, and parts of adjacent counties, the entire area being tributary to the city of Roanoke. It lies along the Valley of Virginia, and includes adjoining parts of the Blue Ridge province on the east and south and the Appalachian Valley Ridges on the north and west. The elevation ranges from 880 to 3,960 feet above sea-level. The drainage is largely into Roanoke River. The climate is pleasant, and a fertile soil permits profitable cultivation.

Despite the wide lowland belt through the middle part, the area is essentially mountainous, the ridges having been produced upon outcrops of resistant rock, whereas the lowlands have been eroded along belts of slightly resistant rock. During the erosion of the region several former base-levels were established, and flattish erosion surfaces or peneplanes were developed, remnants of which may now be recognized. The most important of these peneplanes are: (1) The Summit peneplane, at about 3,500 feet above sea-level and represented only on the summits of the higher mountains; (2) the Upland peneplane, now about 3,000 feet above sea-level and visible as the even crests of the Appalachian Valley Ridges; and (3) the Valley-floor peneplane, at an average elevation of about 1,200 feet and developed as the floors of the Valley of Virginia and its tributary lowlands.

The rocks of the Roanoke area consist of three groups: (1) Pre-Cambrian crystalline and metamorphic rocks; (2) Paleozoic consolidated sedimentary rocks; and (3) Quaternary unconsolidated surficial rocks. The pre-Cambrian crystalline rocks are restricted to the Blue Ridge. They are largely gneisses and schists which have been derived from earlier rocks by excessive metamorphism. They weather readily and produce a heavy red soil. The Paleozoic sedimentary rocks, which underlie the greater part or the area, include more than twenty separable formations ranging in age from Lower Cambrian to Lower Mississippian. Of special interest to geologists are (1) the subdivision of the so-called "Cambro-Ordovician" limestone into Elbrook, Conococheague, and Nittany formations; (2) the occurrence of Trenton and Athens shales in the same trough of deposition; and (3) the occurrence of a thin bed of volcanic ash or bentonite in Ordovician shale. The Quaternary rocks are largely surface deposits of gravel, sand, and residual soil, although small isolated deposits of marl occur.

The structure of the region is typically that of the mountainous central Appalachian Highlands, being a complex of folds and thrust faults with their attendant minor phenomena. The most striking

structure of the region is the great Catawba syncline, which extends across the northern part of Roanoke County and is rimmed by the Tinker-Catawba-Paris Mountain ridge. Several fine sections of the formations can be seen across this syncline. Cambrian to Devonian formations are exposed along the Salem-Newcastle highway. The faults of the Roanoke area are largely of the overthrust type. They trend northeast with the strike of the other structures, but their traces are commonly very sinuous. In the vicinity of Cloverdale, fensters and evidences of "klippen" structure may be seen.

The important mineral resources of the region at present are largely non-metallic, consisting of building and construction stone, clay and shale, nelsonite for phosphorous and titanium, lime and cement rock, glass sand, and ocher. While not all of these resources are being exploited at the present time, there is geological evidence to show that they may be profitably developed. Other materials, such as lead and zinc, coal, barite, and manganese, are known to occur within the area, but not in quantities which warrant mining. A considerable quantity of low-grade iron ore was mined in this region about 40 years ago, and much iron still remains. It is of too low grade for present use, although it may be valuable at some future time. There is no basis for considering the presence of gold, silver, natural gas, and petroleum in economic quantities, and search for these materials should be discouraged.

The region is abundantly supplied with springs, many of which have considerable flow. Crystal Spring in Roanoke has a measured flow of more than 4,500,000 gallons of water daily, and is one of the sources of water for Roanoke. Several other large springs also supply water which is used for domestic purposes. There are many mineral springs in the region. Blue Ridge Sulphur Springs and the springs at Catawba Sanatorium are locally famous for their mineral waters. The abundant underground circulation of water has made channels in the soluble limestones. The Valley is dotted with sinks, some of which lead into caves. Dixie Caverns are the largest known caves in the region.

Geology and Mineral Resources of the Roanoke Area, Virginia

By HERBERT P. WOODWARD

INTRODUCTION

LOCATION OF THE AREA

The nucleus of the area considered in this report is Roanoke County, which is in the west-central part of Virginia. The county is roughly pentagonal in outline. Its greatest north-south dimension is about 17 miles, and its greatest east-west dimension is 20 miles. The area of the county is 195,581 acres or nearly 297 square miles. The county is included between parallels 37°7′ and 37°25′, and meridians 70°50′ and 80°16′. Most of its boundaries are crests of mountain ridges. Roanoke, on Roanoke River, is the chief city.

In addition to Roanoke County, this report treats of (1) parts of Glade Creek Valley in Botetourt and Bedford counties, (2) Fincastle Valley in Botetourt County, and (3) Montgomery County east of Paris, or Roanoke, Mountain. As the territory included in this report outside of Roanoke County may be said to be tributary to the city of Roanoke, the whole region is here called the Roanoke area. (See Fig. 1.)

SCOPE OF THE REPORT

This report has developed from an investigation of the water resources of the Roanoke area, carried on in the interests of the Roanoke Water Works Company. A reconnaissance survey was made during the summer of 1926. During the summers of 1927 and 1928, the writer continued a geologic survey of this area under the supervision of the Virginia Geological Survey.

This report is intended to serve as a guide to the geology of the area tributary to the city of Roanoke. It discusses also the past development and the present and future possibilities of the mineral resources of the area.

ACKNOWLEDGMENTS

For substantial assistance in the preparation of this report, the writer is under various obligations. Special thanks are due to Dr. Charles Butts, of the United States Geological Survey, who has un-

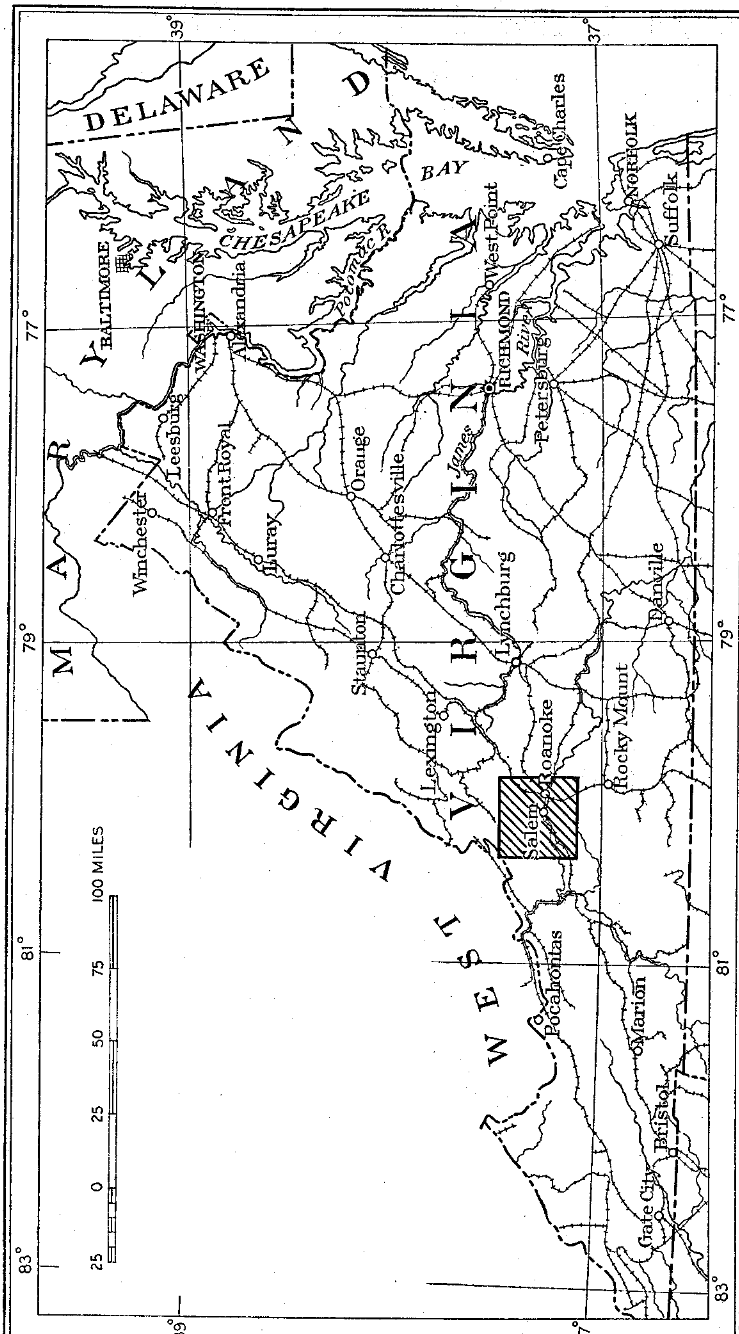


Figure 1.—Index map showing location of the Roanoke area, Virginia.

tiringly guided the writer in his studies of the complex structure and stratigraphy of this general region. Without this generous assistance, much of the report could not have been completed.

To Professor Charles P. Berkey, of Columbia University, the writer is deeply indebted for guidance and supervision during the field work of 1926 and throughout the preparation of the report. Professor Harry S. Ladd, then of the University of Virginia, spent several days in the field with the writer and made many valuable suggestions. Professors Douglas Johnson, J. J. Galloway, and R. J. Colony, of Columbia University, criticized parts of the manuscript and offered much valuable assistance. For criticisms and comments upon various parts of this report, the writer wishes to express his gratitude to Mr. George W. Stose, of the United States Geological Survey, to Professor Roy J. Holden, of Virginia Polytechnic Institute, and to Mr. Francis W. Collins, of the Roanoke Water Works Company.

Hearty cooperation was given the writer by residents of the Roanoke area, and mention should be made of the aid furnished by Mr. J. Price Bowman, Mr. Ben F. Moomaw, and Dr. W. S. Sayers, of Roanoke, and Mr. C. H. Hutchins, of Vinton.

The writer has had the able assistance of his wife, Harriette B. Woodward, in the preparation of the manuscript and of the charts and figures.

Finally, the writer wishes to express his thanks to Professor Wilbur A. Nelson, State Geologist of Virginia during the period of the field work on this report; to Dr. Arthur Bevan, present State Geologist of Virginia; and to Mr. Linwood H. Warwick, chief clerk of the Virginia Geological Survey, all of whom have greatly assisted the writer during the preparation of the report and have kindly given him the full cooperation of the Virginia Geological Survey. The report has been edited and prepared for publication by the present staff of the Survey.

RELIEF[1] AND DRAINAGE

Despite an open broad central valley area, Roanoke County may be said to be essentially mountainous. (See Pls. 1 and 2.) In the northern part, the mountains are typical Appalachian Valley ridges, parallel, even-crested, and trending in a northeast-southwest direction. (See Pl 4.) South and east of the central lowland, the mountains are irregularly distributed and form more massive uplands than to the north. Independent mountain masses, which locally rise as prominent elevations within or at the edge

[1]Technical terms are defined briefly in the Glossary at the end of the report.

of the valley floor, are commonly without any marked ridge characteristics. (See Pls. 5 and 23.) Coyners and Mills[2] mountains east of Cloverdale are of this type.

The highest point in the county is found in the extreme southwest where the central peak of the Poor Mountain mass rises to 3,960 feet in altitude. The lowest elevation in the area, about 880 feet, is where Roanoke River leaves the county. Thus the maximum relief of the county is 3,100 feet. Other high individual summits are: Bent Mountain, 3,150 feet; Mason Knob, 3,217 feet; McAfee Knob, 3,210 feet; Twelve O'clock Knob, 2,707 feet, and Stewarts Knob, 2,472 feet. More peaks reach high elevations in the western part of the county than in the eastern part, and they are more rugged in the southwestern than in the northwestern part.

The gently rolling valley floors average 1,200 feet in altitude, above which the mountains rise 100 to 1,800 feet. The relief is primarily the result of differential erosion of hard and soft rocks, the hill crests being composed of resistant rock, whereas the valleys have been carved out of weaker rocks. There are at least four separate ridge-makers among the formations, and the geological structure of the region is such that scarcely any two adjacent hills are underlain by the same formation.

Seven-eighths of Roanoke County, that is, all the area south of Catawba Mountain, drains into Roanoke River, which cuts through the Blue Ridge at the eastern county line and then flows southeastward. The area north of Catawba Mountain is drained by Catawba Creek into James River which is 40 miles northeast of the Roanoke and flows roughly parallel to it. At Lafayette 1 mile west of the Roanoke County line, the north and south forks of the Roanoke converge to form the main river. These streams drain the dissected upland of eastern Montgomery County. Four large tributaries join the Roanoke in Roanoke County: (1) Back Creek from the southwest; (2) Tinker Creek and its large branch, Carvins Creek from the north; (3) Glade Creek from the northeast; and (4) Mason Creek, which enters the Roanoke near Salem, from the northwest. The extreme southwestern upland is drained through Bottom Creek into South Fork of the Roanoke, and Millers Cove in the extreme northwest drains into the James through Craig Creek.

[2]The hill which is labeled Mills Mountain on the Roanoke topographic map is locally unknown by this name and is called Reeds Mountain. This local name is preferable to the printed name, as it avoids confusion with Mill Mountain which is south of Roanoke.

DESCRIPTIVE GEOGRAPHY

GENERAL FEATURES

Several geographic provinces or divisions may be recognized in the county. The most striking are the Blue Ridge, Roanoke Valley, and the Valley and Ridge section. Catawba Valley and Millers Cove are also subordinate geographic units, as is the open valley formed by the wide recesses of Mason, Carvins, and Bradshaws coves. These divisions are in sharp contrast with adjoining areas, and their individual characteristics have affected the settlement and development of the county.

ROANOKE VALLEY

The Valley of Virginia is constricted to a narrow width where it enters and leaves Roanoke County, so that the Roanoke lowland is somewhat separated from the rest of the Valley. This local division is here called Roanoke Valley, from the city of Roanoke near its center. (See Pls. 4 and 6.) It is the same lowland to which the name Salem Valley has been applied by Stose.[3]

Roanoke Valley is separated from Fincastle Valley to the northeast by Tinker Mountain, which projects far to the southeast, almost to the Blue Ridge at Cloverdale. A mile beyond the southwestern line of the county, the Valley of Virginia is further obstructed by Pedlar Hills which fill the area between Paris and Poor mountains, thus separating Roanoke Valley to the northeast from Dublin Valley to the southwest. There is an extension of Roanoke Valley northeast between Porters Mountain on the east and Mills and Coyners mountains on the west. A southern extension lies between Mill and Sugar Loaf mountains southwest of Roanoke.

Roanoke Valley is thus about 8 miles wide at a maximum, and extends across the entire county, a distance of 20 miles. Its floor stands about 1,000 feet above sea-level, although many small hills rise to higher elevations. In the extreme southwestern part of the county, Roanoke Valley narrows to 1 mile in width, and its floor is about 1,200 to 1,400 feet above sea-level.

The main lines of travel pass through Roanoke Valley, which contains the larger cities and villages of the county. This valley may be entered through five passes, two of which are at low elevations. The most open entrance is from the northeast, the pass at Cloverdale being only 100 feet above Roanoke. This gap is occupied by Tinker Creek, the Shenandoah Valley division of the Nor-

[3]Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, pp. 8-9, 1919.

folk and Western Railway, and the Lee Highway. The northeast extension of Roanoke Valley along Glade Creek is traversed by the main line of the Norfolk and Western Railway and by the Roanoke-Lynchburg highway, which cross the Blue Ridge in Bufords Gap at an elevation of 1,250 feet. Divisions of this railroad enter the valley from the south through Murrays and Maggoty gaps, and from the west along Roanoke River where it cuts between Poor Mountain and Pedlar Hills.

BLUE RIDGE UPLAND

The southern third of the county, south and east of Roanoke Valley, is an upland formed by the Blue Ridge and its foothills. Between Buchanan and Roanoke the Blue Ridge is composed of two parallel ridges, the northern of which ends abruptly towards the south in Fullhardt Knob north of Cloverdale. The southern ridge continues along the eastern boundary of Roanoke County. Buck, Yellow, and Mill mountains are northern foothills. The southwestern upland, composed of Poor and Bent mountains, has an elevation of about 3,000 feet. This is the most rugged part of the county, and is sparsely settled and poorly developed. (See Pl. 7.) The area is largely drained by Back Creek which flows parallel to the Roanoke and joins it near the gap through the Blue Ridge.

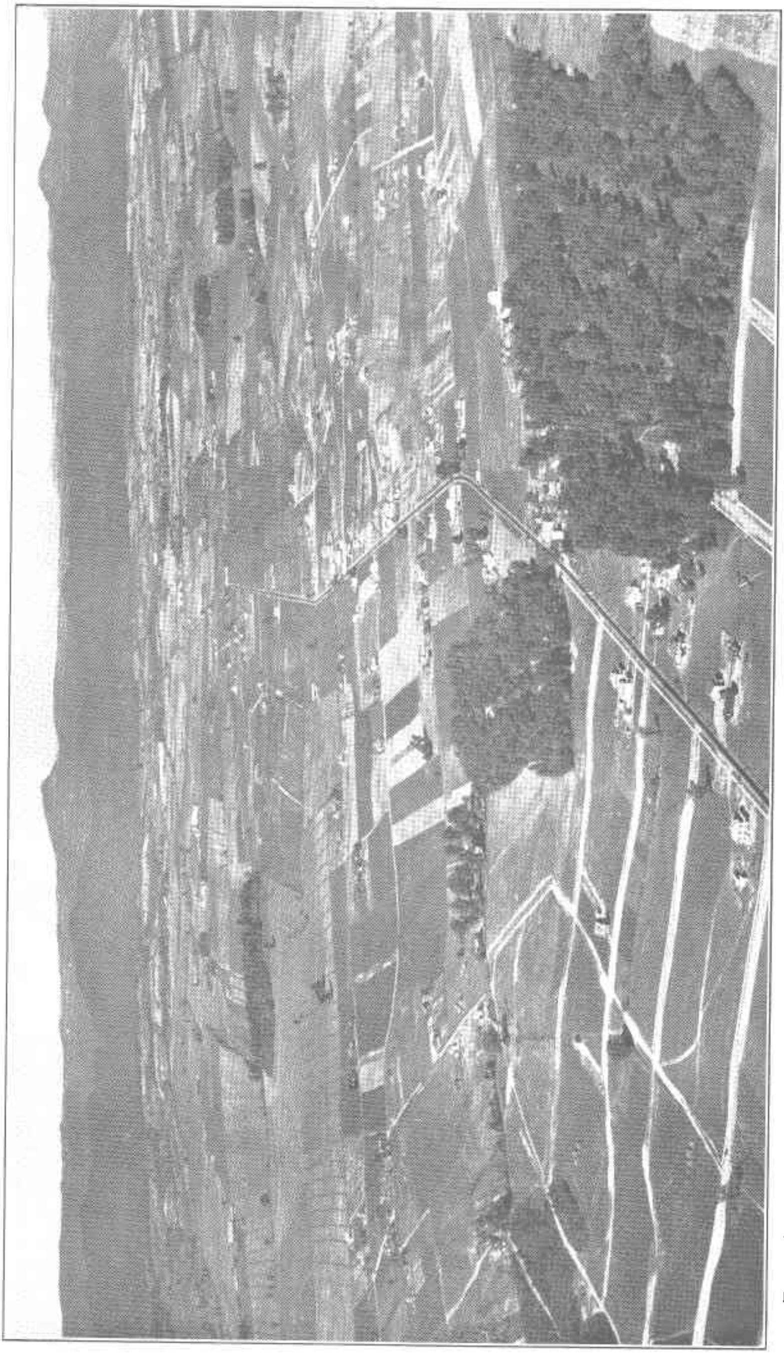
VALLEY AND RIDGE SECTION

The northwestern third of the county consists of parallel northeast-southwest mountains (Pl. 8) with deep and narrow intermontane valleys. The southernmost of these ridges, Fort Lewis Mountain, has been cut through by Mason and Carvins creeks, which, flowing southward into the Roanoke, have opened wide recesses, Mason and Carvins coves, north of the mountain. (See Pl. 9.) The divide between Roanoke and James rivers is along the crest of Catawba Mountain, and the drainage to the north flows into the James through Catawba and Craig creeks. Catawba Valley connects Fincastle Valley on the north with Dublin Valley, which lies west and southwest of Pedlar Hills. Catawba Valley has been considered by some as part of the Valley of Virginia, but it is properly an intermontane valley within the Valley and Ridge section to the northwest. (See Pls. 1 and 2.)

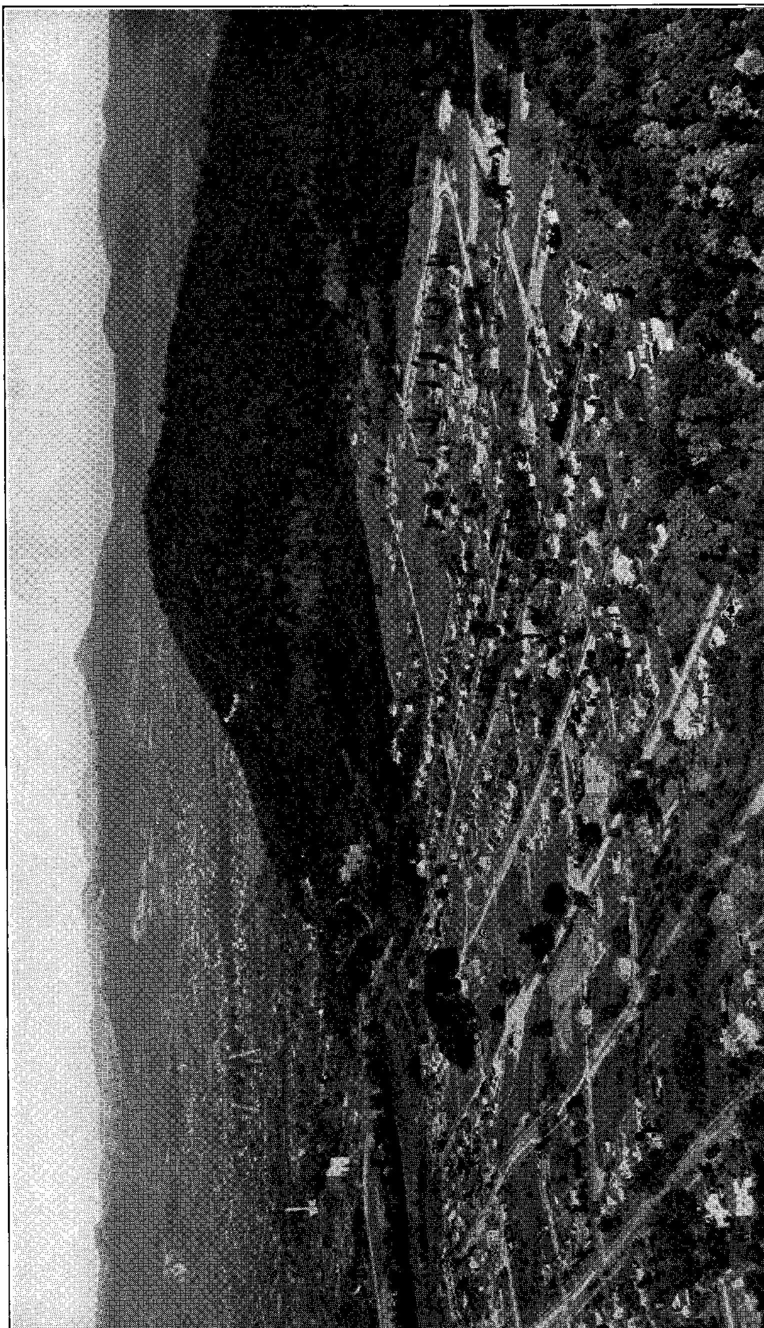
REFERENCES ON THE GENERAL GEOLOGY

BASSLER, R. S., The cement resources of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 2A, 1909.

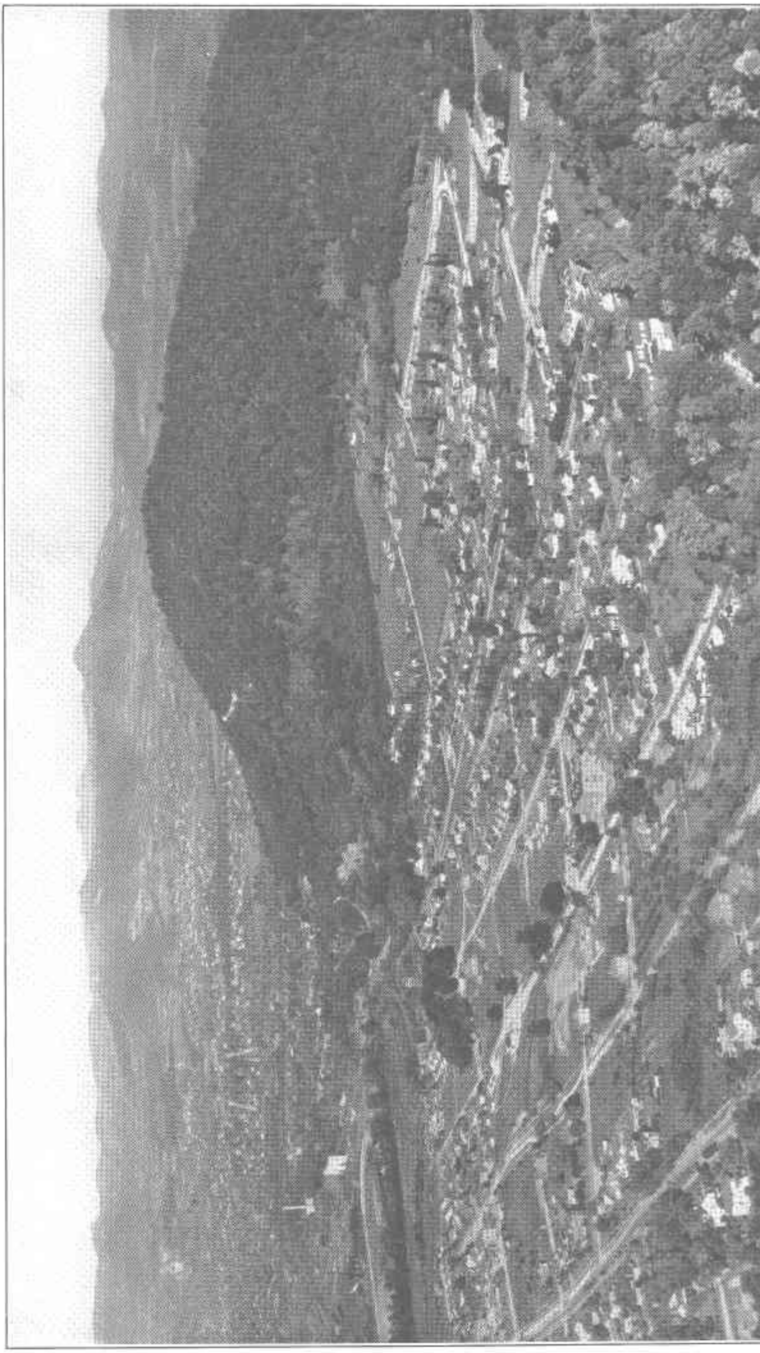
Roanoke Valley showing Valley Ridges in the background. View looking northwest. The wooded areas are on cherty or siliceous soils. (See pp. 7, 14, and 22.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



Roanoke Valley showing Valley Ridges in the background. View looking northwest. The wooded areas are on cherty or siliceous soils. (See pp. 7, 14, and 22.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



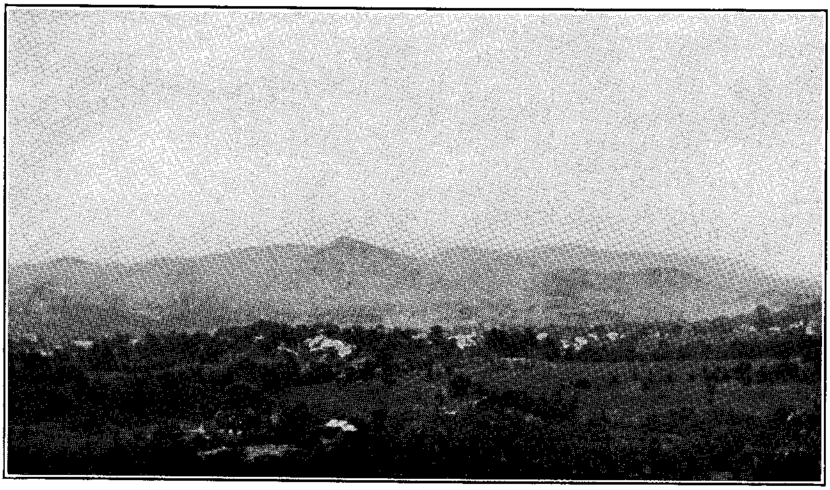
Across the southern part of Roanoke toward Mill Mountain and the Blue Ridge. View looking southeast. Mill Mountain is in the center and the Blue Ridge is in the distant background. (See pp. 6 and 14.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



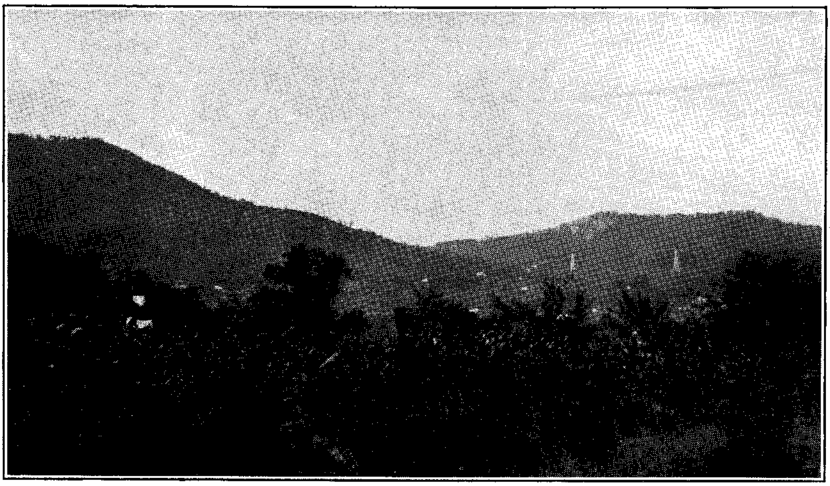
Across the southern part of Roanoke toward Mill Mountain and the Blue Ridge. View looking southeast. Mill Mountain is in the center and the Blue Ridge is in the distant background. (See pp. 6 and 14.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)

Roanoke Valley just east of Roanoke. View looking northeast. Round Hill, a fenster in the Pulaski overthrust, is just below the upper margin. The Valley is here underlain by the Elbrook and Rome ("Watauga") formations. (See pp. 7, 14, and 22.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)

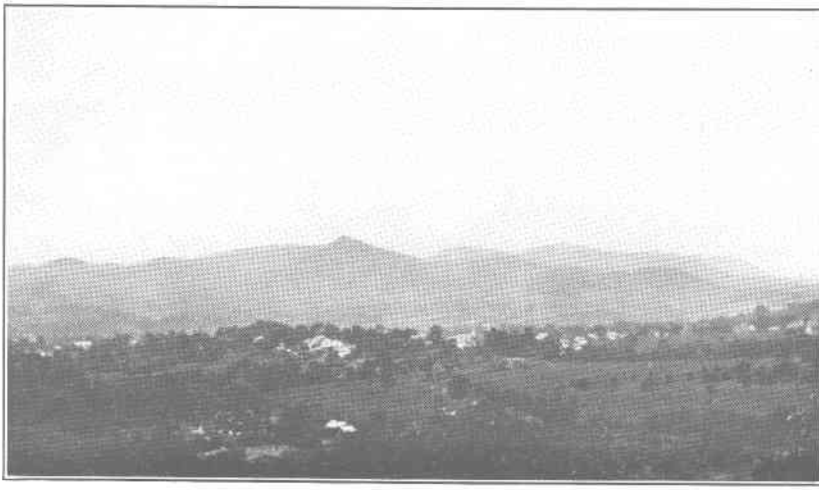
Roanoke Valley just east of Roanoke. View looking northeast. Round Hill, a fenster in the Pulaski overthrust, is just below the upper margin. The Valley is here underlain by the Elbrook and Rome ("Watauga") formations. (See pp. 7, 14, and 22.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



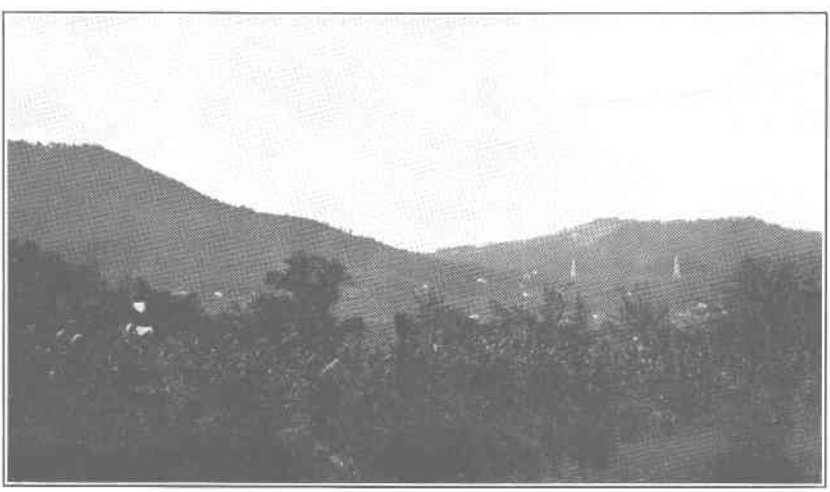
A. Foothills of the Blue Ridge southwest of Salem. View looking south.



B. Rugged foothills of the Blue Ridge south of Roanoke. View looking west. Yellow Mountain at the left. The formations are in the Lower Cambrian Chilhowie group. (See pp. 8 and 29.)



A. Foothills of the Blue Ridge southwest of Salem. View looking south.



B. Rugged foothills of the Blue Ridge south of Roanoke. View looking west. Yellow Mountain at the left. The formations are in the Lower Cambrian Chilhowie group. (See pp. 8 and 29.)

BOYD, C. R., Resources of southwest Virginia, showing the mineral deposits of iron, coal, zinc, copper, and lead, New York, 1881.

CAMPBELL, H. D., The Cambro-Ordovician limestones of the middle portion of the Valley of Virginia: Am. Jour. Sci., 4th ser., vol. 20, pp. 445-447, 1905.

CAMPBELL, J. L., Silurian formation in central Virginia: Am. Jour. Sci., 3d ser., vol. 18, pp. 16-29, 1879.

____________, Geology of Virginia; continuation of section across the Appalachian chain: Am. Jour. Sci., 3d ser., vol. 18, pp. 119-128, 239, 1879.

____________, Geology of Virginia; Balcony Falls; the Blue Ridge and its geological connections: Am. Jour. Sci., 3d ser., vol. 18, pp. 435-445, 1879.

____________, Geology and mineral resources of the James River Valley, Virginia, U. S. A., New York, 1882.

CAMPBELL, M. R., Paleozoic overlaps in Montgomery and Pulaski counties, Virginia: Geol. Soc. America Bull., vol. 5, pp. 171-190, 1894.

____________, Drainage modifications and their interpretation: Jour. Geology, vol. 4, pp. 567-581, 657-678, 1896.

CAMPBELL, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, 1925.

DARTON, N. H., Notes on the stratigraphy of a portion of central Appalachian Virginia: Am. Geologist, vol. 10, pp. 10-18, 1892.

FONTAINE, W. M., Notes on the geology and mineral resources of the Floyd, Virginia, Plateau: The Virginias, vol. 4, pp. 167, 178-180, 185-192, 1883.

____________, Salem and the Roanoke Valley: The Times-Register Office, Salem, Virginia, 1884.

GROVER, N. C., and BOLSTER, R. H., Hydrography of Virginia: Virginia Department of Agriculture and Immigration, Geol. Survey of Virginia, Geol. Ser., Bull. 3, 1906.

HAYES, C. W., The southern Appalachians: Nat. Geog. Soc., Mon. 1, no. 10, pp. 305-336, 1895.

HAYES, C. W., and CAMPBELL, M. R., Geomorphology of the southern Appalachians: Nat. Geog. Mag., vol. 6, pp. 63-126, 1894.

HOTCHKISS, JED, and others: The Virginias, vols. 1-6, Staunton, Virginia, 1880-1885.

HUBBARD, G. D., and CRONEIS, C. G., Notes on the geology of Giles County, Virginia: Denison Univ. Bull., Jour. Sci. Lab., vol. 20, pp. 307-377, 1924.

JACK, G. S., History of Roanoke County, Roanoke, Virginia, [Stone, *ca.*, 1912].

KINDLE, E. M., The Onondaga fauna of the Allegheny region: U. S. Geol. Survey Bull. 508, pp. 46-47, 1912.

KINZER, C. W., A chemical interpretation of the limestones of the Roanoke and Catawba valleys: Unpublished thesis, Roanoke College, Salem, Virginia, 1924.

MACLURE, WILLIAM, Observations on the geology of the United States of America, Philadelphia, pp. 37-38, 51, 58-59, 108, 1817.

MOYER, G. E., The Cambro-Ordovician section in the vicinity of Salem, Virginia: Unpublished thesis, Roanoke College, Salem, Virginia, 1917.

POWELL, S. L., Discovery of the Normanskill graptolite fauna in the Athens shale of southwestern Virginia: Jour. Geology, vol. 23, pp. 272-281, 1915.

RAYMOND, P. E., The correlation of the Ordovician strata of the Baltic Basin with those of eastern North America: Harvard Coll. Mus. Comp. Zool. Bull., vol. 56, pp. 235-238, 1916.

————————, Some new Ordovician trilobites: Harvard Coll. Mus. Comp. Zool. Bull., vol. 64, pp. 273-296, 1920.

————————, Some trilobites of the lower middle Ordovician of eastern North America: Harvard Coll. Mus. Comp. Zool. Bull., vol. 67, pp. 1-180, 1925.

REGER, D. B., and PRICE, P. H., Mercer, Monroe, and Summers counties, West Virginia: West Virginia Geol. Survey, County reports, 1926.

ROGERS, W. B., A reprint of annual reports and other papers on the geology of the Virginias, New York, D. Appleton and Co., 1884.

STEVENS, G. C., Surface water supply of Virginia: Virginia Geol. Survey Bull. 10, 1916.

STEVENSON, J. J., Notes on the surface geology of southwest Virginia: Am. Phil. Soc. Proc., vol. 24, pp. 172-178, 1887.

SUMMERS, L. P., Annals of southwest Virginia, Abingdon, Virginia, 1929.

SURFACE, G. T., Studies on the geography of Virginia: Geog. Soc. Philadelphia Bull., vol. 5, pp. 1-60, 1907.

TOPHAM, A. J., The natural economic resources of Roanoke County, Virginia: Unpublished thesis, Roanoke College, Salem, Virginia, 1923.

UNITED STATES GEOL. SURVEY Geologic Atlas, folios nos. 12, 14, 26, 44, 59, and 61. These folios describe quadrangles in Virginia in the same province as the Roanoke area.

WALCOTT, C. D., Notes on the Cambrian rocks of Virginia and the southern Appalachians: Am. Jour. Sci., 3d ser., vol. 44, pp. 52-57, 1892.

WATSON, T. L., A bibliography of the geological, mineralogical, and paleontological literature of the State of Virginia: Bull. Am. Paleontology, vol. 2, no. 7, 109 pp., 1897.

————————, Mineral resources of Virginia: Virginia-Jamestown Exposition Commission, 1907.

WILLIS, BAILEY, The northern Appalachians: Nat. Geog. Soc., Mon. 1, no. 6, pp. 169-202, 1895.

WOODWARD, H. P., Thrust faults of the Roanoke area, Virginia. Geol. Soc. America Bull., vol. 40, pp. 185-186, 1929.

————————, The age and nomenclature of the Rome ("Watauga") formation of the Appalachian Valley: Jour. Geology, vol. 37, pp. 592-603, 1929.

WRIGHT, F. J., The physiography of the upper James River basin in Virginia: Virginia Geol. Survey Bull. 11, 1925.

PHYSIOGRAPHY

GENERAL STATEMENT

In studying the physiography of an area such as Roanoke County, the factors influencing erosion and the general effects of erosion claim attention. The chief agents of erosion in this area are, and apparently have always been, streams. They have produced the present and past topographic forms as a result of four important factors: (1) Inequalities of level upon the initial land surface; (2) differences of hardness in the underlying rocks; (3) variations in distance from the sea, and hence in local base-levels; and (4) differential uplift or warping of the land surface. These factors have modified, to varying degrees, stream erosion in different erosion cycles, so that, under the predominant influence of one or more of these factors, the surface has passed through various stages of development, some of which may be recognized from the present land forms.

The most obvious result has been the production of similar land forms in districts where similar factors have been equally influential. This has had the effect of producing areas which have had a similar history, and which possess similar land forms. The large areas are called physiographic provinces, or sections, and are readily apparent to the layman.

The stages of development of land forms may be considered in terms of erosion cycles. A complete erosion cycle includes the erosion of any initial surface to an extensive gently sloping plain having few elevations. This erosion surface is a peneplane. If the erosion cycle is interrupted or incomplete, the topography may show any variation from a mountainous surface to a peneplane, depending upon the stage of erosion at the time of interruption. The completion of an erosion cycle depends upon certain factors, chiefly (1) the rate of erosion, (2) the resistance of the rocks to this erosion, and (3) a long period of stability of the earth's crust. Under any conditions, however, an erosion cycle is very long and is seldom completed. It is generally interrupted by an uplift of the land, which rejuvenates the streams and starts a new epoch of erosion or lengthens the old one. As the recognition of these completed, or partially completed, erosion surfaces is an important factor in interpreting the physiographic history of a given area, the old erosion levels in the Roanoke area are herewith described.

The development of the topography of this area, so far as it can be determined from the present topography, is discussed below. The reader will find the following selected references valuable to

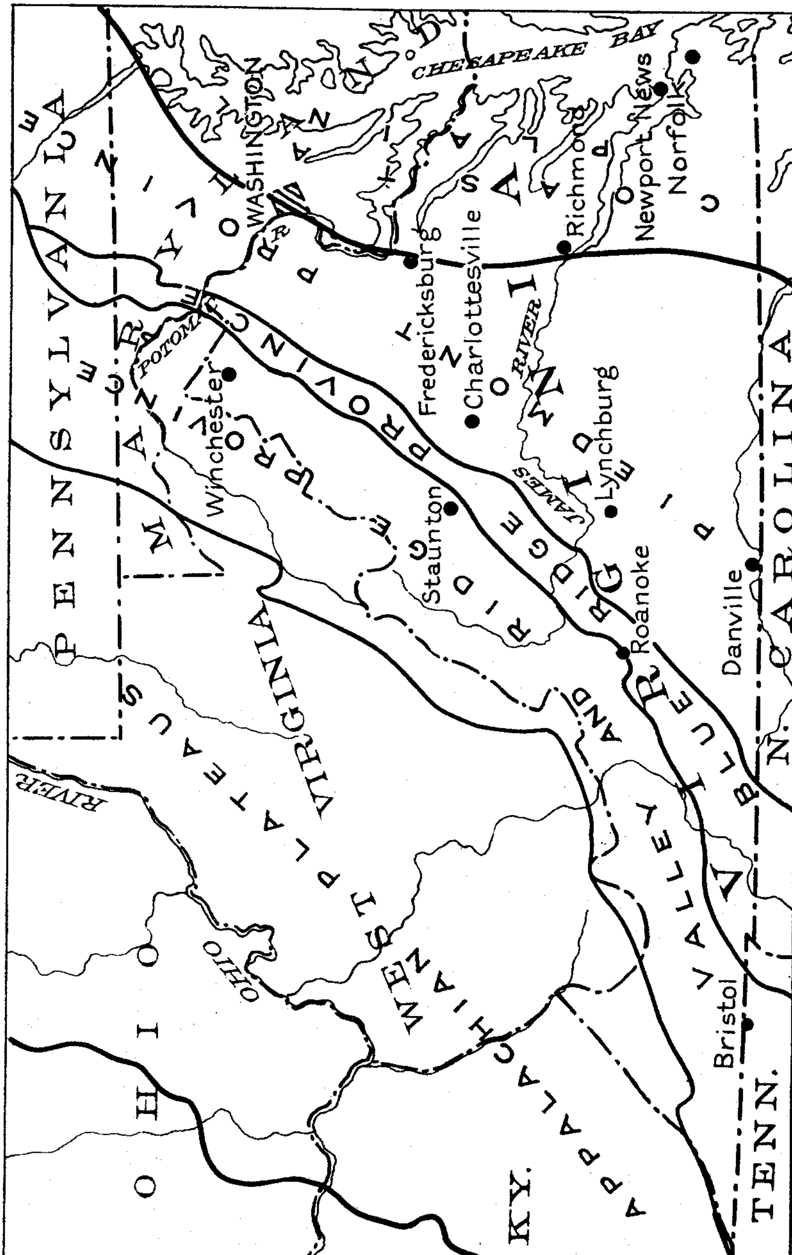


Figure 2.—Physiographic divisions of Virginia and parts of adjacent states. The Roanoke area is partly in the Blue Ridge province and partly in the Appalachian Valley and Ridge province.

an understanding of this development for the Appalachian region, and for Roanoke County and adjacent areas.

SELECTED REFERENCES

CAMPBELL, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, pp. 130-136, 1925.

DAVIS, W. M., The geological dates of origin of certain topographic forms on the Atlantic Slope of the United States: Geol. Soc. America Bull., vol. 2, pp. 545-586, 1891.

HAYES, C. W., The southern Appalachians: Nat. Geog. Soc. Mon., vol. 1, no. 10, pp. 305-336, 1895.

HAYES, C. W., and CAMPBELL, M. R., Geomorphology of the Southern Appalachians: Nat. Geog. Mag., vol. 6, pp. 63-126, 1894.

STOSE, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, pp. 5-11, 34-40, 1919.

STOSE, G. W., and MISER, H. D., Manganese deposits of western Virginia: Virginia Geol. Survey Bull. 23, pp. 16-24, 1922.

WATSON, T. L., and CLINE, J. H., Drainage changes in the Shenandoah Valley region of Virginia: Univ. of Virginia Pub., Philos. Soc. Bull., sci. ser., vol. 1, no. 17, pp. 349-363, 1913.

WILLIS, BAILEY, The northern Appalachians: Nat. Geog. Soc. Mon., vol. 1, no. 6, pp. 169-202, 1895.

WRIGHT, F. J., The physiography of the upper James River basin in Virginia: Virginia Geol. Survey Bull. 11, 1925.

PHYSIOGRAPHIC PROVINCES

DEFINITION AND CLASSIFICATION

A physiographic province is a large area, characterized by similar surface features, whose physical unity has been developed by a closely related physiographic history. The Roanoke area is in two distinct provinces: (1) The Blue Ridge, on the east, and (2) the Appalachian Valley, recently designated the Valley and Ridge province,[4] on the west. About one-third of Roanoke County is included in the Blue Ridge. (See Fig. 2.)

BLUE RIDGE PROVINCE

The Blue Ridge is a narrow belt of continuous mountains which has been developed upon resistant rocks of complex structure. It is the easternmost belt of mountains in the Appalachian Highlands. In parts of Virginia the term Blue Ridge is applied only to the narrow mountainous area underlain by crystalline rocks. This

[4]Fenneman, N. M., Physiographic divisions of the United States: Assoc. Am. Geographers Annals, vol. 18, pp. 261-353, 1928.

usage would be generally adopted except that, in some places, the term is applied also to the immediate western foothills of resistant sedimentary rocks. To restrict the Blue Ridge to the crystalline area would cause some confusion, especially as the name is used otherwise on topographic maps; hence it seems advisable to include in the Blue Ridge province both the mountainous belt of crystalline rocks and the contiguous western foothill belt of resistant sandstones (Lower Cambrian). Parts of the Blue Ridge in the Roanoke area are called Fullhardt Knob, Porters Mountain, Stewarts Knob, Twelve O'clock Knob, Bent Mountain, and Poor Mountain. Some of the larger foothills are Mill, Yellow, and Buck mountains. (See Pls. 5 and 7.)

The Blue Ridge province here contains maturely dissected mountains with more or less accordant summits. The drainage is dendritic, except in some of the narrow valleys between the main ridge and the foothills. The texture of the topography is rather coarse, with broad interstream areas. The Blue Ridge has been eroded chiefly by streams which have developed the relief mainly by lowering the belts of weaker rocks. Roanoke River, the only stream in Roanoke County that crosses the Blue Ridge, divides it into two parts: (1) A northern narrow ridge section underlain mainly by crystalline rocks, and (2) a broad southern plateau and foothill section containing crystalline rocks in the main part and sandstones in two belts of western foothills. (See Pls. 1 and 2.)

APPALACHIAN VALLEY AND RIDGE PROVINCE

GENERAL FEATURES

The Appalachian Valley province, which has recently been designated the Valley and Ridge province,[5] is northwest of the Blue Ridge and its foothills. It has been developed upon parallel belts of weak limestone and shale alternating with belts of resistant sandstone. The eastern part of this province is a conspicuous lowland, which is widely known as the Great Valley, and in this State as the Valley of Virginia. The western part consists of prominent, narrow, linear mountains and elongate, narrow intermontane valleys.

VALLEY OF VIRGINIA

The Valley of Virginia consists of a series of broad, elongate valleys or valley-like lowlands, on the weaker limestones and shales. (See Pls. 4 and 6.) The undulatory floor of the Valley

[5]Fenneman, N. M., op. cit.

in the Roanoke area has an elevation of about 1,000 feet and thus is 1,000 to 2,000 feet or more below the uneven crest of the Blue Ridge. Many hills and ridges rise from the surface of the Valley in some parts of the State, but they are almost lacking in the Roanoke area. Different parts of the Valley are in various stages of dissection, and the texture of the topography is rather coarse. Most of the streams are subsequent, having become adjusted to belts of folded weak rocks. Roanoke Valley is drained solely by Roanoke River and its tributaries.

VALLEY AND RIDGE SECTION

The Valley and Ridge section, as here used, designates that part of the Appalachian Valley (or Valley and Ridge) province northwest of the Valley of Virginia. It has been sometimes called the Allegheny Mountains.[6] It consists of (1) linear mountains developed upon a series of folded resistant sandstones and (2) parallel, intermontane valleys on weak shales and limestones. Most of the drainage thus has a trellis pattern. (See Pl. 1.) The mountains are maturely dissected. They are in a second or later cycle of development, the whole area having been etched out by differential erosion from an extensive peneplane. The long, narrow, even-crested ridges predominate over the valleys, above which they generally rise about 1,000 feet to elevations of 3,000 feet. (See Pl. 4.) Some scattered points are a few hundred feet higher. The crests of the highest ridges are as a rule at about the same elevation as the higher summits of the Blue Ridge, although scattered peaks in the Blue Ridge are higher than any points on the Valley Ridges in this area.

EROSION LEVELS

CLASSIFICATION

In much of the Appalachian region two erosion levels, or peneplanes, which have been extensively developed, make conspicuous reference surfaces. Remnants of old erosion surfaces above and below these levels can thus be readily identified. Five physiographic horizons, or remnants of distinct erosion surfaces, have been recognized and described by Stose[7] in the Appalachian Valley and Ridge province and the Blue Ridge: (1) Somewhat uniform elevations, or remnants of a peneplane, above an upper extensive

[6]A term is needed to designate this part of the Appalachian Valley, or Valley and Ridge, province. Use of the term Allegheny Mountains is somewhat confusing because of the various ways in which it has been used elsewhere.

[7]Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, pp. 34-40, 1919.

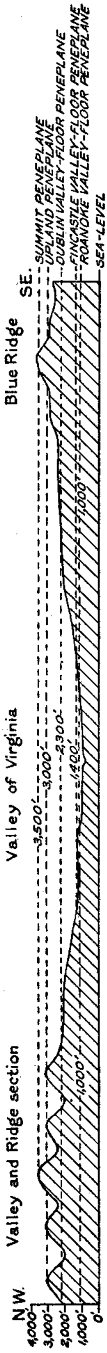


Figure 3.—Ideal profile section across Roanoke Valley and adjacent ridges showing the erosion levels. Remnants of the highest (Summit) peneplane are found on the crest of the Blue Ridge to the southeast, and on the highest ridges in the Valley and Ridge section to the northwest. The marked difference in elevation of the Valley-floor peneplane in three drainage systems is well shown.

peneplane, (2) an upper peneplane, (3) remnants of an erosion surface between two peneplanes, (4) a lower peneplane, and (5) valleys cut below the lower peneplane. Each of these horizons is recognizable in the Roanoke area. (See Fig. 3.) The upper four surfaces have been named by Stose as follows: (1) The Summit peneplane, (2) the Upland peneplane, (3) the Intermediate peneplane, and (4) the Valley-floor peneplane. The fifth, and lowest, horizon consists of trenches below the Valley-floor peneplane.

SUMMIT PENEPLANE

The highest mountains in this area are in the southwestern corner of Roanoke County, and the adjacent part of Montgomery County, where the rugged mass of Poor Mountain reaches a maximum elevation of 3,960 feet. (See Pl. 2.) It rises 1,000 feet above the rolling surface on the summit of Bent Mountain, which represents the Upland peneplane. The summit of Poor Mountain is therefore much older than the Upland peneplane. There is some evidence that this earlier surface was a peneplane, as Poor Mountain is even-crested and shows evidence of benches at an elevation of about 3,500 feet. It is here referred to the Summit peneplane. Its elevation in Roanoke County is about 3,500 feet.

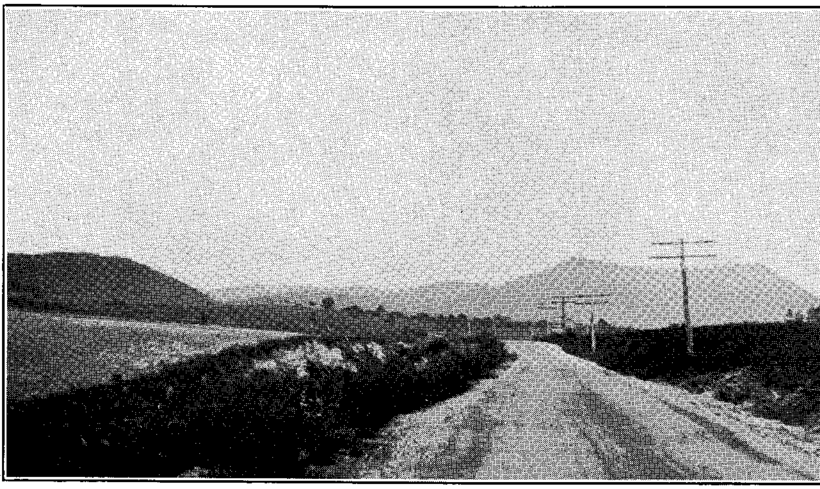
A few other peaks within the county rise almost to the level of the Summit peneplane. They are Mason Knob, 3,217 feet; McAfee Knob, 3,201 feet; and Fort Lewis Mountain, 3,328 feet.

The Summit peneplane is the highest peneplane which can be definitely recognized in the Roanoke area. (See Fig. 3.) This surface in Giles County has been called the Pearis peneplane[8] from its fine development on Pearis Mountain, at an elevation of 3,600 feet.

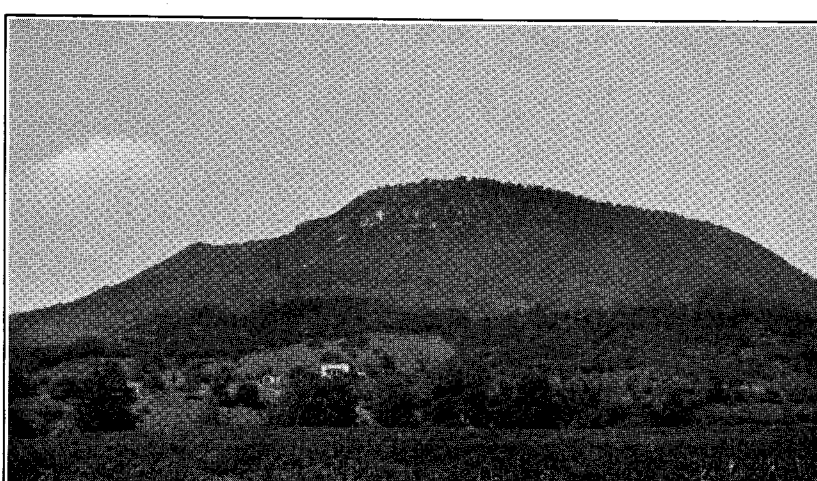
In studying the physiography of the Upper James River basin, Wright[9] found no evidence of a definite erosion surface in the Appalachian Valley and Ridge province older than the Upland peneplane. He did not specially consider the Blue Ridge, and it is probable that some remnants of

[8]Hubbard, G. D., and Croneis, C. G., Notes on the geology of Giles County, Virginia: Denison Univ. Bull., Jour. Sci. Lab., vol. 20, p. 312, 1924.

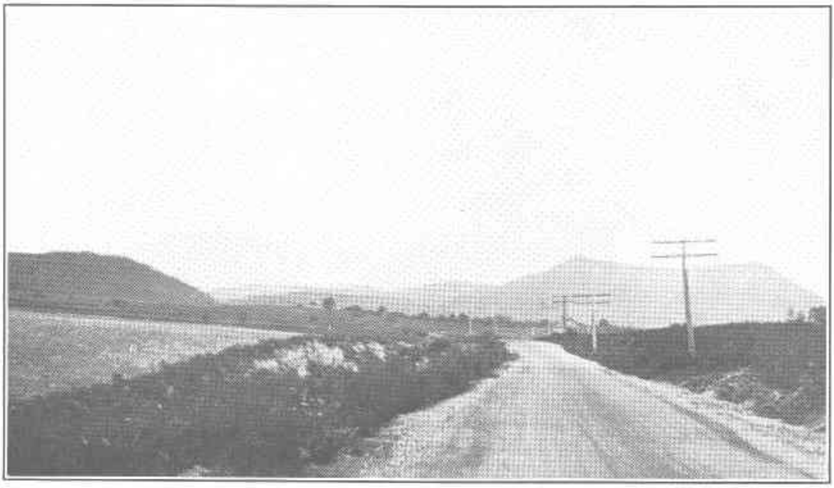
[9]Wright, Frank J., The physiography of the Upper James River basin in Virginia: Virginia Geol. Survey Bull. 11, pp. 5-9, 1925.



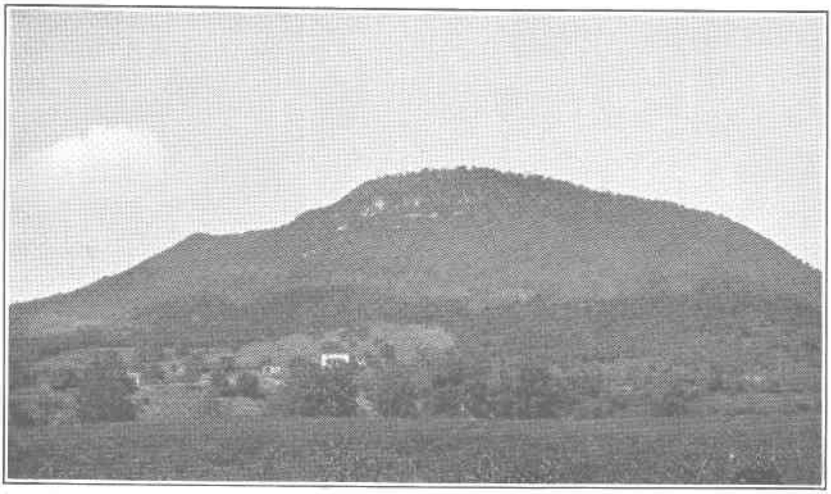
A. Valley Ridges at the northwestern edge of Roanoke Valley. Tinker Mountain at the right, Smith Ridge at the left, and Carvins Creek gap in the left center.



B. Tinker (Dead Man's) Mountain rising above the Roanoke Valley-floor peneplane. The bedrock is Silurian (Clinch) sandstone. (See pp. 17 and 57.)

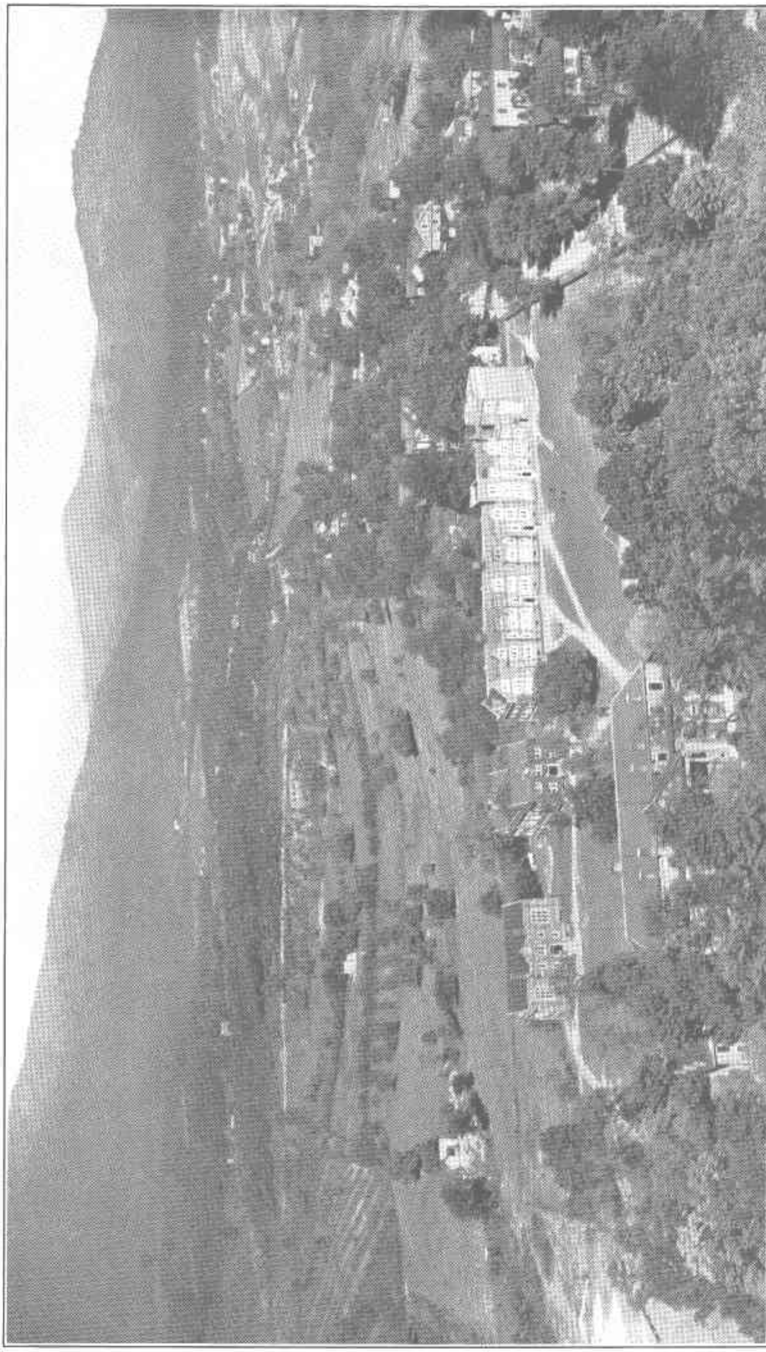


A. Valley Ridges at the northwestern edge of Roanoke Valley. Tinker Mountain at the right, Smith Ridge at the left, and Carvins Creek gap in the left center.

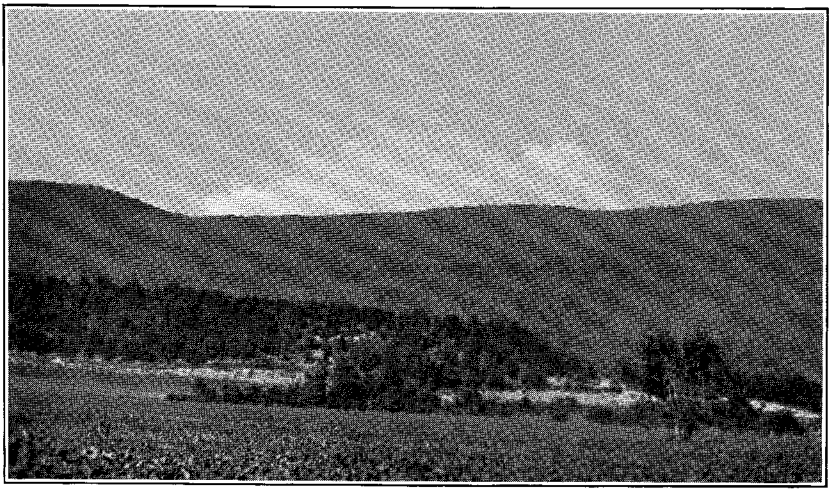


B. Tinker (Dead Man's) Mountain rising above the Roanoke Valley-floor peneplane. The bedrock is Silurian (Clinch) sandstone. (See pp. 17 and 57.)

Across the campus of Roanoke College toward Mason Cove. View in Salem, looking north. Fort Lewis Mountain at the left, McAfee Knob in the central background, and Green Ridge at the right. The Salem fault crosses the area from left to right near the middle of the view. (See pp. 8 and 76.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)

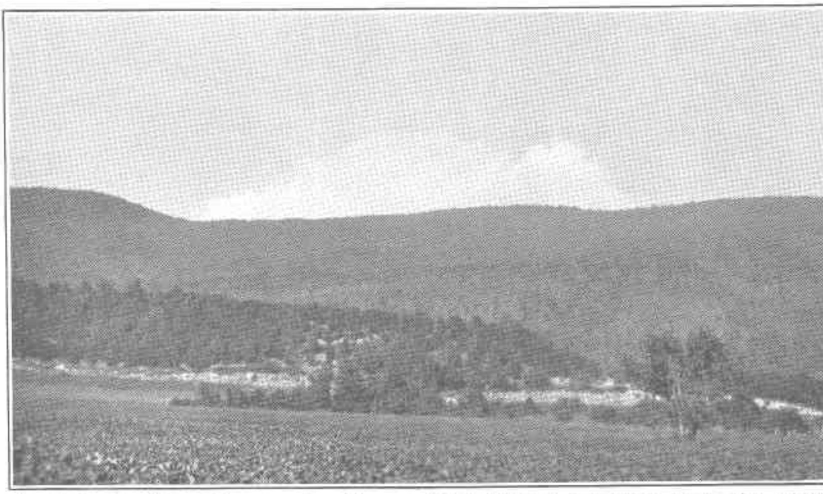


Across the campus of Roanoke College toward Mason Cove. View in Salem, looking north. Fort Lewis Mountain at the left, McAfee Knob in the central background, and Green Ridge at the right. The Salem fault crosses the area from left to right near the middle of the view. (See pp. 8 and 76.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



A. Catawba Mountain showing the modified Upland peneplane along its crest. View looking north. (See p. 17.)

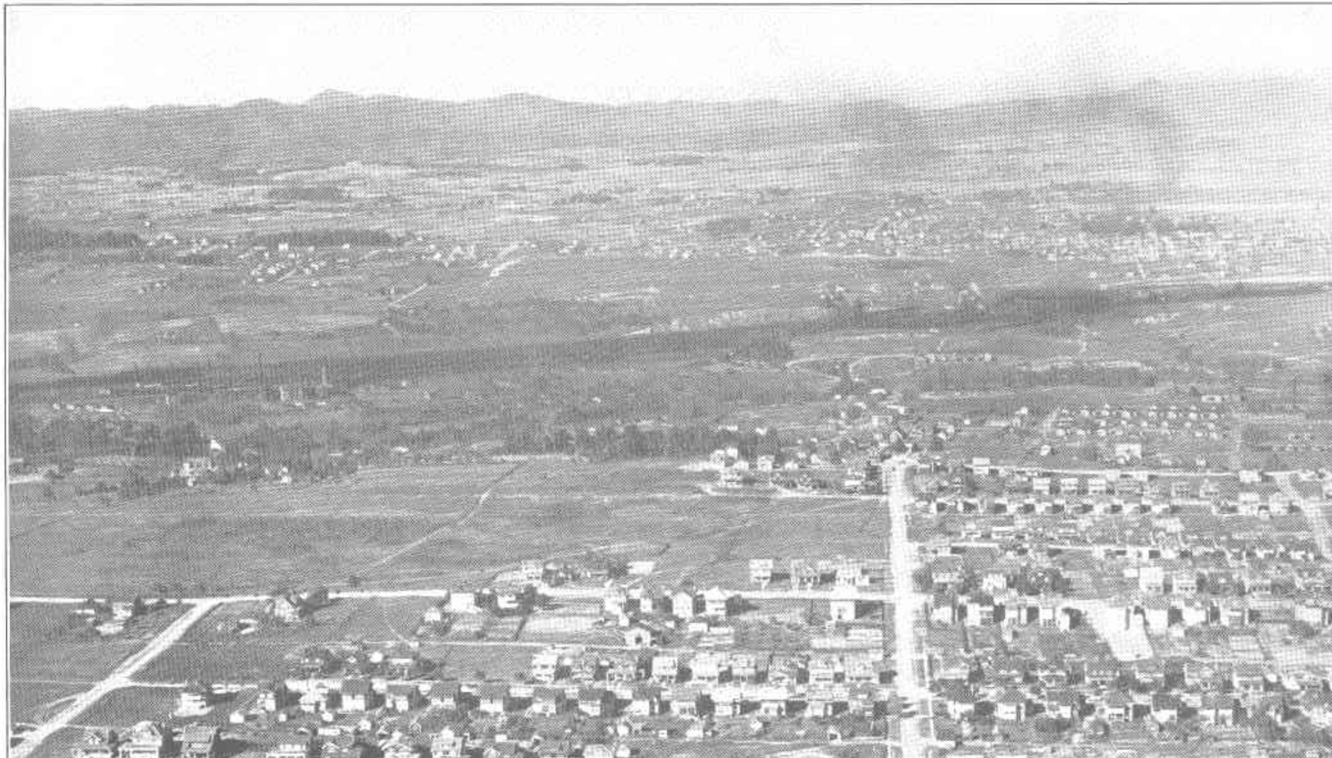
B. Roanoke Valley-floor peneplane with Valley Ridges to the northwest. (See p. 22.)



A. Catawba Mountain showing the modified Upland peneplane along its crest. View looking north. (See p. 17.)

B. Roanoke Valley-floor peneplane with Valley Ridges to the northwest. (See p. 22.)

Across Roanoke Valley-floor peneplane toward Fort Lewis Mountain. View looking north. The peneplane is here on folded Elbrook and Rome ("Watauga") formations. The southeast limb of the Catawba syncline is in the background. (See pp. 17 and 22.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



Across Roanoke Valley-floor peneplane toward Fort Lewis Mountain. View looking north. The peneplane is here on folded Elbrook and Rome ("Watauga") formations. The southeast limb of the Catawba syncline is in the background. (See pp. 17 and 22.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)

this older surface may be found there. Other remnants have been almost entirely destroyed.

The Summit peneplane has undergone more uplift and erosion than younger and lower surfaces; hence its remnants are scarce and small. They are found in protected areas at the headwaters of streams and in areas of exceptionally durable rock. There is little doubt that many of the ridges now standing near the 3,000-foot level were remnants of the Summit peneplane at the close of the next youngest (Upland) peneplane cycle, but they have since been reduced to lower elevations. The age of the highest peneplane here is indeterminate, but, as it antedates the Upland peneplane, possibly of Cretaceous age, it may have been formed in Jurassic time.

UPLAND PENEPLANE

The next highest physiographic level, which is clearly discernible, is preserved on the accordant summits and even crests of the mountains and as broad shoulders near the crests of the higher ridges at a persistent elevation of about 3,000 feet. (See Fig. 3.) This erosion surface is not conspicuous from the Valley, but from a commanding elevation its remnants are prominent. If one imagines the intervening valleys filled to the level of these remnants, the original flattish surface becomes very evident. This surface has been called the Upland peneplane by Stose.[10]

This peneplane is best preserved on the summit of Bent Mountain, a part of the Blue Ridge plateau, about 12 miles southwest of Roanoke. (See Pl. 2.) It is crossed by the Roanoke-Floyd courthouse road which ascends the steep face of Bent Mountain from Poges Mill to the peneplane at Air Point. From the valley of Back Creek near the mill, Bent Mountain looms up as a precipitous scarp, and one is surprised upon reaching the summit to find a plateau extending to the edge of the scarp. The general elevation of this upland is slightly less than 3,000 feet. The surface is strikingly even, except for broad, comparatively shallow valleys between low rounded hills. It slopes gently to the southwest, and is drained by the headwaters of Bottom Creek into South Fork of Roanoke River. This upland is bordered on the southeast and west by ridges which rise 500 to 1,000 feet above it, and which contain remnants of the Summit peneplane.

Isolated remnants of the Upland peneplane are found in many other parts of the Roanoke area. The crest of Fort Lewis Mountain, which extends for 11 miles at an elevation of about 3,000 feet, is a remnant of the Upland surface. (See Pl. 11.) Tinker Mountain (Pl. 8, B), Mason Knob, and McAfee Knob, which are

[10] Op. cit., p. 34.

relics of monadnocks that projected slightly above the Upland peneplane, have shoulders or benches at the 3,000-foot level. The more uneven summits of North, Cove, and Brush mountains have been slightly reduced from the Upland peneplane. The surface is well preserved on the crests of ridges north and west of Roanoke County. The Bent Mountain plateau continues southwestward into Floyd County, much of which is near the level of the Upland peneplane. It is preserved poorly, if at all, on the Blue Ridge northeast of Roanoke, for it is very difficult to trace accordant levels there. This surface has recently been studied by Wright.[11] The area discussed by him does not include any part of Roanoke County, but it extends close to the north boundary of the county.

The Upland peneplane corresponds to the so-called Cretaceous peneplane as that term is commonly used in the Appalachian region, and it is considered to be equivalent to the highest (Kittatinny) peneplane in Maryland, Pennsylvania, and New Jersey. This dating has been questioned, but the Roanoke area offers apparently no solution to the problem. A similar level in Giles County has been called the Spruce Run peneplane.[12]

By the end of the erosion cycle which produced the Upland peneplane, much of the land was worn down to a featureless lowland of very slight relief, close to sea-level. This surface must have been developed during a period of long-continued crustal stability. The surface was not entirely devoid of relief, for monadnocks, bearing remnants of the Summit peneplane, still persist. They are areas of relatively more resistant rock, or areas at the headwaters of streams where erosion was not complete. The peneplanation appears to have been more nearly perfect in the central Appalachian region than in Roanoke County.

Little can be determined about the original drainage upon this part of the Upland peneplane. It is probable that such master streams as Roanoke, James, and New rivers developed their meandering courses upon the gentle surface of the Upland peneplane, as their present courses are not determined by the structure of the rock across which they flow. In the area of the present Valley and Ridge section, the effect of the alternating belts of resistant and weak rocks was probably evident before the close of the Upland cycle, so that a trellis pattern of subsequent tributaries was formed.

The Upland cycle of erosion was ended by gradual vertical uplift of at least 1,000, and possibly 2,000, feet in the Roanoke area, for remnants of the Upland peneplane now stand that much higher

---

[11] Op. cit.

[12] Hubbard, G. D., and Croneis, C. G., Notes on the geology of Giles County, Virginia. Denison Univ. Bull., Jour. Sci. Lab., vol. 20, p. 313, 1924.

above remnants of the Intermediate surface and the Roanoke Valley floor, respectively. The uplift took place without folding of the rocks, but no doubt there was some differential tilting or warping. This uplift caused pronounced rejuvenation of certain streams, especially those now flowing eastward to the ocean. New River, which flows westward, was less affected and, possibly, was even retarded by the uplift, for it has lagged far behind Roanoke River in deepening its valley.

The Upland peneplane is now strongly dissected, and the belts of weaker rocks have been eroded to maximum depths of almost 2,500 feet. The unreduced remnants of the peneplane still preserve the gently rolling surface above which a few of the older monadnocks rise.

INTERMEDIATE HORIZONS

Below the well-developed Upland peneplane and above the Valley-floor peneplane, there are slight benches which represent an intermediate erosion surface. Because they stand above the Valley-floor peneplane, Wright[13] calls them monadnocks on the valley floor. Stose[14] has identified a somewhat constant level at an altitude of 2,250 feet, and has called it the Intermediate peneplane. Hubbard and Croneis[15] recognize in Giles County an intermediate peneplane at an altitude of about 2,500 feet which they have called the Buckeye peneplane.

As there is slight evidence in Roanoke County of a persistent widespread level between the Upland and Valley-floor peneplanes, intermediate benches are here called Intermediate horizons. They are considered merely as phases of the general down-cutting which ensued during late Cretaceous and early Tertiary time. In this area, two horizons between the Upland and Valley-floor peneplanes show suggestions of benches, one at 2,100 feet, the other at 1,700 feet. These benches are found in the eastern half of Roanoke County. They should not be confused with the 2,300-foot level of the floor of Dublin Valley in the western part of the Roanoke area, nor with the 1,400-foot level of Fincastle Valley in the northeastern part of the area. The intermediate benches are well shown on Porters Mountain, and on Stewarts and Weaver knobs. Similar levels are found on the main Blue Ridge south of Roanoke. Several wind gaps in the Blue Ridge have their floors at an elevation of about 1,700 feet. Stose[16] has reported levels upon the even tops of the foothills of the Blue Ridge, and has noted an accordance of some of the low divides in these mountains, which repre-

---

[13]Op. cit., p. 24.

[14]Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge: Virginia Geol. Survey Bull. 17, p. 39, 1919.

[15]Op. cit., p. 313.

[16]Op. cit.

sent the Intermediate peneplane. He states that this level does not appear west of the Blue Ridge and south of the Potomac drainage basin because that area "drained westward and was therefore far from the ocean." He correlates it with the Weverton peneplane at an elevation of 1,400 feet along the Potomac, and dates it as late Cretaceous.

The crests of some of the ridges in the Valley and Ridge section in the Roanoke area produce a somewhat even sky-line at an elevation of about 2,000 feet, which may represent an intermediate peneplane. On the other hand, these ridges are held up by rocks of almost uniform hardness. Where the beds dip gently and have broad outcrops, equal erosion on both sides of a ridge previously peneplaned at a higher level will tend to lower the crest evenly, and thereby form an even summit without peneplanation. Where the ridge-making rock is thin, the mountain crests are commonly irregular in outline. Thus, the summit areas at the 2,000-foot level appear to have been caused by symmetrical erosion rather than by peneplanation.

VALLEY-FLOOR PENEPLANES

One of the most striking physiographic features of the whole Appalachian region is the Great Valley, which crosses Virginia along the northwestern base of the Blue Ridge. In this State it is called the Valley of Virginia, or simply the Valley. The floor of the Valley is an undulatory surface sloping gradually to marginal ridges which rise abruptly from the lowland. No single river drains the Valley of Virginia, and it was not formed by the erosion of a single river. In Roanoke County it is drained to the east by Roanoke River and to the northeast by James River, but in Montgomery County it is drained to the southwest by New River. The Valley floor consists of several wide benches at different levels from 100 to 400 feet apart. Each of these benches represents an erosion surface which was determined by the level of the master stream which drained that part of the Valley. Stose[17] calls this series of levels the Valley-floor peneplane. (See Fig. 3.)

Authors use different terms for these lowland surfaces. Wright[18] calls the "rolling surface" the Valley peneplane. Watson and Cline[19] used the term Tertiary for the level crests of the ridges which rise from the Valley floor, and Shenandoah for the Valley surface. Spencer[20] used the term Shenandoah for the gently roll-

[17]Op. cit., p. 39.
[18]Op. cit., p. 27.
[19]Watson, T. L., and Cline, J. H., Drainage changes in the Shenandoah Valley region of Virginia: Univ. of Virginia Pub., Philos. Sci. Bull. sci. ser., vol. 1, pp. 357-358, 1913.
[20]Spencer, A. C., The geology of Massanutten Mountain in Virginia, Washington, p. 4, 1897.

ing, dissected, Valley floor around Massanutten Mountain. Hubbard and Croneis[21] used the term Pearisburg base-level for the Valley floor in Giles County. Campbell[22] called the Valley-floor peneplane the Blacksburg peneplane from its good development near Blacksburg, Montgomery County. North of Potomac River, similar levels are called the Harrisburg and Somerville peneplanes, and the general term Tertiary peneplane has long been in use for any well-developed erosion level below the so-called Cretaceous, or Upland, peneplane.

Three separate Valley-floor levels are determinable in and near Roanoke County: (1) Dublin Valley, drained by New River, with its floor at an elevation of 2,300 to 2,500 feet; (2) Fincastle Valley, now drained entirely by the James, with its floor at an elevation of 1,400 to 1,500 feet; and (3) Roanoke, or Salem, Valley, now drained by Roanoke River, with its floor about 1,000 feet above sea-level. This region is thus interesting from a physiographic standpoint because it contains Valley-floor levels at three different elevations, although all were apparently formed at approximately the same time.

The triangular area defined by Cloverdale, Buchanan, and Fincastle shows the Fincastle Valley floor mainly at the 1,400-foot level. This surface is one of the most striking of the lowland peneplanes. It extends northward to Eagle Rock and Balcony Falls, as described by Wright.[23] It has been relatively slightly dissected, and is remarkably even to slightly undulatory. This surface can be traced southwestward into Catawba Valley. Surfaces which are thought to be remnants of this peneplane are found in Roanoke Valley on Round Hill, Smith Ridge, and in the benches at an elevation of 1,400 feet on Mills (Reeds) Mountain.

The Dublin Valley floor was formed by New River and its tributaries. It is well developed east of Blacksburg and Christiansburg. Abundant traces of benches at 2,300-2,400 feet above sea-level are found in the western part of Catawba Valley, and in the valley between Paris and Fort Lewis mountains. These valleys are now part of the Roanoke drainage basin, and their floors are now far below the level of these higher benches. This relation has been explained by the capture by Roanoke River of drainage which was previously tributary to New River. Immediately west of Lafayette, the even summits of Pedlar Hills are at the level of the Dublin Valley floor, although this area is now greatly dissected and drains into the Roanoke. There are also levels in the

[21]Op. cit., p. 313.

[22]Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, p. 133, 1925.

[23]Op. cit., p. 32.

western part of Roanoke Valley, which stand at an elevation of 2,300 feet, but the evidence for correlating them with the Dublin Valley floor is far from clear.

The Roanoke Valley-floor peneplane, at an elevation of 1,000 feet, occupies the central part of the county. (See Pls. 4, 6, and 11.) As this peneplane is considerably lower than the other Valley-floor peneplanes, it appears that it may be somewhat younger than the others.

The Valley-floor peneplanes were not so extensively or completely developed as the Upland peneplane. The Valley-floor erosion cycle was sufficient only for the planation of areas underlain by weak rock, although this erosion progressed well toward the heads of the larger streams. Only the limestones and shales were beveled during the Valley-floor cycle as compared with the almost complete plantation of the region during the Upland cycle. In the Valley and Ridge section, the limestones and shales are much less perfectly beveled than in the Valley where the broad belt of Cambrian-Ordovician limestones and shales has furnished a great unit area of slightly resistant rock. Inasmuch as the peneplanation has progressed along the northeast strike of the weak rocks, surface irregularities in the Valley are not especially apparent until one crosses the Valley at right angles to the strike and thus to the "grain" of the topography.

The three main types of monadnocks which rise from the Valley floor are grouped as follows: (1) The most massive ones are mountain ridges, such as Catawba, Tinker (Pl. 8, B), and Fort Lewis mountains, which are monoclines or synclines of resistant Paleozoic rock; (2) monadnocks such as Reeds (Mills) and Coyners mountains (Pl. 23), which are likewise composed of hard sandstone, but have a more complex structure; and (3) small and more or less linear ridges rising 50 to 200 feet above the Valley floor, which are composed of the more resistant beds of the Valley limestones. Examples of the third type are ridges in the northwestern part of Roanoke and low hills east of Salem. Their crests, which approach the level of Fincastle Valley, are probably remnants of that valley floor. These ridges are chiefly on cherty or siliceous beds in the Valley limestones, or upon the harder beds in the adjoining shales. They are generally parallel to the strike of the Valley and are seldom more than a few hundred yards long. Their surfaces are commonly rock-strewn or contain rock ledges, in marked contrast to the thick soils which cover the lowlands.

The Valley-floor peneplanes have been considerably dissected; the present streams being incised several hundred feet. Roanoke

River and its tributaries are incised 100 feet or more below the Roanoke Valley floor; from 400 to 600 feet below the Fincastle Valley floor; and from 700 to 1,000 feet below the Dublin Valley floor.

Considerable quantities of fluvial gravel and sand cover the peneplane remnants. Alluvial fans have been built slightly above the peneplanes at the mouths of some of the narrow ravines. They are generally small with gentle slopes, and are composed chiefly of quartzite pebbles and quartz sand. They are especially noticeable around the flanks of Mills (Reeds) Mountain where they extend almost to Tinker Creek and cover all of the bedrock. Other alluvial fans are found southwest of Salem around the flanks of Twelve O'clock Knob.

The Valley-floor peneplanes were formed during and after uplifts, whose total amount is closely approximated by the difference in elevation between the Upland and Valley-floor peneplanes. This difference in Roanoke County is about 2,000 feet. If the area stood still long enough for the development of an extensive surface at the Intermediate horizon, the amount of the uplift that directly preceded the erosion of the Valley-floor peneplane was about 1,000 feet. The valley floors have been elevated, as is shown by the incision of the present streams and the fact that various parts are in all stages of dissection from early youth to maturity.

The date of formation of the Valley-floor peneplanes is somewhat in doubt, and the data to determine it in the Roanoke area do not seem adequate. In other regions, where the evidence is more complete, this peneplanation has been tentatively assigned to the Tertiary period, but this assignment is somewhat questionable. Stose[24] states that the Valley-floor peneplane "is believed to represent the floor under the earliest Tertiary coastal plain deposits and is therefore regarded as early Tertiary in age." He correlates it with the Harrisburg peneplane in Pennsylvania.

TRENCHES CUT BELOW THE VALLEY-FLOOR PENEPLANES

Recent uplifts of the area have increased stream gradients and closed the cycle of Valley-floor peneplanation. The rivers are again cutting toward a new base-level. Given sufficient time and crustal stability, a new peneplane will ultimately be formed, at least several hundred feet below the Valley-floor peneplane. The elevation of Roanoke River in the water gap through the Blue Ridge is about 880 feet. This elevation determines the present

[24]Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, p. 39, 1919.

local base-level for that river system west of the Blue Ridge. The Roanoke is encroaching upon the drainage basin of New River along the watershed near Christiansburg, and in the near geologic future will probably capture some of the headwaters of that stream. This will increase the volume of Roanoke River, and make a lower local base-level for the upper part of New River, so that the drainage system of Roanoke and Montgomery counties will be considerably rearranged. The Roanoke will more rapidly cut its gap through the Blue Ridge, and the 900-foot surface, which is now being formed, will become a prominent terrace trenched by the rejuvenated streams.

The present streams are flowing in comparatively narrow valleys with flood plains of various widths. They have cut down farther below the Valley-floor peneplane in the western than in the eastern part of the county, so that Roanoke River is 700 feet below the Valley-floor peneplane at Lafayette and only 50 feet below it near Roanoke. The tributary streams are similarly entrenched, and they are, in general, from 50 to 100 feet below the Roanoke Valley-floor peneplane. Many of the smaller streams are being temporarily retarded by resistant rock ledges in their channels. The vertical quartzite (Silurian) of Smith Ridge, forming Carvins Falls (Pl. 3), acts as a control upon the headwaters of Carvins Creek, and, by its resistance to stream wear, is retarding the lowering of the cove floor.

The larger streams have many terraces along their courses. Some are flood-plain terraces cut in alluvial material, whereas others are benches below which streams have cut because of slight regional uplift. They are well developed along the intermontane valleys of the Appalachian Ridges where they are cut in weak shales (Ordovician and Devonian). Most of the terraces are covered with gravel, and can not be correlated with each other or with terraces in adjacent areas. Except on the terraces, the Valley-floor peneplanes are deeply covered with residual soils which have been stripped away only in places where there has been later active erosion.

The Valley lowlands have been eroded upon limestones, and their residual soils are fertile and widespread. The peneplanation of the Valley has produced broad tracts of level or gently rolling land well suited for cultivation, and it has had a large part in determining the human history, as well as the present attractive scenery and the economic resources, of the Roanoke area. The soils and clays are locally of value to the clay industry, and, in many places, deposits of iron and manganese have accumulated during or after peneplanation.

STRATIGRAPHY

GENERAL FEATURES

The bedrock formations of the Roanoke area are shown on the geologic map, Plate 1. (In pocket.) The rocks which occur at the surface or just below the mantle rock, have been classified (Pl. 12), and their distribution has been plotted upon the Roanoke[24a] and Christiansburg topographic sheets of the United States Geological Survey, to form an areal geologic map of the formations. A discussion of the characteristics of the formations, which is essentially an explanatory text to accompany the geologic map, is given below.

The central and northwestern parts of the Roanoke area are occupied chiefly by sandstone, limestone, and shale of Paleozoic age, whereas the southeastern part is occupied by crystalline rocks of pre-Cambrian age. The dividing line is the western edge of the Blue Ridge, which is in most places the trace of a great fault, along which the resistant pre-Cambrian rocks have been overthrust from the south and east upon the less resistant Paleozoic rocks. Most of the formations crop out in belts which strike or trend northeast. This alignment is typical of the Appalachian region. Its relation to the structure of the rocks is discussed on later pages.

The bedrock formations of the Roanoke area are shown in Table 1, where the map units used in this area are indicated. The smaller units are discussed in the text as parts of the larger mapped units. The general conditions of deposition of the sediments are shown graphically on Plate 12.

In the detailed descriptions given below, the rocks are grouped as follows: (1) Pre-Cambrian crystalline rocks; (2) Paleozoic consolidated sedimentary rocks; and (3) Quaternary unconsolidated surficial deposits. The geologic column of the Roanoke area is given in Plate 12.

[24a] The Roanoke 30-minute sheet was used. A part of it has since been resurveyed as the Roanoke 15-minute sheet.

TABLE 1.—*Bedrock formations in the Roanoke area*

- Paleozoic rocks
  - Mississippian system
    - Osage series
      - *Price formation
        - Ingles conglomerate
  - Devonian system
    - *Chemung formation
    - *Brallier shale
    - *Romney shale
    - Onondaga formation
    - *Helderberg group
  - *Silurian system
    - Clinton formation
    - Clinch sandstone
  - Ordovician system (restricted)
    - *Martinsburg shale
      - Maysville division
      - Eden division
      - Trenton division
    - *Moccasin formation
    - Chazyan series
      - Blount group
        - *Athens shale
        - Whitesburg limestone
        - Holston limestone
      - *Stones River group
        - Lenoir limestone
        - Mosheim limestone
  - Canadian system (Ulrich)
    - *Nittany dolomite[a]
  - Ozarkian system (Ulrich)
    - *Conococheague formation[a]
  - Cambrian system (restricted)
    - Calcareous division
      - *Elbrook formation
      - *Rome ("Watauga") formation
      - *Shady dolomite
    - Arenaceous division
      - *Chilhowie group
        - Erwin quartzite
        - Hampton shale
        - Unicoi formation
- *Pre-Cambrian rocks

[a]These formations are together referred to in the text as Cambrian-Ordovician formations. Most geologists place the Ozarkian (Ulrich) in the Upper Cambrian. The Canadian (Ulrich) corresponds to the Beekmantown, or the lower part of the Lower Ordovician of most authors.

*Units shown on the areal geology map, Plate 1.

PRE-CAMBRIAN ROCKS

Character.—The oldest rocks of the Roanoke area are granite-like crystalline rocks which formed the basement upon which all younger rocks were laid down. These rocks have been so greatly altered by metamorphic processes that their original characteristics are entirely destroyed. They served as the shore and floor of the seas in which the Paleozoic sediments were deposited, and thus underlie them throughout the area. They appear at the surface in this area only in southern and eastern Roanoke County and adjacent parts of Botetourt, Bedford, Montgomery, and Floyd counties, where they have been uplifted during mountain-making movements and erosion has laid them bare. Associated with these granite-like rocks are schists and slates of various types, which have also been altered and recrystallized. (See Pl. 13, A.) Several types of intrusive igneous rocks are found in isolated patches in the area of the older crystalline rocks. (See Pl. 13, B.)

The older rocks are wholly crystalline, and all show the typical banding and schistosity of highly metamorphosed rocks. The younger sedimentary rocks, being comparatively free from the effects of dynamic metamorphism, show little or no schistosity or recrystallization. The crystalline rocks show also, by their structure and occurrence under the sedimentary rocks, that they were folded, elevated, and eroded before the sediments were deposited upon them. Thus considerable time must have elapsed between their formation and deposition of the Cambrian sediments. As the oldest sedimentary rocks are Lower Cambrian, the crystalline rocks are undoubtedly pre-Cambrian in age.

The pre-Cambrian crystalline rocks have a great variety of characteristics, and show several rock types. No attempt has been made by the writer to map these rock types, and their relations have not been determined in detail.

Economic products.—Several economic products occur in the pre-Cambrian rocks of the Roanoke area. Nelsonite, containing ilmenite and apatite, which is mined a few miles east of Vinton, is the most important. Barite has been mined near Thaxton, Bedford County. Quartz veins near Brush Creek, Montgomery County, have yielded small amounts of placer gold. Silver, nickel, cobalt, arsenic, copper, graphite, and talc have been observed and prospected, but none of them are of commercial value. Residual clays of adjacent areas have been worked for high-grade kaolin, but none of them have been worked in this area.

The mineral resources of the area are discussed later in detail under the heading "Mineral Resources."

SEDIMENTARY ROCKS

GENERAL FEATURES

The sedimentary beds exposed in this region range in age from Lower Cambrian to Lower Mississippian, consisting of 16 units which have been mapped. (See Pl. 1.) The succession is not complete, some geologic units present in other parts of the Appalachian Valley being absent in this region. It is probable that late Mississippian, and possibly Pennsylvanian and Permian, sediments were deposited here, but have been eroded. The formations give a fairly representative Paleozoic section for the central Appalachian region. Their total thickness is more than 17,000 feet.

The rocks are in general predominantly clastic near the base of the section, calcareous toward the middle, and clastic toward the top of the section. The sediments were deposited in the Appalachian geosyncline, a great troughlike depression occupied many times by the sea, extending approximately along the site of the present Blue Ridge and the Appalachian Valley. The source of the sediments was probably an upland area (old Appalachia) that existed east of this geosyncline. Although the Paleozoic rocks of the Roanoke area have undergone considerable folding and faulting, they have been, with the exception of the oldest Cambrian rocks, only slightly altered. Many of the beds are fossiliferous, and most of the formations contain recognizable fossil faunas.

CAMBRIAN SYSTEM

ARENACEOUS DIVISION

The oldest Paleozoic rocks of the Roanoke area are found immediately west and north of the Blue Ridge, in a line of foothills but slightly lower than the main Blue Ridge.

CHILHOWIE GROUP

Subdivisions.—The Chilhowie group, named from Chilhowie Mountain, Tennessee, by Safford[24b], is in places divisible into three formations: (1) The Unicoi formation, a conglomerate or quartzite of considerable thickness, at the base (Pl. 14); (2) the Hampton shale, a shaly or flaggy formation; and (3) the Erwin quartzite, or quartzose sandstone at the top. In the Roanoke area, it did not appear feasible to differentiate the formations in this group, so it is discussed here as a unit.

Where undisturbed, these rocks rest upon the pre-Cambrian crystalline rocks, but in places the crystalline rocks have been overthrust westward upon the quartzites. The top of the Chilhowie group is marked by a decided change in the type of sediments, which makes it a convenient reference horizon.

Distribution.—The Chilhowie group can be seen at many places in a belt extending from Buchanan southwest to Fullhardt Knob, near Cloverdale. The eastern edge of this belt is marked by a great thrust fault which brings the Chilhowie group in contact with the Elbrook and higher limestones. Yellow, Buck, and Mill mountains south of Roanoke are composed of the Chilhowie group. This belt is cut off on the east and south by the great Blue Ridge overthrust, which swings in a broad **U** around the resistant quartzites. A third belt of the Chilhowie formations is found in the rugged mass of Poor Mountain. It continues from Twelve O'clock Knob southwest into Montgomery County and extends into Pilot Mountain south of Christiansburg. (See Pl. 1.)

[24b] Safford, J. M., A geological reconnaissance of the State of Tennessee: First Rept., pp. 152-153, 1856.

System	Formation	Columnar Section	Thickness Feet	Character of Rocks	Conditions of Deposition	Marine Submergence (Shaded)	Fossils Preserved	Topography and Soil	Mineral Resources
Mississippian	Price formation Ingles conglomerate		Only lower 300 feet present	Bluish-white sandstone, conglomerate, and thin red shales; thin coal seams in middle; heavy conglomerate at base.	Subaerial delta or alluvial fan deposits, derived from southeast, interfingering with thin marine beds in the west.	Mississippian delta-building.	Land plants and brachiopods.	Sharp rocky ridges with thin sterile soil.	Coal, millstones, and clay.
Devonian	Chemung formation		1000–2500±	Interbedded sandstone and shale, weathering red-brown.	Shallow-water alluvial sands and muds interbedded with marine deposits.	Devonian delta-building and progressive emergence.	Marine and fresh-water shells (brachiopods and pelecypods) and land plants.	High wooded ridges; good pasturage where cleared.	Flagstone.
	Brallier shale		2000–3000	Greenish-gray and olive-colored shale and sandstone.	Thin beds of alluvial muds and sands interfingering with thin marine beds.			Thin sandy soils along slopes and near base of ridges.	Flagstone and road metal.
	Romney shale		600±	Black fissile carbonaceous shale.	Black muds and thin beds of sand in marine waters.		Marine cephalopods, brachiopods, and pelecypods.	Valleys containing poor soils.	Clay and road metal.
	Helderberg group		50-60	Thin chert and shale.	Wave-spread sands upon thin marine limestones and muds.		Marine brachiopods and bryozoa.	Thin loose soils.	Iron and manganese.
Silurian	Clinton formation		400±	Buff and red shale and friable red and white sandstone.	Shallow-water marine muds and sands.	The Silurian emergence.		Sandy ridges.	Glass sand and iron.
	Clinch sandstone		10-100±	Coarse cross-bedded massive gray sandstone.	The western part of a great subaerial delta.		Sand-boring worms.	Steep rocky ridges with poor siliceous soil.	Construction stone.
Ordovician	Martinsburg shale {Maysville, Eden, Trenton}		1000–1400±	Gray and greenish-brown sandstone. Gray-brown shale and thin limestones. Gray sandy shale and gray to dark limy shale and limestone.	Shallow-water marine sands and muds grading into limestones and muds deposited in deeper waters.	The great Cambrian-Ordovician submergence.	Abundant marine bryozoa, brachiopods, and pelecypods.	Smooth slopes on mountains; good pasture land.	
	Moccasin formation		150-300	Reddish sandstone and shale.				Knobby shoulders on ridges.	Some road metal.
	Athens shale		0–950	Black hackly shale, weathering chocolate-colored; thin black limestones interbedded in lower part.	Black marine muds, possibly of deltaic origin.		Marine graptolites and trilobites.	Open valleys with poor brownish soil.	Clay and road metal.
	Holston-Mosheim-Lenoir limestones		325±	Crystalline limestone at top; dark knotty and pure limestone below.	Impure marine limestones and calcareous muds.		Marine shells.	Red clay soil in valleys.	Lime and cement rock.
Ordovician — Canadian	Nittany dolomite		800±	Dense massive gray dolomite; chert-producing on exposure.	Deposits of limestone and muds in open marine waters, without much coarse material.		Marine gastropods.	Valleys having deep, fertile brownish-red soil, in places cherty; many sinks.	Clay.
Cambrian — Ozarkian	Conococheague limestone		1200–1600	Cherty magnesian limestone and dolomite.			Marine algae and gastropods.	Deep, red, rich soil, in places sandy.	Clay, lime and cement rock.
Cambrian	Elbrook formation		1200±	Blue-gray thinly bedded limestone and shale; massive toward top.	Alternation of thin beds of mud and thin marine limestones.			Valleys having rich red-brown soil.	Barite, clay, lime and cement rock; road and building stone.
	Rome ("Watauga") formation		900±	Red, purple, and variegated shales with interbedded blue dolomites.	Shallow-water muds and thin marine limestones, with very little coarse material.		Marine trilobites.	Rolling country with productive brown soil.	Lead, zinc, clay, lime and cement rock, and road metal.
	Shady dolomite		1200–1500	Coarse-grained massive dark dolomite; thin beds above, clayey below.	Marine limestones and muds deposited in the deepening Appalachian geosyncline.			Valleys and slopes near foothills, commonly covered with quartzite float and chert. Very deep, red clay soil.	Brown iron, manganese, and clay.
	Chilhowie group: Erwin quartzite		1000±	Fine-grained sandstone and quartzite.	Sands and muds formed on the crystalline oldland to the east and south during the progressive encroachment of the early Cambrian seas, and deposited in the Appalachian geosyncline.	Early Cambrian delta-building and progressive submergence.	Sand-boring worms, probably marine.	Steep cliffs and rocky slopes, thin poor soil.	Construction stone.
	Chilhowie group: Hampton shale		400±	Gray shale, slate, and interbedded sandstone.				Valleys between foothills; thin poor yellowish soil.	
	Chilhowie group: Unicoi formation		1750–2000±	Irregularly bedded sandstone and siliceous shale, arkosic below; some beds of hematite.				Row of foothills next to the Blue Ridge; shallow poor soil.	Iron and construction stone.
Pre-Cambrian				Massive igneous and schistose metamorphic rocks.	Complex and varied sequence of vulcanism, deformation, erosion, and sedimentation.			Ridges and valleys; deep, red sticky soil.	Titanium minerals, apatite, and construction stone.

Character.—The Chilhowie group is a thick series of clastic sediments, in part poorly assorted and obscurely bedded. It contains sandstone, coarse and fine conglomerate, shale, some slate, and possibly pyroclastic material. The basal beds are arkosic and contain pebbles of the underlying rocks. The shale is rarely exposed, but the quartzite makes abundant massive ledges. Some of the beds of sandstone are highly ferruginous and have been mined in places as "mountain," "specular," or "Blue Ridge" hematite.

These rocks have been metamorphosed locally, with the development of pronounced cleavage in the quartzite and slight schistosity in the shale. They are commonly recrystallized with the introduction of secondary quartz and mica. In many places the bedding is obscured, and internal squeezing and mashing are very evident. Small faults are prevalent, and are observable especially along the Roanoke-Rocky Mount highway. Typical exposures of the Chilhowie beds are shown on Plate 14.

The soils of the Chilhowie group are shallow, loose, sandy, and poor. Many of the slopes are barren or strewn with rock fragments.

Thickness.—The Chilhowie group has been so deformed that determination of its thickness is very difficult. In the Roanoke area it is probably at least 2,500 to 3,000 feet thick and may be 3,500 feet thick. The group thickens to the northeast and to the southwest.

Topographic expression.—The Chilhowie group is a ridge-maker of the first order of magnitude, producing rugged mountains which are generally high and sharp-crested. (See Pl. 7.) The formations are reflected in the topography of the western foothills of the Blue Ridge, where two series of flanking hills on the resistant quartzites are separated by valleys underlain by the medial weaker shale. Where the shale is too thin, or dips too steeply to affect the topography, the dual nature of the foothill belt is less apparent and the area of rugged country is wider. The surface of these hills is barren and rock-strewn, and the accumulations of wash and float from the numerous outcrops choke many of the streams. The sharp, rugged hill crests are capped by massive ledges of resistant quartzite, which produces one of the most conspicuous groups of mountains along the eastern side of the Valley of Virginia.

Fossils and age.—Fossils are rare in the Chilhowie beds. Obscure markings, castings, and tubes of worms, referred to *Scolithus,* are found in the upper beds. This fossil is not sufficiently well understood to be considered a reliable horizon marker. Lower Cambrian fossils have been reported from the upper part of the group at Balcony Falls, and tracks and trails of trilobites from the upper beds near Marion, Virginia. As the Chilhowie group is overlain by the Shady dolomite of known early Cambrian age, it belongs without doubt to the Lower Cambrian series.

CALCAREOUS DIVISION

SHADY DOLOMITE

Definition.—The Shady dolomite was named by Keith[25] from Shady, Johnson County, Tennessee. The same formation was later called the Sherwood limestone by Campbell,[26] but the earlier name has priority and is established in the geologic literature.

Distribution.—The Shady dolomite crops out on the northwestern side of the belt of Lower Cambrian rocks, which extends southeast of Buchanan and Troutville, and ends near Fullhardt Knob. (See Pl. 1.) This belt does not enter Roanoke County. The Shady dolomite does not crop out on the south side of Glade Creek Valley from Blue Ridge Springs to Vinton, where pre-Cambrian rocks have been overthust upon the Cambrian rocks, covering the Shady dolomite. (See Pl. 2.) A narrow belt of Shady dolomite occurs south of Roanoke, just north of Mill and Buck mountains. The open cove of Narrows Creek, between Yellow and Buck mountains, is a synclinal valley of Shady dolomite surrounded by Cambrian quartzites. Because the dolomite occurs along the quartzite foothills, and is somewhat protected by them, its topography is rugged and more irregular than that of the other limestones of the area.

Character.—The formation consists of massive, coarse-grained, impure dolomites. The fresh rock is blue to dark-gray, and the surface is locally mottled. The weathered rock is darker, being dark-gray to black. The formation is not homogeneous, but contains many interbedded laminated shales and clays. Some of the limy layers have a glistening or sub-resinous luster, which is elsewhere characteristic of the Shady dolomite. The lower beds are generally soft, and consist of rather finely laminated clays and ochers. The base of the formation is arkosic.

Some chert is found as residual masses in the red clay which covers the outcrops. It is ferruginous, drusy, and varies from a dense black flint to a white, chalky, chalcedonic chert. Some nodules are iron-stained and show concentric banding. The weathered chert disintegrates into small fragments.

[25]Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Cranberry folio (No. 90), p. 5, 1903.
[26]Campbell, H. D., The Cambro-Ordovician limestones of the middle portion of the Valley of Virginia: Am. Jour. Sci., 4th ser., vol. 20, pp. 445-447, 1905.

The Shady dolomite weathers more readily than any other rock in the region; hence outcrops are very rare. A thick mantle of deep-red, ocherous, clayey soil, in places filled with wash from the adjacent quartzite hills, masks this dolomite. The soil is very fertile but is locally impoverished by fragments of chert and quartzite.

Relations.—The upper and lower contacts of the formation are difficult to find because the rock weathers so readily. It disconformably overlies the Erwin quartzite and is conformable with the overlying Rome ("Watauga") shale.

Thickness.—The thickness of the Shady dolomite can not be readily determined in this area. At Natural Bridge, its reported thickness is about 1,800 feet; near Lexington, about 1,700 feet; in Smyth and Wythe counties, about 1,600-2,000 feet; and in Tennessee, about 800 feet. It is estimated to reach a thickness of about 1,500 feet in the Roanoke area, thinning somewhat toward the western part of the area.

Fossils and correlation.—No fossils were found in the Shady dolomite of this area, but the following genera have been listed from it elsewhere:[27] *Salterella, Kutorgina, Olenellus, Cryptozoön,* and *Archaeocyathus.* These fossils indicate that the Shady dolomite is Lower Cambrian. It is equivalent to the Tomstown limestone in Pennsylvania and Maryland. It was included in some early reports in the thick body of undivided "Shenandoah" limestone.

Economic character.—The Shady dolomite contains sandy beds cemented by residual deposits of iron and manganese, which have been mined as low-grade ore at places in the vicinity of Roanoke. It contains beds suitable for lime and road-metal, which have been quarried elsewhere for these products.

ROME ("WATAUGA") FORMATION

Definition.—Directly overlying the Shady dolomite is a series of shales with interbedded thin mottled limestones. The names Watauga[28] and Rome[29] have been applied to this formation, but as Rome has priority, it should be retained in order to avoid confusion. In this paper, the formation will be called the Rome ("Watauga") formation in accordance with a recent discussion of the nomenclature.[30]

---

[27]Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, p. 25, 1919.
[28]Keith, Arthur, op. cit., p. 3.
[29]Hayes, C. W., The overthrust faults of the Southern Appalachians: Geol. Soc. America Bull., vol. 2, p. 143, 1891.
[30]Woodward, Herbert P., The age and nomenclature of the Rome ("Watauga") formation of the Appalachian Valley: Jour. Geology, vol. 37, pp. 592-602, 1929.

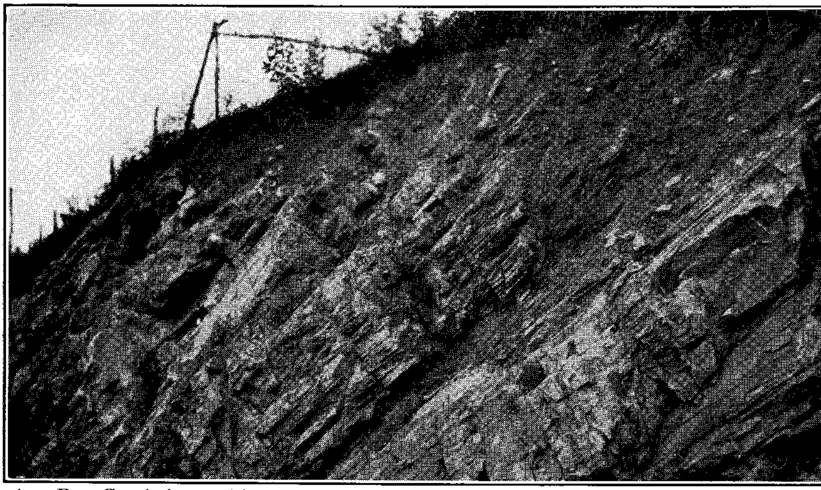
Distribution.—The main belt of the Rome ("Watauga") formation extends from a point about 1 mile north of Blue Ridge Springs, southwest along the northwest flank of the Blue Ridge (Porters Mountain). From Vinton it continues southwest across the open valley of Roanoke River and skirts the hills of crystalline rocks and quartzite from Twelve O'clock Knob to Poor Mountain. It follows the north slope of Pilot Mountain into Montgomery County. The belt has a maximum width of at least 5 miles just west of Roanoke. This uncommon width results from excessive close folding within a thick formation. (See Pl. 1.)

Exposures of the limestones and shales in the formation are numerous in the Roanoke area. The shales are well exposed along (1) the Lynchburg highway northeast of Roanoke, between Tinker Creek and Blue Ridge Springs, (2) in the northeast and northwest parts of Roanoke, and (3) along roads and streams in the western part of the area. Limestone ledges occur along the Lynchburg highway between Roanoke and Tinker Creek, and from Vinton to this road. Most of the quarries of the Adams, Payne, and Gleaves Company near Roanoke are in limestones in this formation. (See Pl. 26.) As the Rome ("Watauga") formation between Roanoke and Salem is generally covered with alluvium, exposures are scarce and unsatisfactory.

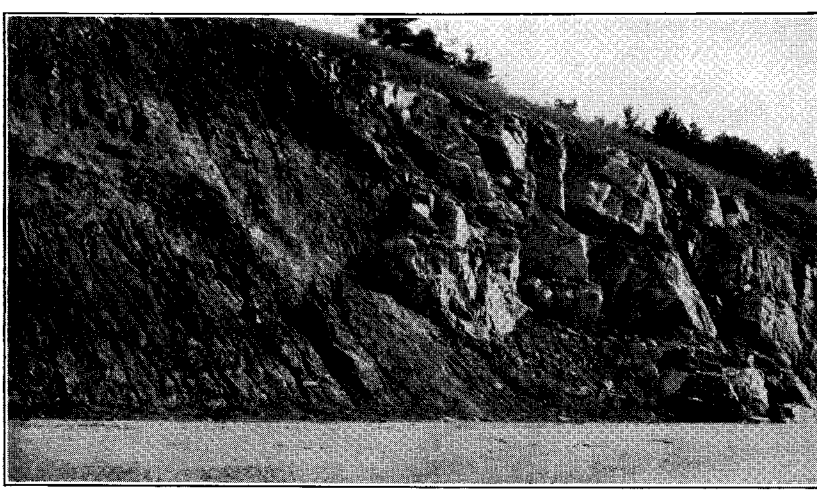
Character.—The shales of this formation are very fine-grained, close-jointed, and break with a splintery or hackly fracture. They are commonly red to rusty-brown but some are purple and others are greenish sericitic shales, weathering yellowish-gray. Red shale is the distinctive feature of the Rome. In places, the shales are cross-bedded and some show sun-cracks, rill- and ripple-marks, and other evidences of shallow-water deposition. These features are found in the exposures along Shenandoah Avenue, Roanoke, east and north of the Norfolk and Western Railway station.

The interbedded limestones and dolomites are seldom more than 20 feet thick, but they are widespread. They are bluish-gray to dark-blue and, in places, show water-worn surfaces. Rather pure limestones occur in some places. The limestones are separated by more or less continuous shales without gradational beds. They crop out generally along the axes of the smaller folds in the formation. The formation contains some calcareous sandstone which weathers to a rusty color.

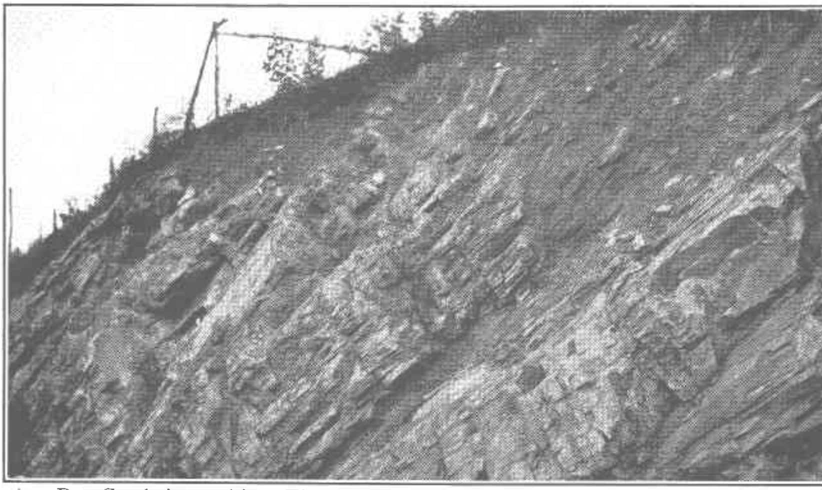
Structure.—The structure of the Rome ("Watauga") formation is exceedingly complex, and the beds are so confused that it is impossible to interpret them in detail. The shales and limestones have been intimately folded into a confused and obscure mass



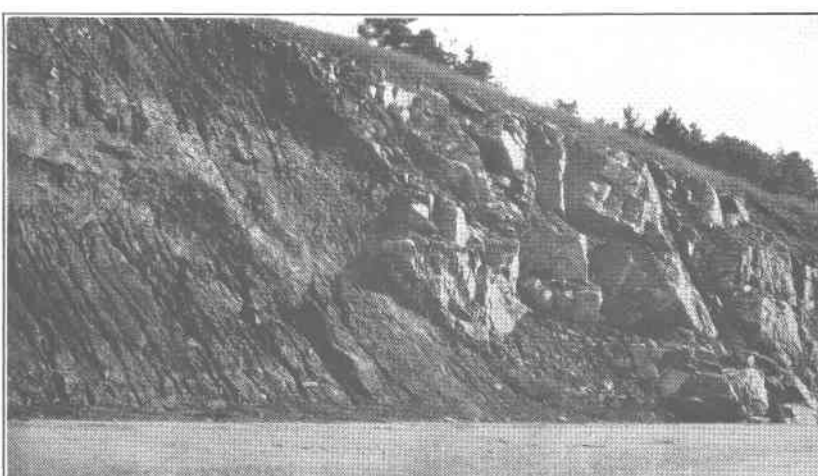
A. Pre-Cambrian schist. The rock is a quartz-sericite schist whose foliation dips to the southeast.



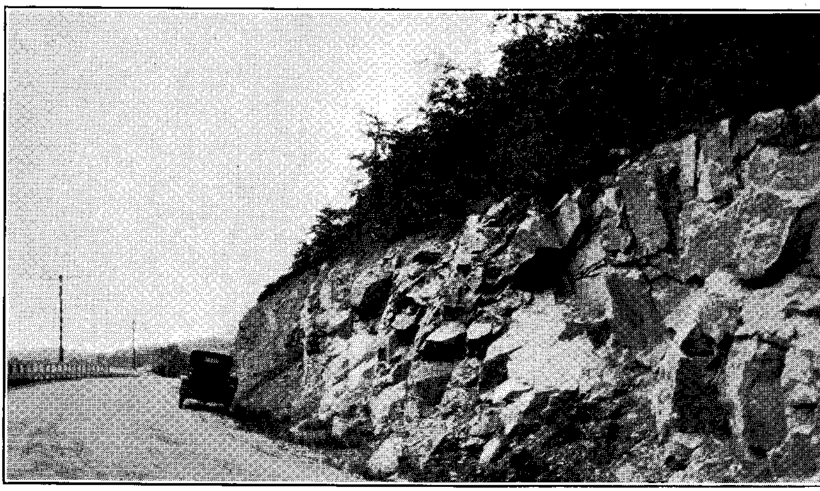
B. Contact of pre-Cambrian syenite (right) and schist 2 miles east of Vinton. This appears to be a fault contact. (See p. 26.)



A. Pre-Cambrian schist. The rock is a quartz-sericite schist whose foliation dips to the southeast.



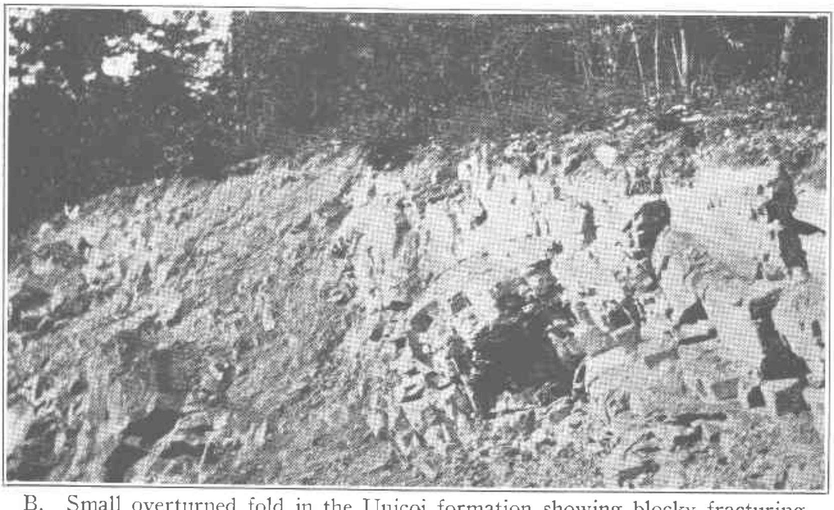
B. Contact of pre-Cambrian syenite (right) and schist 2 miles east of Vinton. This appears to be a fault contact. (See p. 26.)



A. Vertical Unicoi quartzite along the Roanoke-Rocky Mount highway, 1 mile north of Back Creek.

B. Small overturned fold in the Unicoi formation showing blocky fracturing. (See pp. 28-30.)

A. Vertical Unicoi quartzite along the Roanoke-Rocky Mount highway, 1 mile north of Back Creek.



B. Small overturned fold in the Unicoi formation showing blocky fracturing. (See pp. 28-30.)

whose general strike is N. 40° E., with the prevailing dip being to the south. Most of the folds within the formation are so tightly compressed that, until several reliable key beds can be established, the detailed structure of the formation can not be determined. (See Pl. 19.)

Much faulting on a small scale also confuses the relations of the formation. Many of the faults are short gravity (normal) faults of slight throw. They may be located, but not traced, by springs where the limestones have been faulted. Several of these small faults may be seen along the north bank of Roanoke River between the Wasena and 13th Street bridges. Many small thrust faults, which are generally strike faults, break the overturned folds in the shales, as, for example, near the intersection of Clark Street and 18th Avenue north of the Fair Grounds. Other small thrust faults occur along the northern edge of the Rome ("Watauga") belt.

Thickness.—It is difficult to determine the thickness of the formation. At Buena Vista, 70 miles north of Roanoke, the formation is from 600 to 900 feet thick. The following thicknesses have also been reported: 900 feet at Natural Bridge, 420 feet at Marion, 1,000 to 1,400 feet in southwest Virginia, and 1,050 feet in the Cranberry, Tennessee, quadrangle. The thickness in the Roanoke area is estimated to be about 900 feet. So far as the writer knows, an accurate measurement of the thickness of the formation can not be obtained in this area.

Topography.—Because the Rome ("Watauga") formation crops out along the edges of the Valley and the Blue Ridge, its topography has some of the characteristics of both sections. In the Valley, it weathers to form low hills, upheld by more siliceous beds. This topography is well developed in the northwestern part of Roanoke, where, for more than a mile, Orange, Melrose, Loudoun, Center, and Salem streets alternately follow the crests and troughs of parallel hills and valleys. Where the shale abuts against the Blue Ridge, the topography is more rugged, the hills are less linear, and the valleys are more irregular. In the western part of the Roanoke area, the topography is rugged, consisting partly of hills of considerable height and mass.

Fossils and correlation.—The Rome ("Watauga") formation is sparingly fossiliferous. A few specimens of one species of trilobite have been found at five localities in the Roanoke area. This fossil belongs to the genus *Olenellus,* and is close to, if not identical with, *Olenellus thompsoni* Hall. S. L. Powell, of Blue Ridge Summit, Maryland, informed the writer of the occurrence of this fossil in a ledge of shale at the intersection of the Roanoke-Salem trolley-line and the Salem-Catawba Railway about 2 miles east of Salem. Roy J. Holden, of Virginia Polytechnic Institute, Blacksburg, Virginia, showed the writer several specimens of this fossil from purple and gray shales in a cut on the Norfolk and Western Railway about 1 mile south of Blue Ridge Springs. The writer has collected similar specimens from three other localities over a distance of about 20 miles along the strike. The fossils occur in a fine, gray-brown, soft, poorly consolidated clayey shale. The specimens, which consist largely of distorted detached cephala and pygidia, are abundantly scattered through a few very thin laminae. The horizon of these trilobites appears to be below the middle, and is probably near the base, of the formation.

Walcott[31] has mentioned a single specimen of *Ptychoparia* from the Buena Vista shale near Balcony Falls. Butts reports that *Ptychoparia* is common in the Rome in southwestern Virginia, and that the brachiopods *Obolus* and *Linarssonia* occur rarely. The "Russell" formation of southwestern Virginia, which is the same as the Watauga shale, contains an undoubted *Olenellus* fauna. The Waynesboro shale of Pennsylvania and Maryland,[32] which is the northern equivalent of the Rome ("Watauga") shale, contains *Obolus* and other Middle Cambrian fossils. E. O. Ulrich of the United States Geological Survey has identified specimens of trilobites, which were collected by the writer from the Rome ("Watauga") shale near Blue Ridge Springs, as *Olenellus* cf. *thompsoni*, of early Cambrian age. The Rome ("Watauga") shale is considered by the United States Geological Survey to be Lower and Middle Cambrian. The presence of *Olenellus* is very suggestive of an early Cambrian age. The writer has discussed the age of this formation in a recent paper.[33] The formation was included also in the Shenandoah" limestone of some early reports.

ELBROOK FORMATION

Definition.—This formation takes its name from Elbrook in southern Pennsylvania,[34] where it is about 3,000 feet thick and rests upon the Waynesboro shale. It is there overlain by the Conococheague limestone, which is of Ozarkian age.

Distribution.—The largest exposure of the Elbrook formation in the Roanoke area is in the middle of Roanoke Valley and its con-

[31]Walcott, C. D., Notes on the Cambrian rocks of Virginia and the southern Appalachians: Am. Jour. Sci., 3d ser., vol. 44, pp. 52-55, 1892.
[32]Stose, G. W., Sedimentary rocks of South Mountain, Pennsylvania: Jour. Geology, vol. 14, p. 209, 1906.
[33]Woodward, Herbert P., op. cit., pp. 597-602.
[34]Stose, G. W., op. cit., p. 209.

tinuation into Glade Creek Valley. This belt extends across the county and is terminated above Blue Ridge Springs, Botetourt County, by the Blue Ridge overthrust. It continues from the western edge of Roanoke County into Montgomery County. A narrower belt at the northern edge of Catawba Valley is bounded on the north by the Pulaski overthrust. The formation is present over a wide area in Fincastle Valley, between Fincastle and Troutville. It is seldom well exposed except in artificial cuts or quarries. Good exposures occur (1) in the Blue Ridge quarry near Blue Ridge Springs, (2) in the Mundy Brothers quarry along Tinker Creek, and (3) along the Salem-Christiansburg highway between Glenvar and Lafayette. None of these exposures show a continuous and complete section, for the rocks are folded and faulted so as to conceal or cut out a considerable part of the formation. The Elbrook limestones are also exposed (1) in the Salem City Quarry, (2) in the Dixie Caverns near Glenvar, (3) just south of Cambria or Bangs in Montgomery County, and (4) northwest of Shiloh Church in Catawba Valley. (See Pl. 1.).

Character and thickness.—The Elbrook formation consists of a rather thick series of blue and bluish-gray, partly argillaceous, limestones, which are generally thinly bedded, alternating with buff and gray calcareous shales of ochreous character resulting from the leaching of argillaceous limestone. The lower part is more shaly than the upper part. The shales are in places red and yellow, and contain thin, finely laminated, interbedded limestones. These reddish beds resemble some beds of the Rome ("Watauga") shale, but lack their siliceous content. They weather to rich, variegated clay soils which are very different from the brown soils of the Rome ("Watauga") beds. The middle and upper parts of the Elbrook are thicker bedded, and contain blue and bluish-gray limestones with a few thin dolomites. The upper part of the formation is more highly magnesian than the remainder. Typical exposures of the Elbrook formation are shown on Plate 15.

Numerous springs emerge from this formation, and the general character of the rock indicates abundant underground drainage. The large Dixie Caverns near Glenvar are in Elbrook limestone. Many sinks are found in the formation between Round Hill and Mills (Reeds) Mountain.

The thickness of the Elbrook formation in this area is estimated to be about 1,000 to 1,600 feet.

The formation weathers easily and affords few natural exposures. Its soil is deep, fertile, free of chert, and is prevailingly red in Roanoke Valley.

Age and correlation.—No fossils were found in the Elbrook formation in the Roanoke area, but, by its stratigraphic position, it is considered to be Middle to Upper Cambrian. In some parts of southwestern Virginia, beds at the horizon of the Elbrook formation are called the Honaker limestone, which is equivalent to the Rutledge limestone, Rogersville shale, and Marysville limestone of Tennessee and other parts of southwestern Virginia. The Elbrook limestone was also included in the "Shenandoah" limestone of earlier reports.

Economic character.—The Elbrook limestone is quarried in many places for lime, road metal, and construction stone, for which it is entirely satisfactory. Residual clays of good quality are worked at many places for brick. Scattered deposits of residual barite have been worked on a small scale.

OZARKIAN AND CANADIAN SYSTEMS (ULRICH)

GENERAL STATEMENT

These formations are chiefly thick limestones and dolomites which have been generally included until recently with other formations in the "Shenandoah" limestone of central and northwestern Virginia, and have constituted the Knox dolomite of southwestern Virginia. The formations have generally been referred in part to the Cambrian and in part to the Ordovician system. Hence, this thick body of calcareous beds was formerly often designated as "Cambro-Ordovician," awaiting more precise study of its units.

Ulrich[35] has proposed two systems for this body of formations: (1) The Ozarkian system, to include the lower part (uppermost Cambrian of most authors), and (2) the Canadian system, to include the upper part (lowermost Ordovician or Beekmantown of most authors). So far as the writer could discover, the Roanoke area offers no outstanding evidence bearing on the validity of the proposed systems.

The terms Ozarkian and Canadian are used in this report for geologic periods and systems as proposed by Ulrich. The writer is not in entire accord with this usage, and wishes to disclaim any credit or responsibility for it.[36]. He uses here these terms for the uppermost Cambrian and the Beekmantown of other authors.

[35]Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 627-629, 649-650, 1911.

[36]The use of the terms Ozarkian and Canadian is in accordance with the present usage of the Virginia Geological Survey.

OZARKIAN SYSTEM

CONOCOCHEAGUE FORMATION

Definition.—The calcareous rocks directly overlying the Elbrook limestone in this area correspond, as recently determined, to the Conococheague formation of Pennsylvania and Maryland, and that name is, therefore, given them here. It is almost certain that they corespond also to the Copper Ridge dolomite of Tennessee.[37] The Conococheague was provisionally included in the Jonesboro limestone which was named by Ulrich[38] in 1911, from Jonesboro, Tennessee. Both facies are here included under the head of Conococheague formation.

Distribution.—The best outcrops of the Conococheague formation in the Roanoke area are found along the northeast flank of the great Catawba syncline directly north of Sandstone and Crawford ridges where it extends as a continuous belt for more than 30 miles along Catawba Valley and its northeast and southwest extensions, and connects northeast of Tinker Mountain with the Roanoke-Glade Creek Valley belt. This belt averages about half a mile wide. Other belts of the Conococheague extend east and northeast in Roanoke and Glade Creek valleys just north of Mills (Reeds) and Coyners mountains, and along Pedlar Hills between Shawsville and Montgomery White Sulphur Springs. (See Pl. 1.)

A considerable part of the Conococheague formation is exposed along the road directly west of, and at the foot of, Coyners Mountain and in Catawba Valley north of Sandstone Ridge.

Character.—The Conococheague formation consists mainly of highly magnesian limestone and dolomite which are interbedded without any apparent regularity. It contains also several distinct beds of calcareous sandstone which are rather conspicuous in weathered outcrops. These sandstones have diagnostic values, as they are not found in the overlying Canadian (Beekmantown) dolomites, nor in the underlying Elbrook or Honaker dolomite. Sandstones in the Valley limestones of this area are taken to signify the Conococheague formation. The formation is predominantly light-colored, being lighter than the overlying Nittany dolomite. The beds are moderately thick, being intermediate be-

---

[37]Charles Butts, in a letter dated May 24, 1930, states: "The Catawba belt of dolomite below the Nittany is true Copper Ridge so far as I can see. It does not appear to differ from the typical Copper Ridge in character and is in strike with what has been accepted as Copper Ridge in Crocketts Cove in the Wytheville quadrangle next southeast of Walker Mountain just as the Catawba belt is next southeast of Gap Mountain, the northeast continuation of Walker Mountain." He further states (May, 1931) that the Copper Ridge of the Catawba Valley belt is continuous with the Conococheague of the Roanoke-Salem belt along the northeast end of Tinker Mountain.

[38]Op. cit., pp. 637, 672-674, 1911.

tween the thin-bedded Elbrook below and the somewhat massive Nittany above. (See Pl. 16, A.)

It is difficult to determine the upper and the lower contacts of the formation. For convenience in mapping, the top of the Conococheague has been drawn just below the heavy chert-producing beds of the Nittany dolomite. This Nittany chert contains the typical Canadian fossil, *Lecanospira compacta* (Salter) Ulrich, or some other species, and is readily identifiable in the field. The base of the Conococheague has been drawn below the lowest sandy beds which lie upon typical Elbrook limestone. This sandy zone is somewhat porous and friable, and weathers to a deep-red soil, which is slightly darker and more conspicuous than the other soils of the Conococheague formation, but can not be used everywhere to determine the base of the Conococheague, especially in Roanoke Valley, because exposures are scarce and most of the soils are red. Hence the delimitation of the formation in this valley is less accurate than in Catawba and Fincastle valleys.

Some residual chert is found in the soil of the Conococheague formation, although the formation itself does not appear to be especially cherty. The chert is probably the result of replacement of limestone by silica during weathering, as it is not common in the exposed underlying bed rock. The chert of the Conococheague formation is very dense, hard, slabby, and has sharp jagged edges which are seldom rounded by erosion or weathering. Some of it is chalcedonic.

Thickness.—The thickness of the Conococheague formation has not been definitely established in the Roanoke area, but it is not less than 1,000 feet. The formation has been estimated to be about 1,600 feet thick in Catawba Valley, but it is probable that the total thickness is somewhat greater than this estimate.

Topographic expression.—The formation is essentially a valley-maker, and its ready dissolution has contributed considerably to the formation of Catawba Valley. The cherty and sandy beds, which are more resistant to weathering than the dolomitic beds, give rise to low hills. They are lower, however, than the hills developed upon the cherts of the overlying Nittany dolomite.

Fossils and age.—The Conococheague formation is sparingly fossiliferous in this area. Heads of the calcareous alga, *Cryptozoon,* like *C. proliferum* Hall, are exposed in ledges along the south side of the Salem-Newcastle road about 1 mile west of Catawba. A few small gastropod (snail) shells, suggesting *Sinuopea* but not in condition for certain identification, have been observed in the chert.

Recent discovery of a genus of trilobites, *Tellerina,* high in the Conococheague near Natural Bridge, has shown that it is of Lower Ozarkian age.[39] Butts, in view of its stratigraphic position, which is the same as that of the Copper Ridge dolomite, and certain of its lithologic characters, like the occurrence of beds of sandstone and dolomite, is inclined to regard all but the upper few hundred feet at most as of Ozarkian age and a facies of the Copper Ridge dolomite.

CANADIAN SYSTEM

NITTANY DOLOMITE

Definition.—This formation was named by Ulrich[40] in 1911, from Nittany Valley in central Pennsylvania, where it occurs, with a thickness of 1,270 feet, near the middle of a series of calcareous rocks which Ulrich has called Canadian. The Canadian is considered by Ulrich to be a system directly below the Ordovician system (restricted) and above the Ozarkian system, which in turn overlies the Cambrian system as restricted by Ulrich.

Distribution.—The Nittany dolomite crops out in several belts, the greatest being along the north, east, and west sides of the Catawba syncline, on the flanks of Catawba, Tinker, and Paris (Roanoke) mountains. It underlies the southern half of Catawba Valley, where its resistant chert makes the ridge which bisects the valley. This belt widens from about one-fourth of a mile here to more than 2 miles near Blacksburg. This belt is also narrow east of Tinker Mountain. Another belt of Nittany extends for several miles northeast and southwest from Cloverdale. A narrow east-west strip of Nittany dolomite passes through Fincastle in Botetourt County. (See Pl. 1.)

Exposures of the Nittany dolomite are more numerous than those of other Valley limestones. They are found (1) at Daleville, (2) east of Cloverdale, (3) along the creek 1 mile east of Fincastle, and (4) along the road east of Blacksburg. Abundant exposures occur also along the road south of Sandstone Ridge from Catawba Sanatorium to Haymakertown. The Nittany belts contain large areas with no exposures, but in general where the rocks are exposed the surface is covered with ledges, making a rocky and barren zone.

Character.—The Nittany is essentially a light-gray to blue dolomite, whose texture varies from finely crystalline to compact. The rock

[39]Butts, Charles, Personal communication.

[40]Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, p. 658, 1911.

is very dense and difficult to break with a hammer. Exposed ledges weather blue with rounded surfaces that appear water-worn. Both features are characteristic of the formation. (See Pl. 16, B and 17, A.)

The outcrops have great quantities of heavy chert, apparently produced by weathering, giving the effect of a thick cherty member. This chert is very persistent and its presence identifies the formation. It is brittle and rather cavernous. It yields locally good specimens of gastropods (especially *Lecanospira*) and trilobites. It is readily distinguished from the Ozarkian chert which is slabby and dark colored. The Nittany chert weathers with difficulty and hence forms ridges which are locally prominent, for example, Crawfords and Sandstone ridges.

The Nittany dolomite weathers to a deep, reddish-brown fertile soil.

Thickness.—The Nittany dolomite is somewhat thinner than the other calcareous formations in the Valley of Virginia, being about 800 feet thick.

Relations.—The Nittany dolomite appears to rest conformably upon the Conococheague formation, but may be separated from it by an erosion interval, or disconformity.[41]

Topography.—The Nittany dolomite gives rise to flattish topography, which locally has many sinks, some being very large. Several large sinks in Catawba Valley are more than 100 feet deep.

Fossils and correlation.—The Nittany dolomite is not very fossiliferous, but the chert yields some fossils. The fossils are chiefly silicified molds of the interiors of gastropods and trilobites. The whorls of the gastropods so closely resemble cavities in the porous chert that many masses of chert must be carefuly examined to find the fossils. The most abundant and diagnostic fossil is *Lecanospira*,[42] which is probably represented by several species. The genus may be taken as the guide fossil for this horizon from Canada to Alabama.

One of the best collecting places in the Roanoke area is at the sharp east turn in the road leading south from Hollins College, at a point about 1 mile south of the college. Heaps of chert fragments in a field west of the road contain numerous fossils. *Lecanospira* was

[41]Charles Butts, in a letter of May 24, 1930, states: "If the upper part of the Conococheague is equivalent to Stonehenge then there would be no hiatus between it and the Nittany so far as known."

[42]This genus has usually been called *Ophileta*, but Ulrich has determined that *Ophileta* is a dextral or right-handed shell, and he has adopted the term *Lecanospira* for the form which, when viewed from the flat side, is sinistral or left-handed.

found in the heavy chert just north of Coyners Mountain, on Sandstone Ridge, and just east of Fincastle. Several other gastropods were collected, among them being *Maclurea* sp. and *Hormotoma* sp.

The age of the Nittany dolomite is Beekmantown, or Lower Ordovician of some authors. It is referred by Ulrich to the Canadian system. The Nittany is equivalent to the upper part of the "Natural Bridge" limestone of H. D. Campbell. It was included in the "Shenandoah" limestone and the Knox dolomite of early reports. It is equivalent to the Longview limestone of Tennessee and Alabama.

It seems probable, according to Butts, that the Nittany dolomite as shown on the geologic map (Pl. 1) includes some younger Canadian beds which are known to occur in the Valley. These beds, carrying the *Ceratopea* zone, correspond in part to the Newala limestone of Alabama and the Bellefonte limestone of Pennsylvania. They are too thin to be mapped separately, and they can be differentiated only by more detailed work.

ORDOVICIAN SYSTEM

Subdivision and Character

The typical Ordovician system of the central Appalachian region is well displayed in Roanoke County and vicinity. Most authors include in the Ordovician system the formations herein designated as Ozarkian, in part, and Canadian. The writer follows in this report the present usage of the Virginia Geological Survey in tentatively considering the Ozarkian and Canadian as systems between the Cambrian (restricted) and Ordovician (restricted) systems.

The Lower and Middle Ordovician rocks are mainly limestone, black shale, and gray calcareous shale, with about 300 feet of sandy beds just above the base of the Martinsburg shale. The Upper Ordovician rocks are predominantly shale with interbedded thin flaggy sandstone. The Roanoke area is unique in having a full representation of both the Trenton and Athens sediments, for these sediments are not found elsewhere in this general region in the same trough of deposition.

The Ordovician system in the Roanoke area is here subdivided as follows:

Ordovician formations in the Roanoke area, Virginia

	Feet
Upper Ordovician	
Martinsburg shale	
Maysville division	50-125
Eden division	100-200
Middle Ordovician	
Martinsburg shale	
Trenton division	750±
Moccasin formation	150-300
Lower Ordovician (restricted)	
Chazyan series	
Blount group	
Athens shale	970±
Whitesburg limestone	0-15
Holston limestone	0-50
Stones River group	
Lenoir limestone	50±
Mosheim limestone	0-30
	2,070-2,490±

CHAZYAN SERIES

GENERAL FEATURES

The Chazyan series, which overlies the Nittany dolomite, consists of the Stones River group below and the Blount group above. Ulrich and Butts include the Mosheim and Lenoir limestones in the Stones River group, and the Holston limestone, Whitesburg limestone, and Athens shale in the Blount group.

All of the formations here included in the Chazyan series have been found in the Roanoke area, but not all at the same place. Because of the relatively slight thickness and limited areal extent of the Mosheim, Lenoir, and Holston limestones in this area, they have been mapped together as a unit on the geologic map accompanying this report (Pl. 1). For the same reasons the Whitesburg limestone has been mapped with the basal part of the Athens shale, to which it is closely related.

DISTRIBUTION

The combined Mosheim, Lenoir, and Holston limestones crop out in a narrow belt, seldom more than 200 yards wide, beside the Athens shale. The most extensive outcrop is along the main road in Catawba Valley. This belt continues west into Montgomery County, passing near MacDonalds Mill and Bennetts Mill, where it turns south and passes about a quarter of a mile east of Trinity Crossroads, following Mill Branch. About 2 miles south of Trinity Crossroads it is cut off by the Salem fault. The same belt may be traced east from Roanoke County into Botetourt County, where it parallels the northeast slope of Tinker Mountain until cut off by a fault about 2 miles north of Cloverdale. About 1 mile west of Fincastle, another belt extends along the south side of Catawba Creek for several miles east and west of Howell Mills. The limestones crop out also in a narrow belt parallel to, and about an eighth of a mile south of, the Lee Highway from near Cloverdale to a point north of Roanoke. These beds are not continuously exposed in any of the belts, and ledges showing the various members are uncommon.

The Chazyan series is best exposed along active streams and on hillsides. A fine exposure of the lower formations is found in the bed of Tinker Creek about a fourth of a mile northwest of Cloverdale station on the Norfolk and Western Railway. Another good exposure is along the Salem-Newcastle road near Catawba Post Office, where the Mosheim limestone is exposed in a ledge on the north side of the road, and the Lenoir limestone is exposed a short distance farther east and south of the road. East and west of Catawba, the main road through Catawba Valley passes along the Chazyan series and many exposures can be seen. About 3 miles east of Blacksburg, the outcrop is crossed by a road leading east from there. The Whitesburg limestone is here exposed beneath the Athens shale. Another good exposure of the Chazyan is found on the south banks of Catawba Creek, just south of the ford on the road leading south from Howell Mills.

MOSHEIM LIMESTONE

Definition.—The Mosheim limestone was named by Ulrich[43] from Mosheim, in Greene County, Tennessee.

Character and relations.—This formation is well exposed along the north side of the Salem-Newcastle road a short distance west of Catawba.

The Mosheim is a pure, fine-grained limestone of uniform blue or dove color. It is the purest limestone in the Roanoke area and, in Catawba Valley, is about 30 feet thick. The lower 7 feet here is conglomeratic. This basal conglomerate consists of angular blocks of Nittany dolomite, some containing *Lecanospira,* embedded

[43]Op. cit., pp. 413-414, 538, 543-547, Pl. 27.

in a matrix of limestone. The Mosheim is here conformably overlain by the Lenoir limestone, with a very sharp contact. The contact is "welded," so that a hand specimen of rock shows the dark impure Lenoir limestone on one side and the dove-colored pure Moheim limestone on the other, with the contact as sharp as a pencil line.

Fossils.—The Mosheim limestone contains many species of fossils, chiefly bryozoa, gastropods, and trilobites. *Tetradium syringoporoides* is very common, and specimens of *Lophospira* and *Maclurea* were collected in Catawba Valley. The Mosheim is basal Chazyan.

LENOIR LIMESTONE

Definition.—This formation was named by Safford and Killebrew,[44] from Lenoir City, in Loudon County, Tennessee.

Character.—In Catawba Valley, the Mosheim limestone is overlain by 50 feet or more of dark, impure limestone from which Raymond[45] has collected trilobites which he considers to be, in part at least, probably of Lenoir age.

The Lenoir is a body of limestone, some beds of which are impure, coarse, dark, and knobby. The lower part is siliceous and cherty and the upper part is crystalline. Upon weathering, the formation disintegrates readily into dark knotty shale interbedded with thin beds of dark limestone or marble.

Relations.—The Lenoir limestone was deposited apparently upon the unevenly eroded surface of the Mosheim limestone. It is overlain in most of the Roanoke area by the Athens shale. In Catawba Valley, a band of dark crystalline limestone, about 6 feet thick, which corresponds to the Holston marble of Tennessee, occurs between the Lenoir limestone and the Athens shale. The Lenoir is overlain near Blacksburg by the Whitesburg limestone, or basal part of the Athens formation.

Fossils and correlation.—The Lenoir limestone is very fossiliferous. Some of the thin beds of limestone in ledges along the Salem-Newcastle highway are composed mostly of shells and bryozoa. Raymond[46] has collected a large fauna from this formation in Catawba Valley. He has described the following trilobites:

[44]Safford, J. M., and Killebrew, J. B., The elementary geology of Tennessee, pp. 108, 123, 130-131, 137, 1876.
[45]Raymond, P. E., Some trilobites of the lower Middle Ordovician of eastern North America: Harvard Coll., Mus. Comp. Zoology Bull., vol. 67, pp. 171 and 174, 1925.
[46]Op. cit., p. 171.

Homotelus indentus Raymond.
    laevis Raymond.
    obtusus (Hall).
Pterygometopus annulatus Raymond.
Remopleurides canadensis Billings.
Illaenus valvulus Raymond.
    fieldi Raymond.
    lautus Raymond.
Bumastus lioderma Raymond.
Acrolichas minganensis (Billings).
Glaphurus decipiens Raymond.
Ceraurus hudsoni Raymond.
Nieszkowskia sp.

In discussing the trilobite faunas of Catawba Valley and other areas, Raymond[47] states that "the trilobites of the Lenoir, so far as known, have a decidedly Chazyan aspect. . . . The general resemblance is, therefore, to the fauna of the Middle and Upper Chazy."

HOLSTON LIMESTONE

Definition.—The Holston limestone (or marble) was first named by Keith[48] from Holston River in eastern Tennessee.

Character.—In a few places in the Roanoke area certain beds appear to be the Holston marble. The local beds are similar to the Holston at its type locality in Tennessee, except that the red color is commonly lacking. The local Holston is gray, massive, and so coarsely crystalline that it resembles marble. It contains more than 90 per cent calcium carbonate and has been burned for lime at places in central Virginia. The lower part contains some chert nodules. The Holston weathers into a deep-red clayey soil.

The Holston is best exposed in the Roanoke area along Tinker Creek, about an eighth of a mile west of Cloverdale station on the Norfolk and Western Railway, where there is about 50 feet of dark-blue, coarsely crystalline marble, with scattered crystals of reddish calcite. The ledges weather deep-blue with surfaces that appear water worn. The Holston here appears to be conformable with the overlying Athens shale. It is much better exposed at Eagle Rock, Botetourt County, where it is quarried for lime.

Fossils.—The formation contains some fossils, but it has few easily recognizable forms. The upper surfaces of weathered ledges show ramose bryozoa, and masses of *Solenopora compacta* (Billings)

[47] Op. cit., p. 172.
[48] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Knoxville folio (No. 16), map, 1895.

are common. The writer did not collect fossils from the typical Holston in this area.

The Holston limestone was called the Murat limestone in some reports, this name having been proposed by H. D. Campbell.[49] It is now known that the Murat limestone is the same as the Holston limestone, and the latter term has priority.

WHITESBURG LIMESTONE

Definition.—The Whitesburg limestone is named from Whitesburg, Tennessee. The formation has recently been defined by Ulrich.[50] The undefined name was published in 1924.[51] This limestone was discussed by Butts[52] in 1926 as the "basal limestone member" of the Athens shale. He stated that it "is locally thick enough to be treated as a distinct formation as at Whitesburg, . . . Tenn."

Distribution and character.—This limestone is well exposed along the road leading east from Blacksburg, at the bottom of the hill about 3 miles to the northeast.[53] The rock is light-gray to chocolate-colored, coarse-grained, and is very fossiliferous. Smooth, velvet-black, chitinous fragments, some as large as a half-dollar, of the glabellae and pygidia of trilobites are scattered through it. The Whitesburg is here about 12 feet thick. It is in a lens between the typical Athens above and the Lenoir below. It is found only in the Athens trough of sedimentation. Another exposure is found north of Tinker Mountain about half a mile east of the bridge over Catawba Creek, about 3 miles northwest of Haymakertown.

Fossils.—A considerable fauna of trilobites has been listed by Raymond[54] from this horizon on the Thomas farm, 3 miles northeast of Blacksburg. The species are as follows:

Arthrorhachis elspethi Raymond.
Eoharpes sp.
Ampyx camurus Raymond.
Nileus scrutator Billings.
Bronteopsis gregaria Raymond.
Homotelus obtusus (Hall).

---

[49]Campbell, H. D., The Cambro-Ordovician limestones of the middle portion of the Valley of Virginia: Am. Jour. Sci., 4th ser., vol. 20, pp. 445-447, 1905.

[50]Ulrich, E. O., Ordovician trilobites of the family Telephidae and concerned stratigraphic relationships: U. S. Nat. Mus. Proc., vol. 76, art. 21, p. 2, footnote, 1930.

[51]Ulrich, E. O., *in* Marble deposits of East Tennessee: Tennessee Dept. Educ., Div. Geol., Bull. 28, p. 34, 1924.

[52]Butts, Charles, The Paleozoic rocks, *in* Geology of Alabama: Geol. Survey of Alabama, Spec. Rept. No. 14, p. 111, 1926.

[53]The writer is indebted to Prof. R. J. Holden, Department of Geology, Virginia Polytechnic Institute, Blacksburg, who directed him to this exposure.

[54]Op. cit., p. 173. He states that the fauna "is in the limestone at the top of the Holston, near the contact with the Athens."

Illaenus protuberans Raymond.
Bumastus longiops Raymond.
Onchaspis confraga Raymond.
Calymene sp.
Ceraurus granulosus Raymond and Barton.
Sphaerexochus parvus Billings.
    discrepans Raymond.
Pterygometopus transsectus Raymond.

ATHENS SHALE

Definition.—The Athens shale was named by Hayes,[55] from Athens, Tennessee. Apparently the same horizon in central Virginia was once called the Lexington limestone,[56] and later the Liberty Hall formation.[57] The name Lexington was later found to be preoccupied, hence the formation was renamed the Liberty Hall. The term Athens has been widely used and has priority over the term Liberty Hall.

Distribution.—The Athens shale crops out mainly in the Roanoke area around the Catawba syncline. It extends the full length of Catawba Valley, occurring near its middle, with Catawba Creek meandering along its strike. (See Pl. 1.) This belt is narrow, being seldom more than an eighth to a quarter of a mile wide. The Athens shale is found around Tinker Mountain in Botetourt County, and around Paris Mountain in Montgomery County. The belt is terminated at both ends by thrust faults. The Athens shale is slightly north of the middle of Roanoke Valley, extending from 1 mile north of Salem northeast to Cloverdale, where it is cut off by a thrust fault. The Lee Highway and the Salem-Hollins road follow this belt. A small area of the Athens shale is found along the south flanks of Mills (Reeds) and Coyners mountains, being cut off at the southeast by a fault. The formation crops out on Little Brushy Mountain northwest of Salem.

Exposures of the Athens shale are numerous. Very good exposures along Catawba Creek about 8 miles north of Salem have been described by Powell[58] and Raymond[59] has reported upon the trilobites here.. Good exposures occur along Carvins Creek, from

---

[55]Hayes, C. W., U. S. Geol. Survey Atlas, Kingston folio (No. 4), p. 2, 1894.
[56]Campbell, J. L., Geology of Virginia: Am. Jour. Sci., 3d ser., vol. 18, p. 24, 1879.
[57]Campbell, H. D., The Cambro-Ordovician limestones of the middle portion of the Valley of Virginia: Am. Jour. Sci., 4th ser., vol. 20, pp. 445-447, 1905.
[58]Powell, S. L., Discovery of the Normanskill graptolite fauna in the Athens shale of southwestern Virginia: Jour. Geology, vol. 23, pp. 272-281, 1915.
[59]Raymond, P. E., The correlation of the Ordovician strata of the Baltic basin with those of eastern North America: Harvard Coll., Mus. Comp. Zoology, Bull., vol. 56, no. 3, 1916; Some trilobites of the lower Middle Ordovician of eastern North America: Harvard Coll. Mus. Comp. Zoology, Bull., vol. 67, no. 1, p. 175, 1925.

Carvins Falls to Hollins College, and along Catawba Creek near Howell Mills, Botetourt County. Abundant exposures are found about 3 miles northeast of Blacksburg, Montgomery County, especially at Laskers Gate, on the Thomas farm, and near MacDonalds Mill.

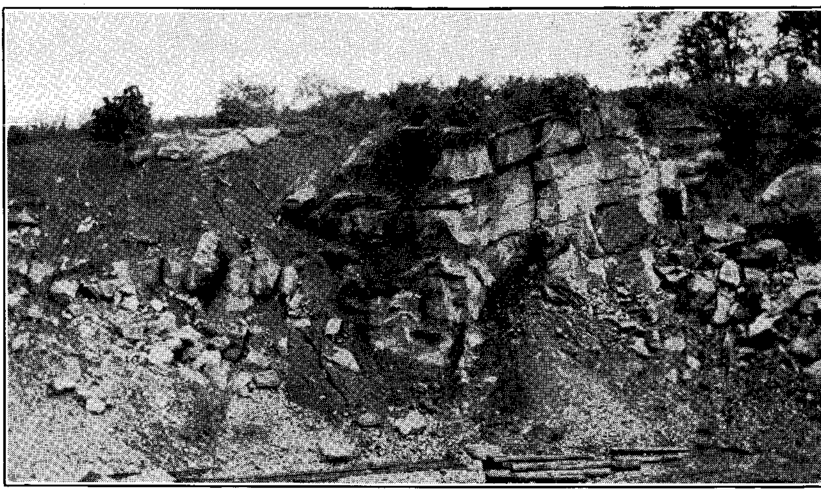
Character.—The Athens shale in this area is a thick mass of black shale and thinly bedded blue-black limestone. (See Pl. 17, B.) The formation is calcareous near the base and slightly sandy toward the top. The shale is black below, changing to blue upward. The blue shale when fresh is actually thinly bedded light-blue limestone, but weathering decreases the lime content so that the limestone becomes bluish-gray and cleavable into thin leaves and plates. The formation as a whole weathers dull yellow to grayish-yellow. A section of the Athens shale in Catawba Valley is given below.

Section of the Athens shale along road east of Catawba, Roanoke County, Virginia

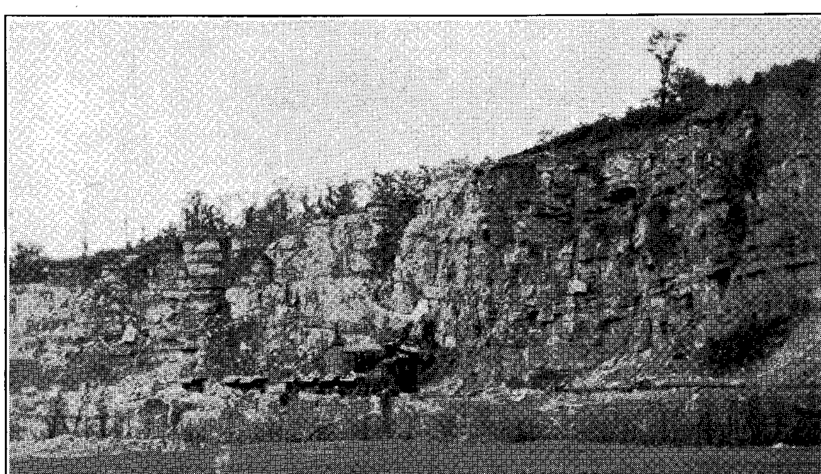
	Feet
Moccasin formation:	
Sandstone and shale, red-brown; 40 feet thick	
Athens shale:	
4. Shale, blue-black, calcareous	400
3. Limestone, dark-gray, thinly bedded, and shale, black; contains trilobites	190
2. Shale, black, calcareous, thinly bedded	168
1. Shale, black, very thin beds; contains graptolites	215
Total Athens shale	973
Lenoir limestone:	
Limestone, black, knobby, fossiliferous; 50± feet thick.	

The Athens formation is conspicuously thinly bedded, and it is easily recognized in the field. Fresh beds appear massive, but the thinness of the beds is accentuated by weathering. The formation is much folded and broken, and many of the cracks are filled with veins of white calcite which are in sharp contrast to the dark-colored shale. The Athens shale weathers to a brownish soil containing many small splinters of the harder shale, which decrease the fertility.

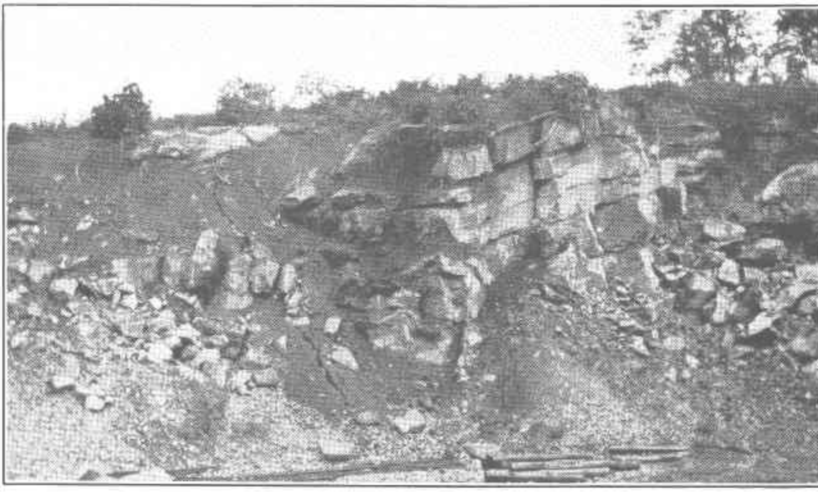
Thickness.—The Athens shale is about 970 feet thick, as measured in Catawba Valley north of Salem. It appears to thin toward the



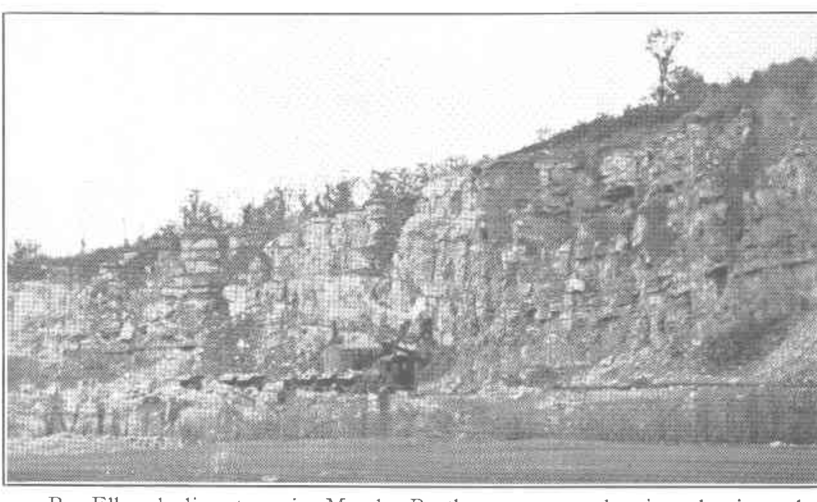
A. Elbrook limestone in Blue Ridge Springs quarry, showing gentle folds and intercalated thin beds.



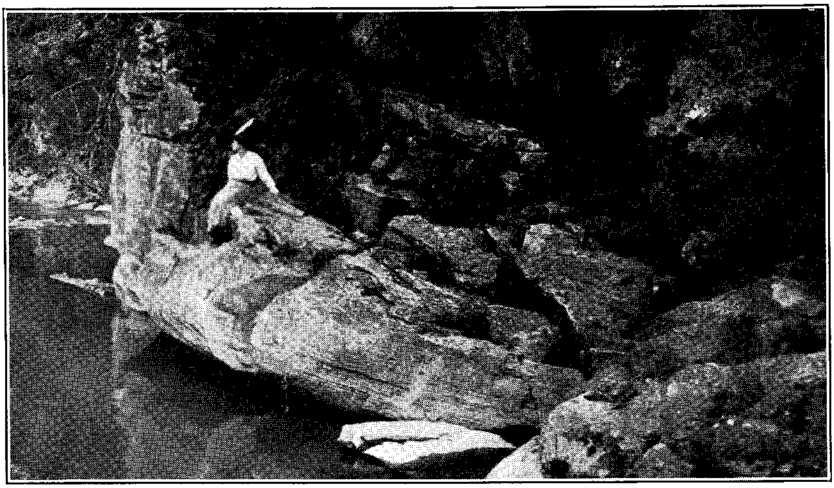
B. Elbrook limestone in Mundy Brothers quarry, showing the irregular bedding and gentle warping. Looking north along the strike of Mills (Reeds) Mountain. (See pp. 35 and 123.)



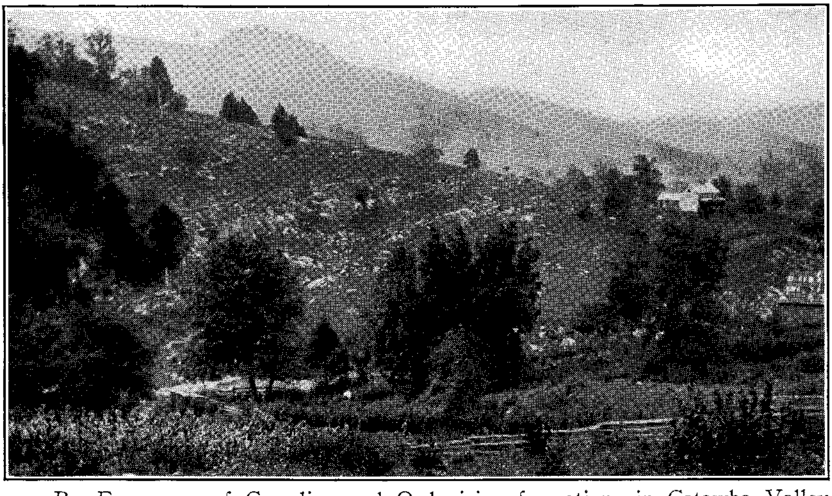
A. Elbrook limestone in Blue Ridge Springs quarry, showing gentle folds and intercalated thin beds.



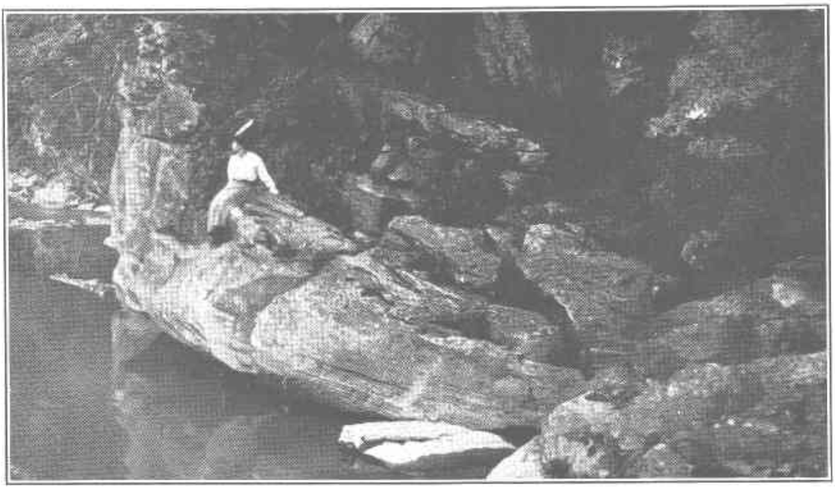
B. Elbrook limestone in Mundy Brothers quarry, showing the irregular bedding and gentle warping. Looking north along the strike of Mills (Reeds) Mountain. (See pp. 35 and 123.)



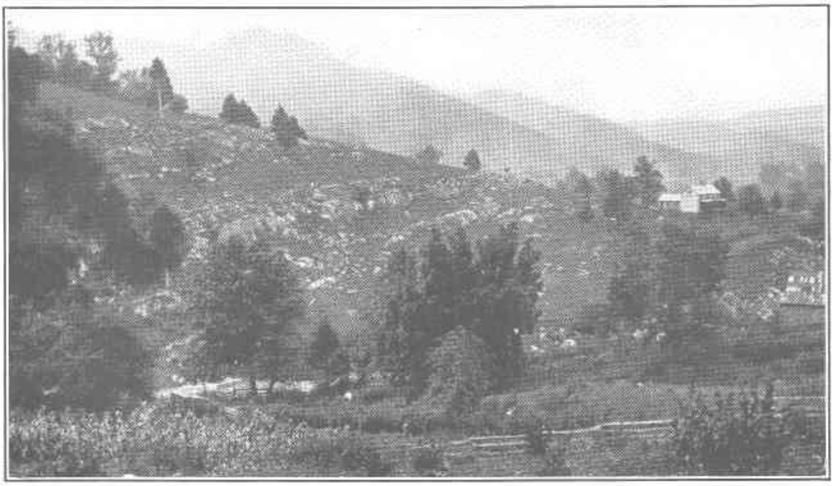
A. Massive beds of Conococheague dolomite along Carvins Creek. (See pp. 37-39.) Photograph by Davis Photo Co. (Courtesy of Roanoke Chamber of Commerce.)



B. Exposures of Canadian and Ordovician formations in Catawba Valley north of McAfee Knob. The slope in the middle background is covered with ledges of Nittany dolomite which dips to the south (left). The highest ledge on the hill at the left is Stones River limestone and the smooth slope above is on Athens shale. (See pp. 39-45.)



A. Massive beds of Conococheague dolomite along Carvins Creek. (See pp. 37-39.) Photograph by Davis Photo Co. (Courtesy of Roanoke Chamber of Commerce.)



B. Exposures of Canadian and Ordovician formations in Catawba Valley north of McAfee Knob. The slope in the middle background is covered with ledges of Nittany dolomite which dips to the south (left). The highest ledge on the hill at the left is Stones River limestone and the smooth slope above is on Athens shale. (See pp. 39-45.)

northeast and the southwest, for it is reported to be only 350 feet thick in Augusta County, and 600 feet thick in western Montgomery County. No section was accurately measured south of the Catawba syncline, but the thickness here appears to be considerably less. The Athens formation, according to Butts,[60] is unknown northwest of the strike of Catawba Valley north of New River.

Fossils and correlation.—The Athens shale is very fossiliferous. The fossils are chiefly graptolites and trilobites, which are well preserved. Graptolites are the most characteristic Athens fossils, and their abundance in the black shale serves to identify this horizon in the Roanoke area. They are found through the lower half of the Athens shale and they are seldom distorted. Many of them occur in original colonies. Raymond[61] lists the following trilobites from the Athens shale in Catawba Valley, about 8 miles north of Salem:

Triarthrus caecigenus Raymond.
Raphiophorus powelli Raymond.
Cryptolithus sp.
Robergia schlotheimi (Billings).

He reports the species from thinly bedded limestones in the upper part of the Athens:

Raphiophorus powelli Raymond.
Ampyx americanus Safford and Vogdes.

At the same place the following graptolites and other forms were identified by Powell:[62]

Fossils from the Athens shale in Catawba Valley, 8 miles north of Salem, Virginia

Climacograptus bicornis Hall.
  modestus Hall.
  parvus Hall.
  putillus Hall, mut. eximus.
  putillus Hall.
  scalaris Hall.
  typicalis Hall, mut. spinifer.
  scharenbergi Lapworth.
Corynoides gracilis Hopkins, mut. perungulatus.
Cryptograptus tricornis Carruthers.

[60] Personal communication.
[61] Raymond, P. E., Some trilobites of the lower Middle Ordovician of eastern North America: Harvard Coll., Mus. Comp. Zoology, Bull., vol. 67, no. 1, p. 175, 1925.
[62] Op. cit., pp. 278-279.

Dicellograptus sextans Hall.
intortus Lapworth.
Dicranograptus spinifer Lapworth.
nicholsoni Hopkins.
ramosus Hall.
Didymograptus serratulus Hall.
sagittacaulis Gurley.
subtenuis Hall.
Diplograptus amplexicaulis Hall.
angustifolius Hall.
foliaceous, var. incisus.
foliaceous Murchison var. acutus Lapworth.
foliaceous Murchison.
Dictyonema sp.
Glossograptus quadrimucronatus Hall, var. cornutus.
Lasiograptus mucronatus Hall.
Nemagraptus exilis Lapworth.
exilis Lapworth, var. linearis.
gracilis Hall.
Phycograptus laevis (Graptolithus laevis Hall).
Retiograptus eucharis Hall.
Leptobolus walcotti.
Triarthrus becki (Eaton).

From a locality 3 miles northeast of Blacksburg, Raymond[63] collected the following fossils:

Trinucleus acervulosus Raymond.
Dionide holdoni Raymond.
contrita Raymond.
Triarthrus caecigenus Raymond.

The Athens is middle Chazyan in age. It corresponds to the Normanskill shale of New York, containing the remarkable assemblage of graptolites known as the Normanskill graptolite fauna. The beds now identified as Athens were once called the Liberty Hall limestone, but this term has been abandoned because Athens has priority.

Economic character.—The Athens shale in Roanoke County has not been utilized for any economic purpose, except locally for road material. The following chemical analysis was made of a sample from typical Athens shale near Catawba:[64]

[63]Op. cit., p. 175.
[64]Bassler, R. S., The cement resources of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 2A, p. 136, 1909.

Analysis of Athens shale near Catawba, Roanoke County, Virginia

(W. M. Thornton, Jr., Analyst.)

SiO_2	23.56
Al_2O_3 / Fe_2O_3	5.48
MgO	.88
CaO	37.54
$MgCO_3$	1.85
$CaCO_3$	67.03
	97.92

MOCCASIN FORMATION

Definition.—This formation was named by Campbell,[65] from Moccasin Ridge, Scott County, Virginia.

Distribution.—The Moccasin formation is well exposed along the north slopes of Catawba and Paris mountains, where it makes a row of sharp hills and shoulders along the smooth sides of the mountains. It crops out in Millers Cove, and is found in a narrow belt along the northern part of Roanoke Valley from Salem to Carvins Creek.

Character and thickness.—The Moccasin formation in the Roanoke area consists largely of bluish-gray and red-brown calcareous sandstone in layers from 4 to 8 inches thick, closely interbedded with thin layers of sandy and red shale. The beds are thicker toward the base of the formation. The base of the Moccasin is characterized by flaggy red and purplish sandstone which is very hard and fine-grained. The middle part consists of red, gray, and brown sandstone and shale. The upper part contains more shale and the sandy lenses are coarser-grained than in the lower part. The fresh rocks are hard and resistant, but during weathering the lime disappears and they become porous and crumbly. The Moccasin formation is from 150 to 300 feet thick.

The formation is generally marked by a series of round, conical hills on the slopes of mountains capped by Clinch sandstone, or by a series of ridges which are of the third order of magnitude. Its soils are deep-red and fertile, but they wash readily and are too easily drained to be of high value.

Bentonite.—During the summer of 1927, Wilbur A. Nelson, in company with the writer, discovered a thin bed of bentonite in the

[65]Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Estillville folio (No. 12), p. 2, 1894.

Moccasin formation on the north slope of Catawba Mountain along the Salem-Newcastle highway. The writer later discovered two other expostures of bentonite, farther north in Millers Cove, at apparently the same horizon. The bentonite has no peculiar surface indications, so that it was not observed at other localities although a search was made for it.

This bed of bentonite is about 80 feet above the top of the Athens shale. The intervening beds are red-brown sandstone and shale, thick-bedded at the base and flaggy near the bentonite. A massive, brown sandstone, about 3 feet thick, is found midway between the Athens shale and the bentonite. The beds just above the bentonite are shale and flaggy sandstone. Several of the shale zones are purple and yellow. A species of *Lingula* was found below and above the bentonite.

The bentonite is in thin beds whose total thickness is about 2 feet. Dark-purple and yellow-green layers are interbedded. The bentonite is extremely smooth and unctuous and contains tiny flakes of mica. Upon microscopic examination the material appears to be pyroclastic in origin, as it contains numerous fragments of volcanic glass.

The presence of bentonite in beds of this age has been known for some time, as Nelson [66] has described several occurrences. Recent papers by Giles[67] and by Ross[68] also deal with its occurrence in Virginia. This bentonite is of scientific interest only, because it is a decomposed volcanic ash, and its presence in Ordovician rocks indicates volcanic activity in the eastern United States at a time which has generally been considered devoid of volcanism.

Fossils.—Only a few specimens of a fossil resembling *Lingula nicklesi* (Bassler) have been found in the Moccasin formation.

MARTINSBURG SHALE

Definition.—The Martinsburg shale of this report is the thick mass of gray and brown shale which overlies the Athens shale and underlies the thick Silurian sandstone. The name was given by Darton[69] from Martinsburg, West Virginia. This formation has been called the Sevier shale in many of the geologic folios on parts of southwestern Virginia, because it was formerly considered to be equiva-

[66]Nelson, W. A., Volcanic ash bed in the Ordovician of Tennessee, Kentucky, and Alabama: Geol. Soc. America Bull., vol. 33, pp. 605-615, 1922; Volcanic ash deposit in the Ordovician of Virginia (abstract): Geol. Soc. America Bull., vol. 37, pp. 149-150, 1926.

[67]Giles, A. W., The origin and occurrence in Rockbridge County, Virginia, of so-called "Bentonite:" Jour. Geology, vol. 35, pp. 527-541. 1927.

[68]Ross, C. S., Altered Paleozoic volcanic materials and their recognition: Am. Assoc. Petroleum Geologists, Bull., vol. 12, pp. 143-164, 1928.

[69]Darton, N. H., Notes on the stratigraphy of a portion of central Appalachian Virginia: Am. Geologist, vol. 10, p. 13, 1892.

lent to the Sevier shale of Tennessee. It is now known to be younger than the typical Sevier. The Martinsburg shale includes beds of Trenton, Eden, and Maysville age.

Distribution.—The Martinsburg shale crops out in a belt between the Athens shale and Clinch sandstone along the north and west slopes of Catawba and Paris mountains from Montgomery County to Botetourt County. It is found also along the northern side of Roanoke Valley, from Little Brushy Mountain along the south base of Smith Ridge to a point beyond Carvins Creek. (See Pl. 1.) Exposures of the shale are common in both of these belts. The creeks which flow northward along Catawba Mountain expose abundant ledges of the shale, and Mason, Peters, and Carvins creeks have entrenched themselves in the southern belt of the formation.

As the Martinsburg shale crops out along belts of the resistant Clinch sandstone, the topography of the shale is largely controlled by the harder formation. The lowest beds are more resistant and make shoulders along the higher slopes. They form a series of hills of the third order of magnitude in the valleys.

Character and thickness.—The Martinsburg formation is a mass of calcareous shale, thin flaggy sandstone, and thinly bedded crystalline limestone. It ranges in thickness from 900 to 1,100 feet. The lowest part consists of gray to buff sandstone and shale. The middle part comprises yellow sandy shale and an abundance of dark-gray limy shale and thin crystalline limestone. The uppermost part consists of coarse brown sandstone and brown sandy shale. Marine fossils are found abundantly in most of the beds except in the lowest 250 feet, which is almost barren.

The soils are light brown, in contrast to the deep-red soils of the limestones in this area. The soils of the Martinsburg shales are chiefly on slopes too steep for cultivation, but they furnish good pasturage where cleared.

Relations.—There was an erosion interval between the deposition of the Athens shale and the Martinsburg shale, but there does not seem to be a structural unconformity between the two formations. The Clinch sandstone was deposited upon an undulatory erosion surface in the Martinsburg shale. There is a great hiatus between the Athens and Moccasin, and a smaller one between the Moccasin and Martinsburg, due to the absence of the Chambersburg limestone.

Subdivisions.—The Martinsburg shale is subdivisible into three divisions on the basis of its fossil content and, to a lesser degree, its lithology, namely, (1) the Trenton, (2) the Eden, and (3) the Maysville. These divisions are discussed below.

Trenton division.—The lowest division of the Martinsburg shale is of Trenton age. This division consists predominantly of knotty, fissile, calcareous, fossiliferous, gray shale alternating with impure, sandy gray limestone. The fresh shale resembles gray, thinly bedded limestone similar to the lighter-colored beds of the Athens shale, with which it might be confused, but the gray Trenton shale does not weather into slivers as does the gray Athens shale. The top of the Trenton in this area is marked by several thick limestones which contain many small gastropods.

The beds disintegrate rapidly under the attack of the weather and the soils are easily washed away. The soils weather to a yellow-brown clay which, where mixed with other soils, is very fertile.

The thickness of the Trenton division is about 750 feet, which is greater than in adjacent regions. The Trenton beds are well exposed along the north slope of Catawba Mountain, just below the crest. They are found at the northern edge of Roanoke Valley along the base of Smith Ridge, and on Little Brushy Mountain, northwest of Salem.

Some horizons of the Trenton are abundantly fossiliferous, and others are barren. The following fossils were observed in outcrops along the Salem-Newcastle highway on Catawba Mountain:

Lasiograptus sp.
Prasopora simulatrix Ulrich.
Zygospira recurvirostris (Hall).
Plectambonites sericeus (Sowerby).
Pholidops cf. cincinnatiensis.
Dalmanella testudinaria (Dalman).
Parastrophia hemiplicata Hall.
Rafinesquina alternata (Emmons).
Hebertella borealis (Billings).
Sinuites cancellatus Hall.
Orthoceras sp.
Crinoid stems.
Cryptolithus tesselatus Green.
Ceraurus cf. pleurexanthemus.
Calymene sp.
Triarthrus becki (Eaton).

Eden division.—The beds above the Trenton beds consist principally of shale which becomes increasingly sandy upward. These shales and sandstones constitute the Eden and Maysville divisions of the Martinsburg shale.

The lower part of the Eden division consists of about 100 feet of fissile, gray-brown shale containing scattered beds of limestone. The upper part consists of calcareous shale and gray-green sandstone, about 50 feet thick. The shale weathers commonly into small rhombic or triangular blocks. The beds crumble readily and are generally exposed only in roadside gullies or in creek beds. Their soils are yellow and brown, and moderately productive, although their outcrops are not everywhere suitable for farming.

The Eden beds apparently are conformable to the Trenton below, and there is no evident unconformity at the top of the Eden.

These beds are fossiliferous, containing typical Eden fossils and many species common to both the Eden and the Trenton divisions. The following fossils were collected from the Eden division of the Martinsburg shale along the north slope of Catawba Mountain:

Callopora sigillaroides Nicholson.
Rafinesquina alternata (Emmons).
Dalmanella testudinaria (Dalman).
Plectambonites sericeus (Sowerby).
Zygospira recurvirostris (Hall).
Calymene callicephala Green.

Maysville division.—The upper 125 feet of the Martinsburg formation on Catawba Mountain contains Maysville fossils. The rock is gray and greenish-brown, thinly-bedded, sparsely fossiliferous sandstone. The horizon is easily recognized by (1) its deep-brown color, (2) the friable nature of the rocks, (3) an abundance of *Orthorhynchula,* and (4) its position just below the thick Clinch sandstone. The formation is comparatively thin and has no distinctive topographic expression. Its soils are generally polluted by wash and float from the overlying Clinch sandstone, so that the belt of Maysville is seldom cleared for farming, although it makes fair pasture land.

The following fossils are found in the Maysville division of the Martinsburg shale in the Roanoke area:

Lingula nicklesi (Bassler).
Orthorhynchula linneyi James.
Byssonychia radiata Hall.
    walkerensis Grabau.
Modiolopsis modiolaris Conrad.

There is an unconformity or hiatus at the top of the Martinsburg, due to the absence of the Oswego sandstone and Juniata formation; the latter is locally present, however, on Catawba Mountain several miles south of Catawba.

SILURIAN SYSTEM

CLINCH SANDSTONE

Definition.—This formation was called by Safford[70] the Clinch Mountain sandstone, from Clinch Mountain, Tennessee. In 1869, he[71] shortened the name to Clinch sandstone, including both the "white Clinch sandstone of present usage, which is of Silurian age, and the underlying red Bays sandstone, which is of Ordovician age. The name Clinch was restricted by Keith[72] in 1895 . . . to the upper white sandstone, to which it is now universally applied."[73]

Distribution.—The Clinch sandstone is one of the most persistent and conspicuous formations in western Virginia. It extends through the Appalachian Valley in this State. Its hardness, color, and bold topography make it one of the most easily recognizable horizons in the region, and thus a most convenient keybed for field correlation.

Exposures of the Clinch may be observed anywhere along the crests of Catawba, Cove, Mills (Reeds), or Tinker mountains. They are especially fine in the gorge of Carvins Creek through Smith Ridge, consisting of nearly vertical beds. (See Pl. 3.)

Character.—The Clinch consists of several sandstones and conglomerates separated by thin shale beds. The whole mass is unevenly bedded, dense, highly indurated, and very resistant to weathering. The sandstones are extremely hard, almost quartzitic, and seldom are friable even after weathering. They are composed of rounded, fine to coarse, quartz grains. Many beds are cross-bedded and some are ripple-marked. The sandstones are prevailingly white, gray, and pink, and commonly weather rusty-brown. The conglomeratic beds are massive, and contain rounded quartz pebbles in a matrix of sand grains. The shale beds are generally red, thin, flaggy, and sandy. They are more abundant toward the top of the formation.

The Clinch has been folded into large open folds, but has not been excessively crushed or crumpled in the process. Many of

[70]Safford, J. M., A geological reconnaissance of the State of Tennessee; being the author's first biennial report: p. 15, Nashville, 1856.
[71]Safford, J. M., Geology of Tennessee, Nashville, 1869.
[72]Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Loudon folio (No. 25), p. 4, 1896.
[73]Wilmarth, M. Grace, Personal communication.

the surfaces show slickensides, caused by internal slipping along bedding-planes. The formation contains many small faults.

The Clinch soil is sandy, sterile, and sparse, and is seldom advantageously situated for agriculture. It commonly supports hardwood forests with scattered evergreens.

Thickness.—The thickness of the Clinch sandstone in the Roanoke area ranges from 10 to 100 feet. The formation is thinner than in northern Virginia where it is reported to be 500 to 800 feet thick.

Relations.—The Clinch formation is disconformably overlain by the Clinton formation. It generally rests disconformably upon the Maysville division of the Martinsburg shale, as beds of Richmond age are absent, except locally, in this area.

Topographic expression.—The Clinch sandstone is a ridge-maker of the first order of magnitude, and its hills are massive, prominent, and picturesque. Where the formation is tilted at moderate angles, it forms sharp-crested ridges; where horizontal, its hills are flat-topped and of medium height. Its outcrop is generally bare with many cliffs and ledges.

In the Roanoke area, five distinct ridges may be attributed to the Clinch sandstone. The largest is the Catawba-Tinker-Paris Mountain ridge, which reaches its highest elevation of 3,201 feet in McAfee Knob. This mountain continues southwest into Montgomery County, and northeast into Botetourt County. Other ridges formed by the Clinch sandstone are Johns Creek Mountain, Sinking Creek Mountain, Cove Mountain, and Mills (Reeds) and Coyner mountains. (See Pls. 1, 2, 8, and 20.)

Fossils and correlation.—Fossils are uncommon and poorly preserved in the Clinch sandstone. The dubious markings called *Arthrophycus* and *Scolithus* were observed along Catawba Mountain, but no other forms, except a vague arthropod-like fragment, were noted. In Giles County,[74] 20 miles to the northwest, the following species are from this horizon:

Arthrophycus alleghaniensis (Hall).
Scolithus sp.

The same fauna has been reported in Scott and Wise counties.

The Clinch sandstone is of Medina, or early Silurian age. It corresponds to the Tuscarora quartzite of northwestern Virginia. It is also probably equivalent to the lower part of the "Massanutten sandstone" of Massanutten Mountain in Rockingham County, Virginia.

[74]Hubbard, H. D., and Croneis, C. G., Notes on the geology of Giles County, Virginia: Denison Univ. Bull., Jour. Sci. Laboratories, vol. 20, p. 347, 1924.

CLINTON FORMATION

Definition.—The Clinton horizon of New York is represented in the Roanoke area and in most of western Virginia. In western Virginia it has generally been correlated with the Rockwood formation of Roane County, Tennessee, but according to Ulrich[75] the Rockwood of the type locality does not include beds as young as the true Clinton. The lower part of the Clinton of the Roanoke area apparently corresponds to the Cacapon sandstone, and the upper part to the Keefer sandstone of northwestern Virginia.

Distribution.—The Clinton formation crops out in belts parallel to the Clinch sandstone. The largest single belt in this area is along the upper third of the south slope of Catawba Mountain and its extensions. The Clinton crops out also along the Salem-Newcastle road which crosses Catawba Mountain near Catawba. The beds dip southeastward at moderate angles. The Clinton is also exposed along Cove Mountain, in the northwestern part of Roanoke County, and is well exposed along the wagon road which ascends Dead Man's Mountain to Camp Lamotte. It is probable that the upper sandstone at the dam on Carvins Creek is the Keefer division of the Clinton, as is the sandstone on the upper slope of the south side of Catawba Mountain.

Character and thickness.—In the Roanoke area, the Clinton formation consists of a heterogeneous mass of shale and sandstone of variable thickness and composition. The shale is green and buff, and the sandstone is prevailingly white and red. A few lenticular calcareous beds are found in the Clinton. The lower 100 feet of the formation consists of soft red sandstone and shale which appear to be equivalent to the Cacapon sandstone of northern Virginia. These beds weather readily into benches along the slopes of ridges of Clinch sandstone. As their soil is fertile compared to the sandy soils of the upper Clinton and of the Clinch, this belt is in places cleared and farmed. It is thus conspicuous along the crests of the mountains, although few exposures of the basal beds can be found.

Above the lower beds there is about 300 feet of red and white sandstone interbedded with red and buff shale. The sandstones are generally massive but are very friable. Some beds are very hard, resistant, and ferruginous. These beds are brick-red and resemble bedded iron ores.

[75]Butts, Charles, Personal communication.

Fossils.—The Clinton formation is poorly fossiliferous in Roanoke County. No fossils were collected from it here. The following species have been reported from Giles County:[76]

Atrypa reticularis Linne.
Camarotœchia neglecta (Hall).
Anoplotheca hemispherica (Sowerby).
Buthotrephis gracilis var. crassa Hall.
Mastigobolbina lata (Hall).
Calymene clintoni (Vanuxem).

These fossils have been found in the Clinton formation in Scott and Wise counties:[77]

Anoplotheca hemispherica (Sowerby).
Mastigobolbina typus Ulrich and Bassler.
Bonnemaia sp.
Zygobolba sp.
Calymene clintoni (Vanuxem).

Economic character.—The Clinton formation contains beds equivalent to the beds of Clinton iron in New York and Alabama. No workable deposits of this iron were found in the Roanoke area, but float was observed along Catawba, Little Brushy, and Mills (Reeds) mountains. The Clinton iron deposits of the Roanoke region are of no commercial value. Some of the sandstone has been quarried for glass sand along the south slope of Catawba Mountain in Roanoke County.

DEVONIAN SYSTEM

HELDERBERG GROUP

General statement.—The Lower Devonian, or Helderberg group, is poorly represented in the Roanoke area. In the section along the southeastern base of Catawba Mountain, about 25 feet of friable cross-bedded sandstone overlying the Clinton formation is considered to be in this group. Several miles farther north, along the Salem-Newcastle road half a mile south of Newcastle, about 50 feet of dark-blue fossiliferous limestone of Helderberg age is found directly below Onondaga shale. This limestone is absent or concealed in the Catawba Mountain section. The Helderberg is found also along the road to Camp Lamotte at the top of Tinker Mountain.

[76]Hubbard, G. D., and Croneis, C. G., Notes on the geology of Giles County, Virginia: Denison Univ. Bull., Jour. Sci. Laboratories, vol. 20, p. 348, 1924.

[77]Stose, G. W., *in* Eby., J. B., and others, The geology and mineral resources of Wise County and the coal-bearing portion of Scott County, Virginia: Virginia Geol. Survey Bull. 24, pp. 33 and 36, and Pl. XXXII, 1923.

The Lower Devonian beds have been grouped in southwestern Virginia under the "Giles formation," named from sections in Giles County. In this report these beds are referred to the Helderberg group. It should be noted that uppermost Silurian beds, not unlike rocks of true Helderberg age, have been found in western Virginia. It is thus possible that the belt of Helderberg rocks shown on the geologic map (Pl. 1) may include thin beds of late Silurian (Monroan or Cayugan) age which have not been differentiated from the Helderberg formations, although none have been observed in this area.

No undoubted Oriskany beds were observed in the Roanoke area. The sandstone which has generally been described as the Oriskany sandstone is now known to underlie Helderberg limestone.

Distribution and character.—The most conspicuous member of this group is a rough-bedded, granular, generally soft and friable sandstone. It is commonly gray or brown, is in places ferruginous, and closely resembles the typical Oriskany sandstone of areas farther north. This sandstone here, and in many other areas, underlies fossiliferous Helderberg limestone and is, therefore, of earlier age.

This sandstone occurs along the Salem-Newscastle highway at the base of the southeastern slope of Catawba Mountain. Here is exposed about 25 feet of coarse, cross-bedded sandstone, the lower part being very friable and ferruginous, and the upper part being dense and white. The lower half of this sandstone is much stained with manganese. Silicified remains of bryozoa and brachiopod shells are weathered out on the surfaces of the exposed ledges. Several large orthoceroid cephalopods, and specimens of *Cladopora* and *Rhipidomella* were found here. This sandstone overlies the Clinton formation.[78]

In the region south of Newcastle, a massive dark-blue fossiliferous limestone occurs between this sandstone and the Onondaga shale above. It contains beds of black chert which weather into bands along exposed ledges. About 50 feet of this limestone is exposed along the Salem-Newcastle road half a mile south of Newcastle. This limestone contains an abundance of typical Helderberg fossils, which are of Becraft age. The following species were collected:

[78]Since this report was written the results of a study by Frank McKim Swartz, entitled "The Helderberg group of parts of West Virginia and Virginia," have been published as U. S. Geol. Survey Prof. Paper 158, pp. 27-75, 1929. It is thought by the writer that the Helderberg sandstone of this report corresponds to the Clifton Forge sandstone, named and described by Swartz as a member of the Keyser formation, but it may be younger.

Spirifer concinnus Hall.
Eatonia peculiaris (Conrad).
Leptaena rhomboidalis (Wilckens).
Uncinulus vellicatus (Hall).
Strophonella leavenworthana (Hall).
Meristella lata (Hall).

This limestone has not been found south of Catawba Valley in the Roanoke area.

Thickness.—The observed thickness of the Helderberg beds in the Roanoke area does not exceed 60 feet. To the north, near Eagle Rock, Botetourt County, and to the west in Giles County, thicknesses of 150 to 200 feet have been observed.

ONONDAGA FORMATION

Occurrence and character.—Above the Helderberg (?) sandstone in the Catawba area is found about 15 feet of thinly bedded white chert and smooth drab shale, which is equivalent to the Onondaga limestone of New York and Pennsylvania. Kindle[79] reports the following fossils from these beds in Catawba Valley:

Zaphrentis cf. simplex Hall.
Cladopora sp.
Leptaenisca australis Kindle.
Dalmenella lenticularis (Vanuxem).
Anoplotheca acutiplicata (Conrad).
Odontocephalus aegeria Hall.
Bollia ungula Jones.

ROMNEY SHALE

Definition.—Above the Helderberg rocks in the Roanoke area are several hundred feet of black and drab shale, the Romney shale of this report. This shale occupies about the same stratigraphic position as the Romney shale as defined by Darton,[80] at Romney, Hampshire County, West Virginia. It does not, however, entirely represent the horizon of the true Romney shale, which comprises beds of Onondaga, Marcellus, and Hamilton age.

Character.—The Romney formation consists of dark-gray to black, fissile, carbonaceous shale. The shale is lighter colored toward the top and grades into the overlying Brallier shale. A few calcareous

[79]Kindle, E. M., The Onondaga fauna of the Allegheny region: U. S. Geol. Survey Bull. 508. pp. 46-47, 1912.
[80]Darton, N. H., Notes on the stratigraphy of a portion of central Appalachian Virginia: Am. Geologist, vol. 10, p. 17, 1892.

lenses occur near the base. The shales are uniformly thinly bedded, and crumble into small splintery fragments in the soil. The soils are generally unproductive, resulting in a series of valleys which are sparsely settled.

The shale has been mistakenly prospected for coal at several places on Fort Lewis Mountain, in Carvins Cove, and between Mills (Reeds) and Coyners mountains. It does not contain coal. The exposed shale exfoliates readily into thin even laminae. Its surface is commonly stained with iron, and the beds become slightly olive-colored upon weathering.

Thickness.—The maximum thickness of the Romney shale is about 500 feet. In Montgomery County it has been assigned a thickness of 800 feet, and northeast of Roanoke County, from 100 to 600 feet. The beds are closely folded and are broken by small local faults, so that it is impossible to determine accurately the thickness of the formation.

Distribution and topography.—As the Romney shale is relatively soft and slightly resistant to erosion, it produces wide, open valleys between the hills of the resistant Clinch sandstone and the moderately resistant Upper Devonian sandy shale and sandstone. The formation crops out in a long narrow continuous valley south of the Catawba-Tinker mountain ridge, and north of the Green Ridge-Fort Lewis mountain mass. This great valley is called Carvins Cove to the northeast, Mason Cove near the Catawba Sanatorium, and Bradshaw Cove to the southwest. It is drained to the south by Carvins, Mason, and Bradshaw creeks. The divides between the headwaters of these creeks are very low and poorly defined. A second belt of the Romney shale extends south of Green Ridge and Fort Lewis Mountain from Carvins Cove to a point near Salem. This belt is marked also by a sharp valley, which is well developed between Smith and Green ridges. This belt merges into the first belt at Carvins Falls, and forms a wide, open basin behind Smith Ridge. A small exposure of the black shale was noted between Mills (Reeds) and Coyners mountains, and along the northwest slope of Coyners Mountain. This belt is terminated at each end by a fault, and the shale in it has been much crushed and broken.

Good exposures of the shale can be seen (1) along the road through Mason, Bradshaw, and Carvins coves, (2) in a cut at the north end of the Catawba Branch of the Norfolk and Western Railroad, and (3) along the Salem-Newcastle road.

Relations.—The Romney shale in Roanoke County rests upon Helderberg beds, without structural unconformity, although there is evidence of an erosional disconformity. This hiatus is commonly marked in this area by the absence of the greater part of the Oriskany group, which is reported by Butts[81] to be 300 to 500 feet thick in central Pennsylvania. On Massanutten Mountain, 150 miles to the northeast, Spencer[82] records an angular unconformity between the Romney and the Oriskany. The Romney shale grades into the overlying Brallier shale.

Fossils.—Some beds in the lower part of this formation are very fossiliferous but others are barren. In the cut at the north end of the Catawba Branch of the Norfolk and Western Railway, the following forms were observed:

Leiorhynchus limatare Vanuxem.
Stropholosia truncata Hall.
Schizobolus cf. concentricus.
Tentaculites sp.
Styliolina fissurella Hall.
Nuculites oblongatus Conrad.
Goniatites (two species).
Plant remains.
Fucoidal markings.
Fish scale (?).

Fossils are relatively rare in the upper part of the Romney shale, although an abundance of *Lingula* and *Orbiculoides* was found along the road in Carvins Cove about 1 mile north of Carvins Falls. Near Cove Alum Springs, beds of black shale contain the large coiled goniatites, *Probeloceras* and *Manticoceras,* some conodonts, *Styliolina,* and *Buchiola.* This black shale has a Portage fauna. According to Butts,[83] "The Romney undoubtedly includes the lower Portage, Naples, beds and very thin representatives of the Marcellus and Hamilton." For convenience in mapping, the base of the Portage (Brallier) shale in this area has been arbitrarily drawn at the top of the black shale.

BRALLIER SHALE

Definition.—This formation was named by Butts[84] at Brallier, Bedford County, Pennsylvania, where the shale is well exposed. It is upper Portage in age. Brallier is used in the Roanoke area at the suggestion of Butts[85] who advises that the use of the name Portage

[81]Butts, Charles, Letter of May 24, 1930.
[82]Spencer, A. C., The geology of Massanutten Mountain in Virginia, Washington, p. 13, 1897.
[83]Personal communication.
[84]Butts. Charles, Geologic section of Blair and Huntingdon counties, central Pennsylvania: Am. Jour. Sci., 4th ser., vol. 46, p. 523, 1918.
[85]Personal communication.

here is objectionable, as only a part of the Portage group, namely, the Gardeau shale, is represented.

Distribution.—The most continuous outcrop in the Roanoke area is in a belt 1 mile wide in the Catawba syncline, on the north flanks of Fort Lewis Mountain and Green Ridge. (See Pl. 1.) This belt can be traced continuously for 22 miles. Other outcrops are found in Moomaw Gap and on the north slope of Brush Mountain. Good exposures can be seen in Mason Cove along the main highway, and along the road about 3 miles west of Lafayette.

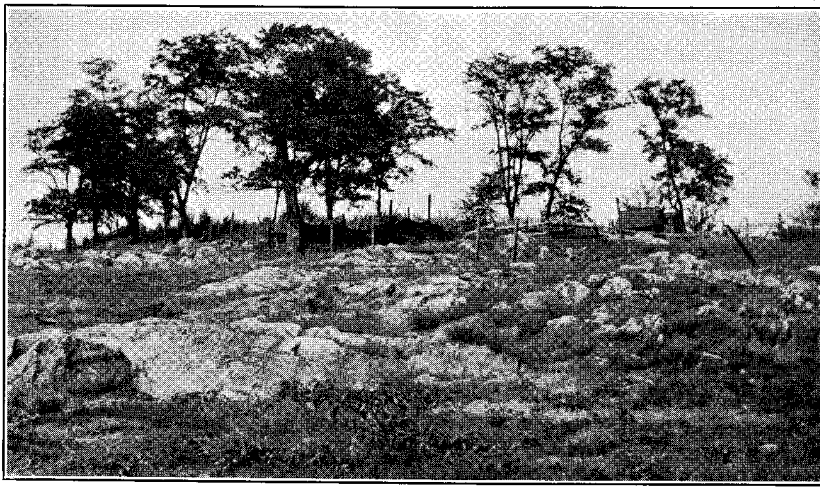
Character and relations.—The Brallier formation consists largely of greenish-gray shale interbedded with greenish-gray flaggy sandstone, all of which is so monotonously similar that it is impossible to divide the formation into smaller units. (See Pl. 18, A.) It is in part of marine origin, but contains many thin beds possibly of non-marine origin.

The base of the Brallier in this area has been arbitrarily chosen at the top of the black shale which is here called the Romney shale. This contact is poorly marked by a gradation from black shale below to greenish-gray or olive shale above. It is possible, as mentioned above, that some of the black shale in this area may be of Portage age.

The lower part of the Brallier is composed of irregularly alternating shale and thin flaggy sandstone. The shales are sandy, olive-brown to greenish-gray, and fissile. The sandstones are generally slightly darker than the shale, medium- to fine-grained, micaceous, and show abundant marks of shallow-water deposition. Toward the top of the formation, some of the shale gives place to sandstone. In this part of the Brallier, the sandstones are persistent and suitable for use as flagstones.

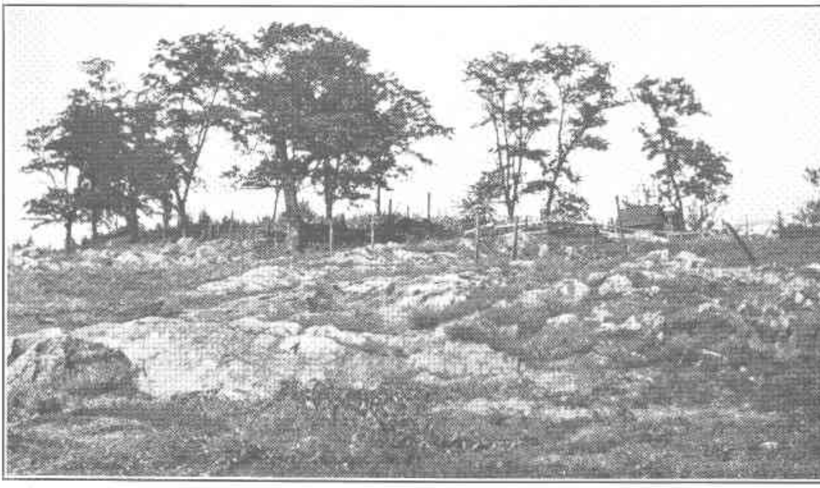
The Brallier shale grades imperceptibly into the Chemung formation above. It is very difficult to draw a definite lithologic boundary and fossils are so scarce that they can not be uniformly used. On the accompanying geologic map (Pl. 1), the contact has been taken at the base of the thick red-brown sandstone which characterizes the Chemung. This sandstone locally contains *Ambocoelia umbonata* (Conrad). There is no evidence of an unconformity between the Brallier and the adjacent formations, and no breaks were observed in the formation.

As the Brallier shale occurs between the slightly resistant Romney shale and the resistant Chemung formation, its topography is intermediate between the shale valleys and the sandstone ridges. Its soils are thin and sandy, but support hardwood forests and considerable underbrush. They give good pasturage where cleared.



A. Typical outcrops of Nittany dolomite, northwest of Daleville, Botetourt County. (See pp. 39-41.)

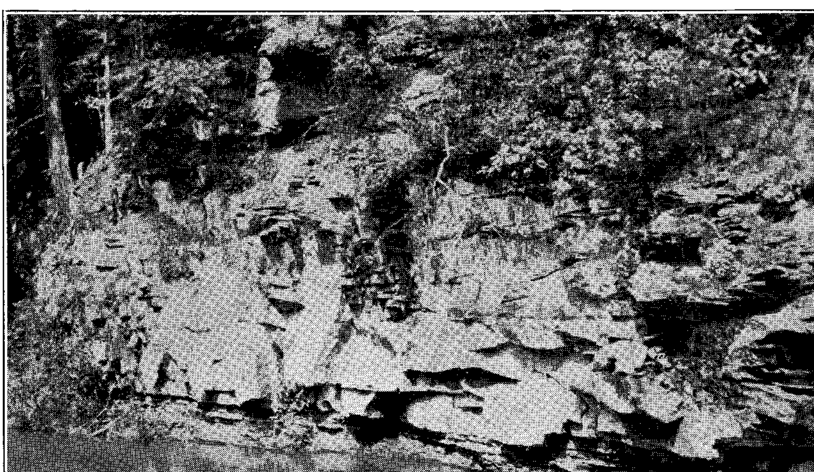
B. Athens shale along the Salem-Hollins road north of Roanoke. (See pp. 47-49.)



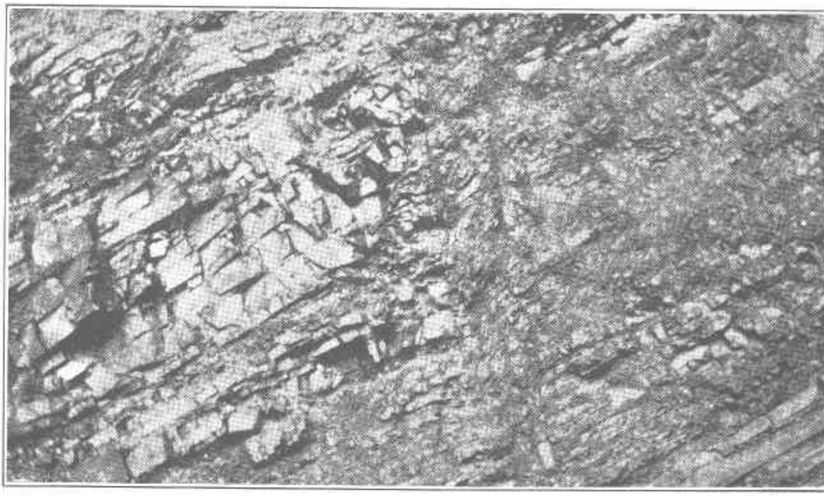
A. Typical outcrops of Nittany dolomite, northwest of Daleville, Botetourt County. (See pp. 39-41.)

B. Athens shale along the Salem-Hollins road north of Roanoke. (See pp. 47-49.)

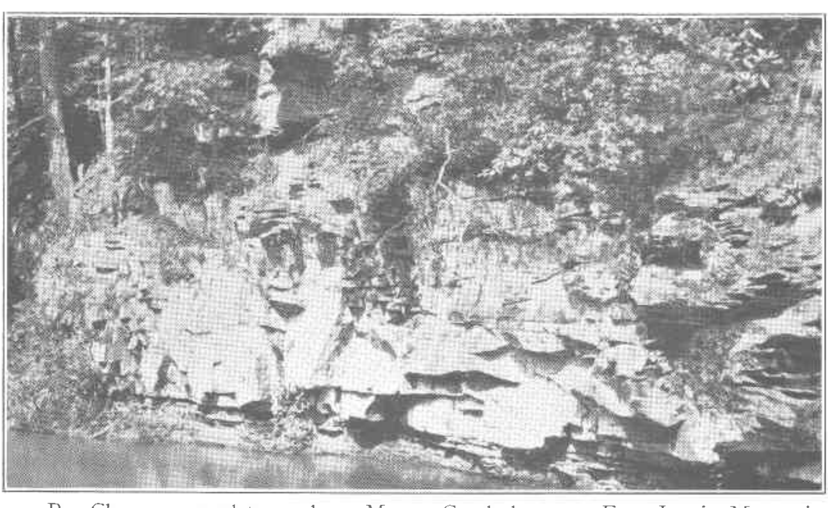
A. Brallier shale on Mason Creek in Mason Cove. Note the small fault in the center of the view. (See p. 64.)



B. Chemung sandstone along Mason Creek between Fort Lewis Mountain and Green Ridge. Looking northeast along the axis of the Catawba syncline. (See p. 65.) Photograph by Davis Photo Co. (Courtesy of Roanoke Chamber of Commerce.)



A. Brallier shale on Mason Creek in Mason Cove. Note the small fault in the center of the view. (See p. 64.)



B. Chemung sandstone along Mason Creek between Fort Lewis Mountain and Green Ridge. Looking northeast along the axis of the Catawba syncline. (See p. 65.) Photograph by Davis Photo Co. (Courtesy of Roanoke Chamber of Commerce.)

Thickness.—The Brallier shale is between 2,000 and 3,000 feet thick.

Fossils and correlation.—Only the lower part of the formation is known to contain fossils, and they are scarce. One of the most abundant forms is *Buchiola retrostriata* (von Buch). Several small pelecypods occur in the lower shale.

The Brallier shale is of Portage age, and according to Butts corresponds in part to the Gardeau beds of the New York section. This shale has been commonly included, together with the Chemung formation, in the Jennings formation in the northern counties of Virginia. With the Chemung formation it is the equivalent of the Kimberling shale as mapped in Tazewell and Giles counties.

CHEMUNG FORMATION

Character.—The Chemung formation contains many beds of sandstone and shale. (See Pl. 18, B.) The sandstones are thinly bedded or flaggy, micaceous, even-grained, greenish-buff and brownish-gray. They weather reddish-brown. Some beds are cross-bedded, ripple-marked, rill-marked, and contain mud-cracks. The shales are fissile, and in layers a few inches to several feet thick. They are more abundant toward the base of the formation, whereas the sandstones increase in number and thickness toward the top, so that the upper part of the Chemung formation is very similar to the lower part of the overlying Price formation. The contact between these two formations is conveniently drawn below a conglomerate (Ingles) at the base of the Price. The Chemung is similar to the Brallier but is more sandy.

Some of the more massive sandstones contain concretionary masses of sandy material up to 2 feet in diameter. These concretions contain no obvious nuclei, nor do they differ essentially in composition from the enclosing beds. They are enclosed by, but do not cut, the bedding planes of the sandstones. The outer rind of these concretions often breaks into curving slabs about 1 inch thick. Many of these concretions are found along Mason Creek, between Fort Lewis Mountain and Green Ridge, and along the Salem-Newcastle road about 2 miles beyond McAfee Gap, just north of the Roanoke County line.

The upper beds of this formation are dense and resistant and produce ridges of the first and second order of magnitude. Decay proceeds slowly so that ledges are abundant. The soils are thin, sandy, and full of tiny rock splinters. The outcrop where cleared makes good pasturage and supports sturdy hardwood forests.

Thickness.—Accurate determination of the thickness of the Chemung formation in this area is difficult. To the north where the formation is widely exposed, thicknesses of from 1,400 to 2,200 feet are reported. Its thickness in this area is estimated as at least 1,000 feet, and it may be as much as 2,500 feet.

Fossils.—Fossils are not common in the Chemung formation, although several horizons contain many specimens, chiefly crinoid stems. Along Mason Creek between Fort Lewis Mountain and Green Ridge, the following fossils were collected:

Spirifer disjunctus Sowerby.
  mesicostalis Hall.
Chonetes scitulus Hall.
Ambocoelia umbonata (Conrad).
Sphenotus contractus Hall.
Crinoid stems.
Plant remains.

MISSISSIPPIAN SYSTEM

OSAGE SERIES

PRICE FORMATION

Definition.—This formation was first called the "Montgomery Grits."[86] No description of the rocks was given, so that the exact application of the term is uncertain. Campbell[87] in 1896 renamed the formation from Price Mountain in Montgomery County, calling it the Price sandstone. He[88] later changed it to the Price formation. This term is here used for the coal-bearing Lower Mississippian rocks of the Roanoke area.

In Montgomery County, the Price formation includes at its base a white quartz conglomerate, which Campbell[89] called the Ingles conglomerate member, from Ingles Mountain in that county.

Character.—The Price formation consists of bluish-white sandstone, with thin beds of red shale near the top, and with a few conglomeratic beds of variable thickness. Most of the beds are lenticular and change rapidly from place to place.

Interbedded with the clastic sediments of the Price formation are a few beds of coal, some of which are of workable size and

[86]Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, New York, p. 717, 1884.
[87]Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Pocahontas folio (No. 26), p. 3, 1896.
[88]Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, p. 25, 1925.
[89]Op. cit., p. 26.

quality. In Pulaski and Montgomery counties, the important Merrimac seam occurs in this formation. The Merrimac seam does not crop out in Roanoke County, probably because it is covered by the Pulaski overthrust fault-block. Most of the coal beds are in the middle of the formation. Some have been prospected and mined in Roanoke County. The most important workings are on the T. G. Chapman property northeast of Catawba Sanatorium, where some pyritiferous coal has been mined.[90]

Ingles conglomerate.—The only persistent member of the Price formation is the basal Ingles conglomerate, which is 20 feet or more thick. It is a gray to white sandstone, generally containing white quartz pebbles scattered through it in thin and irregular masses. These pebbles have a maximum size of half an inch in diameter. Although the Ingles conglomerate is absent in some places and its outcrops are rather inaccessible, it makes a convenient horizon-marker where available. The Ingles conglomerate has been quarried at several places in Montgomery County for millstones and grindstones.

Distribution.—Exposures of the Price formation are common, with the sandstones forming conspicuous cliffs and ledges. The most important belt extends along the southeast slope of North Mountain from McAfee Gap to the north edge of Roanoke County. (See Pl. 1.) The most accessible exposures are back of Catawba Sanatorium. The formation here is cut off at the south by the great Pulaski overthrust, which has carried Cambrian-Ordovician formations upon the middle and upper beds of the Price formation. A second and similar belt extends along the south flank of Brush Mountain for about 5 miles in Roanoke County. Campbell[91] described a third outcrop as follows:

"The outcrop of the Price formation . . . . occupies a narrow zone on the south side of Fort Lewis Mountain extending from near Lafayette on the west toward Salem, but is probably cut off by the Salem fault before reaching a point opposite that town." The Price here goes to Mason Creek and probably crosses into Green Ridge.

The Price formation and the resistant sandstones of the underlying Chemung formation produce sharp ridges that are much like the mountainous ridges on the Clinch sandstone. The soils are thin and rocky and not adapted for agriculture, although they support hardwood forests.

---

[90]Campbell, M. R., and others, op. cit., p. 279.
[91]Op. cit., p. 276.

Thickness.—Campbell[92] records a thickness of 1,700 to 1,800 feet for the entire Price formation in Montgomery County. No complete section is available in Roanoke County. The Price is found in Roanoke County only in narrow belts, and it is probable that only the lowest beds are present here. It is about 600 feet thick in Bland County.

Fossils and age.—Fossils were not found in the Price formation in the Roanoke area. No faunal lists are given in descriptions of the formation in adjacent areas. Campbell[93] mentions marine fossil shells in these beds in Montgomery and Pulaski counties. According to Butts, the Price is in general non-marine, but there were a few brief marine invasions leaving thin fossiliferous layers, at least nearly as far north as Blacksburg.

The formation is of early Mississippian age. It is the southern extension of the Pocono sandstone of Pennsylvania and West Virginia. In the geologic folios on the Bristol and Estillville quadrangles in southwestern Virginia the horizon of the Price sandstone was included in the Grainger formation.

QUATERNARY DEPOSITS

GENERAL STATEMENT

The next youngest sediments above the Price formation in this area are unconsolidated deposits of Quaternary age. All of the later Paleozoic formations and the Mesozoic formations are wanting here.

The Quaternary deposits in this area are gravels, clays, and sands which occur along the streams and in terrace remnants scattered irregularly along the larger valleys. These deposits are not shown on the geologic map of the area because their distribution was not studied in detail. They are rarely more than 50 feet thick.

Two types of Quaternary deposits may be distinguished, namely, (1) transported gravels and sands, and (2) residual clays and loams.

STREAM DEPOSITS

The transported materials are largely stream deposits which have been made in favorable places along present and former beds of streams. They are found at various elevations in the area up to a considerable height above the present streams. The materials were derived by weathering and erosion of the older rocks. The gravels are composed of resistant materials, chiefly chert, quartzite,

[92]Op. cit., p. 24.
[93]Op. cit., p. 24.

and igneous rocks. They are commonly subrounded, but many boulders are angular or rounded. The sands are composed largely of pure quartz grains derived from the erosion of older sandstone or from the decomposition of quartz-bearing crystalline rocks. In most places the Quaternary deposits are poorly assorted.

ECONOMIC USE

Where the deposits are assorted into beds of sand and gravel, they may be profitably used for building materials. Upon the Valley-floor peneplane, there occurs in places much gravel and sand, which have been spread out from the adjacent mountains. The southwest end of Mills (Reeds) Mountain has furnished material for a wide blanket of sand and gravel which is spread around three sides of the mountain. Similar deposits are found along the north side of the Blue Ridge from Fullhardt Knob to Buchanan.

RESIDUAL DEPOSITS

The residual soils and clays have been developed largely in the valleys. The clays are typical products of the decay of the underlying limestones. Where the rock is chert-producing, as is the Nittany dolomite, the soil is peppered with fragments of the unweathered chert. Where no chert occurs, the residual clays may be very fertile and productive.

MARL

Mention should be made of small scattered deposits of marl which have been formed upon the outcrops of some of the limestones. The largest deposit occurs about 1 mile north of Daleville, Botetourt County. It is about 20 feet thick at a maximum. It occupies the bed of an old lake which had an area of about 1 acre. The marl contains abundant leaves, stems of plants, and a few gastropod shells. Marl beds are found also near the Lynchburg, or Grubb, iron mines west of Blue Ridge Springs.

While many of the Quaternary deposits are of Recent age, others are undoubtedly of Pleistocene age. Some of these unconsolidated deposits may be Pliocene.

FOSSILS

Plants.—Fossils are very rare and the forms which do occur are seldom diagnostic. Abundant plant remains can be obtained from the marl, but none have been identified. Roy J. Holden of Blacksburg informed the writer that a collection of plants had been identified from marls and clays near the Lynchburg mines as being of Recent age.

Mastodon remains.—Early in September, 1927, a few mammal bones were unearthed in the course of an excavation in the "east-end" yards of the Norfolk and Western Railway in Roanoke. These bones were about 8 feet below the surface and were in a fair state of preservation. They consisted of the jawbone and tooth of a mastodon embedded in mud and loam through which small decayed fragments of bone were scattered. The tooth was 6½ inches long and about 3 inches wide. The jawbone measured about 3½ inches between the sockets. The fossils probably belonged to the mastodon *Mammut americanum* Kerr which ranged over eastern North America, and became extinct about the time that the American Indians first became established here. Remains of these animals are found in many scattered localities in the eastern part of North America, but are generally rare in a given locality. The writer knows of no other discovery of these fossils in this area.

Indian Relics

Flints and arrow-heads made by the Indians are common in the surface gravels, but these date back no farther than a few centuries.

MEASURED SECTION

The sedimentary rocks of the Roanoke area south of the Salem overthrust are seldom exposed in continuous sections in which it is possible to determine the true thickness by trigonometric computation. North of this fault, in the Catawba syncline, such measurements may be made, but at no place more conveniently than across Catawba Mountain along the Salem-Newcastle road. The rocks here dip southeastward at high angles, averaging 60°, and are ideally located for study. Ozarkian to Middle Devonian formations are well exposed. This section has been studied by several geologists, and two discussions of the formations have been published.[94]

There follows a complete measured section of the beds exposed along the Salem-Newcastle road from the base of the Romney shale to the Pulaski thrust-fault, which cuts through the Ozarkian lime-

[94]Powell, S. L., Discovery of the Normanskill graptolite fauna in the Athens shale of southwestern Virginia: Jour. Geology, vol. 23, pp. 272-281, 1915.
Raymond, P. E., The correlation of the Ordovician strata of the Baltic Basin with those of eastern North America: Harvard Coll., Mus. Comp. Zoology Bull., vol. 56, no. 3, pp. 235-238, 1916.

stone at the base of North Mountain. Similar sections measured by Reger[95] in Giles County about 40 miles to the west, and in Monroe County, West Virginia, about 30 miles to the northwest have been published.

Formations on Catawba Mountain, Roanoke County, Virginia

Section starting in the Salem-Newcastle highway at the southeast base of Catawba Mountain and traversing northwestward along the road to Catawba Post Office; then offsetting one-quarter of a mile to the west and continuing along the road from the top of the Athens shale, and ending about half a mile south of North Mountain and about 2 miles west of Catawba Post Office. Length of traverse is about 14,000 feet; dip is southeast; beds are arranged in descending stratigraphic order.

	Thickness	
Romney shale (not measured)		
Onondaga formation (15 feet):	Feet	Feet
1. Thinly bedded white chert and olive-drab shale	15	15
Helderberg sandstone (24 feet):		
2. Dense friable white sandstone	12	27
3. Friable cross-bedded ferruginous sandstone containing *Rhipidomella* and *Cladopora*	12	39
Clinton formation (390 feet):		
4. Red and white thin sandstone and red and buff shale	70	109
5. Soft, friable white to buff sandstone and red shale	15	124
6. Red and white sandstone and shale	23	147
7. Red sandstone	5	152
8. Massive white sandstone	15	167
9. Red shale	2	169
10. Red and white evenly bedded sandstone	115	284
11. Crumbly white and buff sandstone	25	309
12. Hard white sandstone	10	319
13. Soft buff shale, mostly covered	110	429
Clinch sandstone (55 feet):		
14. Hard white quartzite, in ledges, conglomeratic at base	55	484

[95]Reger, D. B., Geology of Mercer, Monroe, and Summers counties, West Virginia: West Virginia Geol. Survey, County Reports, pp. 209-211, 234-236, 1926.

	Thickness Feet	Feet
Martinsburg shale, Maysville division (126 feet):		
15. Thinly bedded gray and brownish-green sandstone containing *Orthorhynchula, Byssonychia,* and *Modiolopsis*	126	610
Martinsburg shale, Eden division (148 feet):		
16. Thick gray-green sandstone	10	620
17. Thin, fissile shale and thin sandstone	35	655
18. Gray-green sandstone, conchoidal weathering	3	658
19. Thin, fissile gray-brown shale containing *Rafinesquina, Dalmanella,* and *Zygospira*	100	758
Martinsburg shale, Trenton division (754 feet):		
20. Thick-bedded gray limy sandstone, containing gastropods	19	777
21. Gray shale and limestone containing *Zygospira, Plectambonites,* and *Dalmanella*	52	829
22. Massive gray limestone containing gastropods	4	833
23. Thick-bedded limy sandstone and gray shale	50	883
24. Thin, fissile gray shale	50	933
25. Thin gray-brown knotty shale containing *Plectambonites, Zygospira,* and *Pholidops*	50	983
26. Limestone, in part knotty, with gray shale partings	94	1,077
27. Thin sandstone and gray knotty shale	80	1,157
28. Gray fissile and knotty shale	47	1,204
29. Knotty shale containing an abundance of *Prasopora*	4	1,208
30. Thin, fissile, gray, knotty shale containing *Dalmanella, Cryptolithus,* and *Sinuites*	84	1,292
31. Thin gray shale	50	1,342
32. Sandy shale, more massive than above	30	1,372
33. Thin gray shale containing *Calymene, Dalmanella,* and *Herbertella*	40	1,412
34. Mostly covered; gray limy shale	100	1,512
Moccasin formation (181 feet):		
35. Thin sandstone with shale partings	41	1,553
36. Thin yellow and purple shale	4	1,557
37. Sandstone and thin beds of shale	18	1,575
38. Thin purple shale	3	1,578

	Thickness Feet	Feet
Moccasin formation—Continued.		
39. Thin yellow and purple shale	11	1,589
40. Thin, fissile brown shale and sandstone; contains two species of *Lingula*	21	1,610
41. Bentonite, red and greenish-blue	3	1,613
42. Thin, flaggy sandstone and shale	21	1,634
43. Thin sandstone and shale containing *Lingula*	16	1,650
44. Massive brown sandstone, conchoidal weathering	3	1,653
45. Flaggy red-brown sandstone and shale containing *Lingula*	40	1,693
Athens shale (971 feet):		
46. Blue-black limy shales containing *Triarthus, Nemagraptus,* and *Climacograptus*	400	2,093
47. Dark-gray thin limestone and black shale containing *Cryptolithus, Robergia,* and *Nemagraptus*	190	2,283
48. Black thinly bedded limy shale containing *Cryptolithus, Dionide,* and *Nemagraptus*	168	2,451
49. Very thin black shale containing an abundant graptolite fauna: *Climacograptus, Nemagraptus, Diplograptus,* and *Lasiograptus*	213	2,664
Whitesburg limestone (6 feet):		
50. Black knobby crystalline limestone containing *Illaenus, Ceraurus,* and *Remopleurides*	6	2,670
Lenoir limestone (50± feet):		
51. Dark-colored knobby limestone, mostly covered; containing *Pianodema, Plaesiomys, Isotelus,* and *Orthis*	50±	2,720
Mosheim limestone (30 feet):		
52. Very pure fine-grained dove-colored limestone containing *Tetradium, Maclurea,* and *Lophospira*	30	2,750
Nittany dolomite (464 feet):		
53. Blue and dove-colored dolomite	94	2,844
54. Blue and dove-colored limestone and chert	85	2,929

	Thickness Feet	Feet
Nittany dolomite—Continued.		
55. Thinly bedded bluish limestone with chert containing *Lecanospira, Hormotoma,* and *Maclurea*	35	2,964
56. Bluish cherty dolomite	250	3,214
Conococheague formation (700 feet exposed):		
57. Mostly covered, base not exposed; bluish cherty limestone and dolomite containing *Cryptozoön*	700	3,914

(Pulaski thrust fault at base of the section)

STRUCTURAL GEOLOGY

GENERAL FEATURES

The two main kinds of geologic structure in the rocks of this area are folds and faults. Folds are commonly divided into anticlines, or upfolded beds, and synclines, or downfolded beds. There are two distinct types of folds here: (1) Large open folds whose width is measured in miles, for example, the great Catawba syncline (Pls. 1 and 2), and (2) small local folds, whose width is measured in hundreds of feet, such as the folds in the Rome ("Watauga") shale along Roanoke River. (See Pl. 19.) Faults are commonly divided into thrust faults, often called overthrusts, and normal, or gravity, faults. The first type, resulting from compression, is by far the most common in the Roanoke area. Very few normal faults have been observed. Other geologic structures, such as joints and cleavage, are also common.

MAJOR FOLDS

CATAWBA SYNCLINE

The Catawba syncline, which crosses the northern part of Roanoke County, is the most striking geologic structure in the area. The central part of the syncline is in Roanoke County, but the northeastern and southwestern rims are in Botetourt and Montgomery counties, respectively. (See Pls. 1 and 2.) If the syncline had not been faulted, it would have an average width of about 8 miles, but the southeastern rim has been nearly obliterated by the Salem thrust fault, so that the present maximum width is about 5 miles. The length of this great fold is almost 30 miles, about half of which is in Roanoke County. It is one of the largest single folds along the Valley of Virginia.

The syncline is bounded for three-quarters of its circumference by a single continuous mountain ridge variously called Paris, Roanoke, Catawba, Tinker, and Dead Man's Mountain. (See Pl. 20.) This rim is everywhere produced by the resistant Clinch and Clinton sandstones, which dip steeply. The Martinsburg shale below and the Devonian shales above these sandstones weather readily, so that the mountain ridge is paralleled by linear valleys which emphasize its relative height. These Silurian sandstones are so resistant to erosion that the rim of this syncline is not breached by a stream except at the south and east, where the Salem fault has shattered the rocks. The elbow-shaped Tinker and Paris mountains, in which the rocks are almost vertical, are at opposite plunging ends of the fold. The south end of Tinker Mountain, just northwest of Cloverdale, hooks around sharply to the west to become the massive Dead Man's Mountain along the northern edge of Roanoke Valley. About 7 miles only of the south rim of the syncline has been preserved as a low symmetrical hill, Smith Ridge, which extends from Dead Man's Mountain southwestward to a point beyond Mason Creek. Throughout this ridge the almost vertical Silurian sandstones are partly cut out by faults. The relatively low height of Smith Ridge is the result partly of the vertical attitude of the sandstones, for the Silurian sandstones have their maximum ridge-making ability when inclined at moderate angles.

The center of the Catawba syncline is marked by the massive Fort Lewis Mountain (Pl. 9), whose greater height is caused by resistant Chemung and Price sandstones. Its northeastern extension is marked by Green Ridge, which is capped by resistant Upper Devonian sandstone.

The Catawba syncline trends N.60°E., parallel to the linear folds and thrust faults of the region, and also to the general structure of the Appalachian province. The rocks involved range from the top of the Cambrian through the Lower Mississippian.

NORTH MOUNTAIN SYNCLINE

The synclinal tract which lies between North and Broad Run mountains, and between the Pulaski and Miller thrust faults, is here called the North Mountain syncline. (See Pl. 2.) Campbell and Holden[96] have called this syncline in this area the North Mountain syncline, and elsewhere the Craig Creek syncline. The former name seems more appropriate, and will be used here.

This syncline is similar to the Catawba syncline but is less well preserved, having been more intricately faulted and crushed. The rim is likewise composed of Silurian sandstones, but it has been so cut by thrust faults that it is continuous for very short distances. North Mountain appears to lie along the axis of this fold, and has the same position in this syncline as has Fort Lewis Mountain in the Catawba syncline. A small part only of the North Mountain syncline is in Roanoke County. The southeastern slope of North Mountain is in Roanoke County, and contains the outcrop of the Price formation which, above Catawba Sanatorium, has been mined for coal. The most important extension in this area is the hook-shaped Cove Mountain at the southwestern end of the structure. This unusual hill has the same shape as Tinker and Paris mountains, and similarly terminates a syncline. It is a complex

[96]Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, p. 80, 1925.

fault-block included within three faults of triangular pattern. (See Pl. 1 and Fig. 4.)

This fold has been badly crushed. It has been overthrust northwestward upon the great Sinking Creek anticline as a part of the Miller overthrust block, and it has been overridden by the great overthrust block of the Catawba syncline, which has been thrust northwestward along the Pulaski fault. The North Mountain syncline has, therefore, been involved intimately with two great overthrusts, which have greatly crushed and broken it. Its original dimensions were comparable to those of the Catawba syncline, and its mode of formation was probably similar.

MILLERS COVE ANTICLINE

Between the Miller and Pulaski thrust faults, in the extreme northwestern corner of Roanoke County, is the end of an anticline which plunges sharply to the northeast. (See Pls. 1 and 2.) The east edge of this anticline is Cove Mountain; elsewhere the rim has been obliterated. The northwest rim has been broken along the Miller overthrust, and the remainder of the structure has been overridden by the Pulaski overthrust block. Erosion of this anticline has cut through the Ordovician shale into the Nittany and Conococheague formations, making in the mountain a great recess called Millers Cove. A small area of Elbrook limestone 5 miles to the southwest in Montgomery County, at the foot of Brush Mountain and north of the Pulaski overthrust, has been considered by Campbell and Holden[97] to represent a remnant of this anticline caught up and pushed forward by the Pulaski overthrust. This anticline is contiguous to and closely related to the North Mountain syncline, and is not separated from it by a fault.

MINOR FOLDS

The Cambrian and Ordovician shales, between the Blue Ridge overthrust at the southeast and the Salem overthrust at the northwest, show evidence of great crushing, which has produced a series of minor folds having slight or no connection with the great open folds of the region. These small folds are especially numerous and well developed in the Rome ("Watauga") shale and to a less extent in the Elbrook formation and Martinsburg shale. (See Pl. 19.)

The minor folds differ essentially from the major folds only in size, the great open folds being measured in miles and the small folds in hundreds of feet. In the vicinity of Roanoke, one may cross eight or ten of these small folds in a mile. The structure of

[97] Op. cit., p. 44.

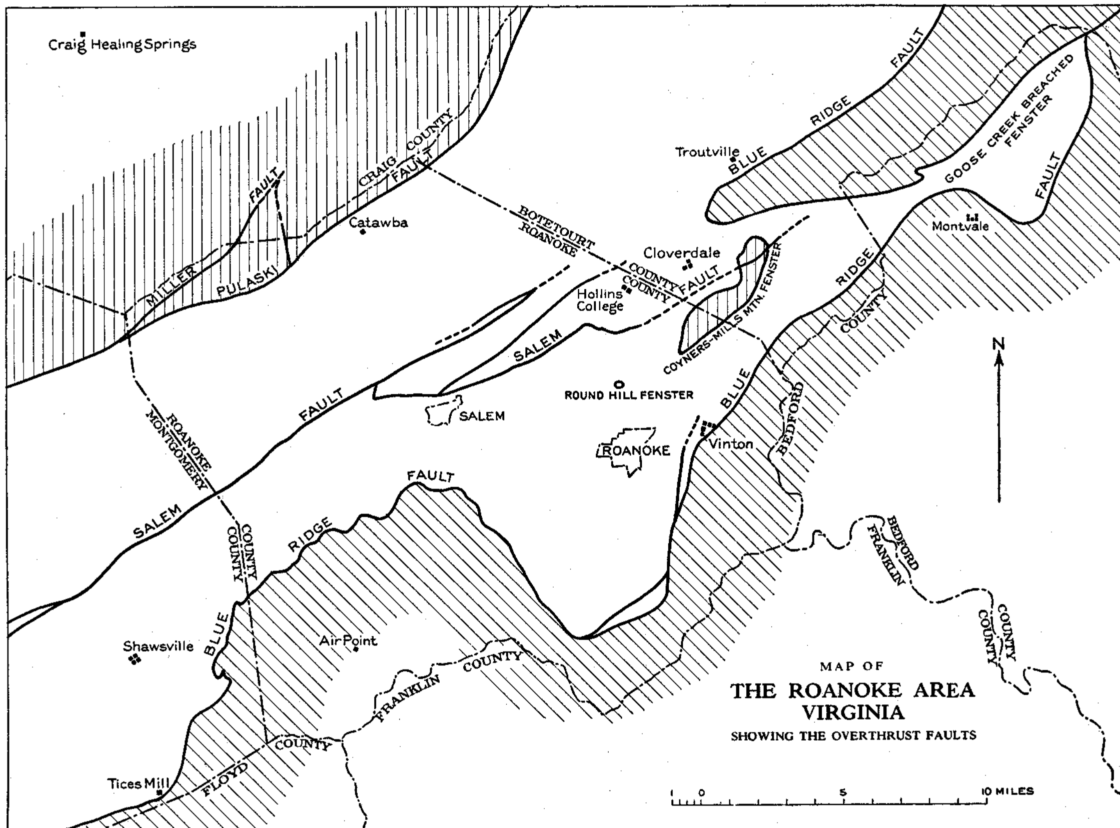


Figure 4.—Distribution of faults in the Roanoke area. Note the trace of the Blue Ridge overthrust and the fensters in the Pulaski overthrust north of Roanoke.

the minor folds is very involved, because the hard, competent beds, which govern the shape of the folds, are very thin and have been faulted. In the Rome ("Watauga") formation, the shales are weak and incompetent, and the interbedded limestones are the competent members. Erosion has commonly removed the less resistant material, so that the limestones are exposed on the crests of the small anticlines and in the troughs of the synclines. (See Pl. 19, A.) Because of this close folding the apparent thickness of the limestones is generally exaggerated. In some places, the anticlines have been breached and worn away to form valleys and the synclines have been left by erosion to form small hills; at other places hills have been eroded in the anticlines and valleys in the synclines. The effect of these small structures upon the topography appears to depend upon the level at which the streams planed the structures. Thus the production of either a hill or a valley upon an anticline at a particular place depends upon the stage and degree of peneplanation.

The strike of the minor folds is about N. 40° E., which is parallel to that of the major folds, although the two series may not have been formed at the same time. The smaller folds appear to be the result of severe compression during the Salem and Blue Ridge overthrusting, which buckled the weaker Cambrian and Ordovician shales against the competent Cambrian-Ordovician limestones. That much of the crumpling of the Rome ("Watauga") shale was caused by the thrust of the Blue Ridge fault-block is evidenced by the change of direction of these folds as they approach the line of the thrust fault. Along the south side of Glade Creek Valley the Blue Ridge fault trace trends slightly more to the north than do the regional folds. The axes of the minor folds, however, as they approach the overthrust mass, swing more and more to the north until they are parallel to this great thrust fault. This adjustment of the strike of the folds shows that they were, to a considerable degree, the result of this overthrusting, although the rocks were no doubt partly folded prior to this faulting.

Sharp minor folds are found in the Lower Cambrian rocks, especially in the quartzites of the Chilhowie group. These folds are even smaller than those in the Rome ("Watauga") shale, and many of them can be seen in a single exposure. They were caused largely by thrusting during the times of folding, but they may have first been compressed long before the late Paleozoic folding of the region. If our interpretation of Appalachian history is correct, the Cambrian rocks may have been involved in episodes of folding prior to those in late Paleozoic time which caused the large open folds.

THRUST FAULTS

BLUE RIDGE OVERTHRUST

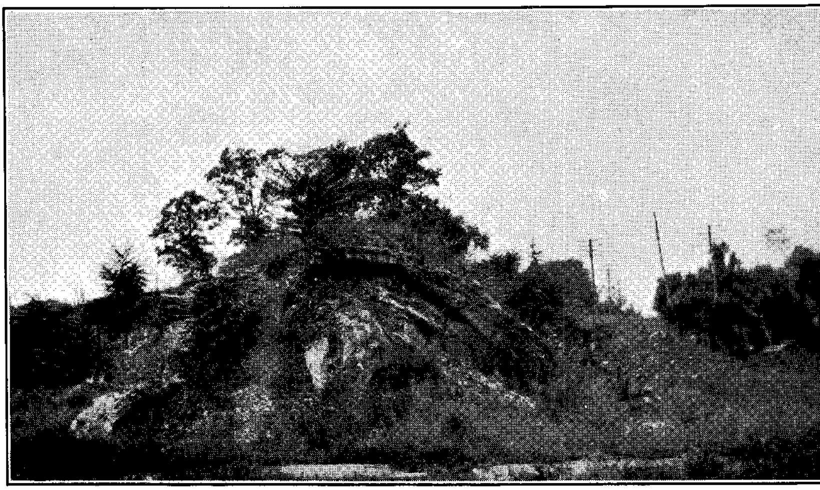
The pre-Cambrian crystalline rocks in the Roanoke area are separated from the Paleozoic rocks by a great thrust fault, which is here called the Blue Ridge overthrust. (See Pls. 1 and 2.) In the western part of the area, the Chilhowie group is part of the overthrust mass; elsewhere the fault is between the crystalline rocks and the Cambrian formations. This fault, or zone of faults, extends across the State.[98]

This overthrust enters the Roanoke area from the northeast along the north side of the Blue Ridge, and passes not far east of Nace, Lithia, and Troutville. The trace of the fault swings around Fullhardt Knob, then continues eastward along the north side of Glade and Goose Creek valleys to Powell Gap in Bedford County, where it swings sharply back along the south and east sides of these valleys, along the west slopes of McFalls, Taylors, and Porters mountains. From Blue Ridge Springs southward, its trace lies just east of Glade Creek, crossing Roanoke River at the mouth of Glade Creek. Farther south, the fault swings in a great curve around Yellow and Buck mountains, and turns northward near Cave Spring to follow the Valley side of Twelve O'clock Knob and Poor Mountain into Montgomery County, crossing South Fork of Roanoke River about 1 mile above Tices Mill. The fault was not studied beyond this point. The trace of this fault is very sinuous, a characteristic which the other faults of the area do not have.

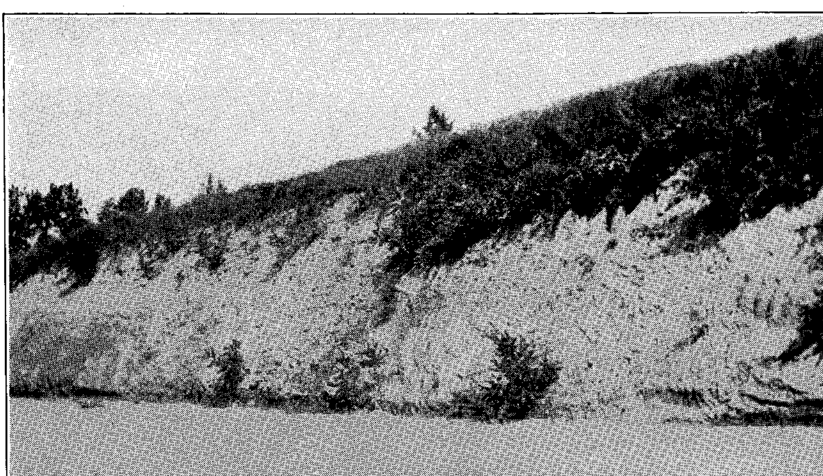
The horizontal movement along this fault must be great, at least the distance from the south flank of Buck Mountain to the north flank of Twelve O'clock Knob, which is 9 miles. This probably does not indicate the total amount of horizontal movement. The dip of the fault surface is low, as is indicated by the sinuosity of the fault trace. Although the actual dip can not be determined, it is probably less than 20°.

The line of the fault is easily determined in many places by differences in topography, but it is not easy to find the actual fault, because it crops out commonly along the foot of hills which are covered with talus. The fault zone can be seen east of Blue Ridge Springs, in Vinton, and along the Garden City road south of Roanoke. Along the Roanoke-Rocky Mount highway, at the road intersection 1 mile north of the Back Creek bridge, the fault can be seen parallel to, and at the side of, the intersecting road. Along the main highway north of this side road, Erwin quartzite occurs,

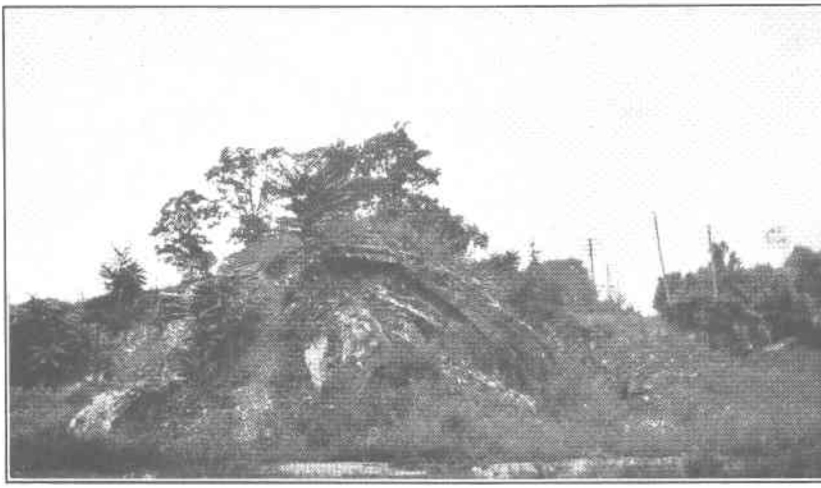
[98] This is well shown on the new geologic map of Virginia. Virginia Geol. Survey, 1928.



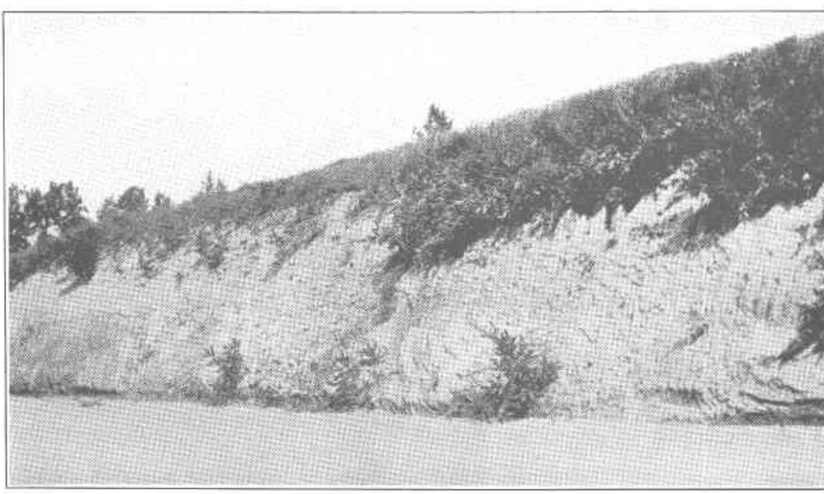
A. Small anticline in Rome ("Watauga") shale in the eastern part of Roanoke. One of the interbedded limestones has been quarried from the crest of this anticline. (See pp. 33 and 77.)



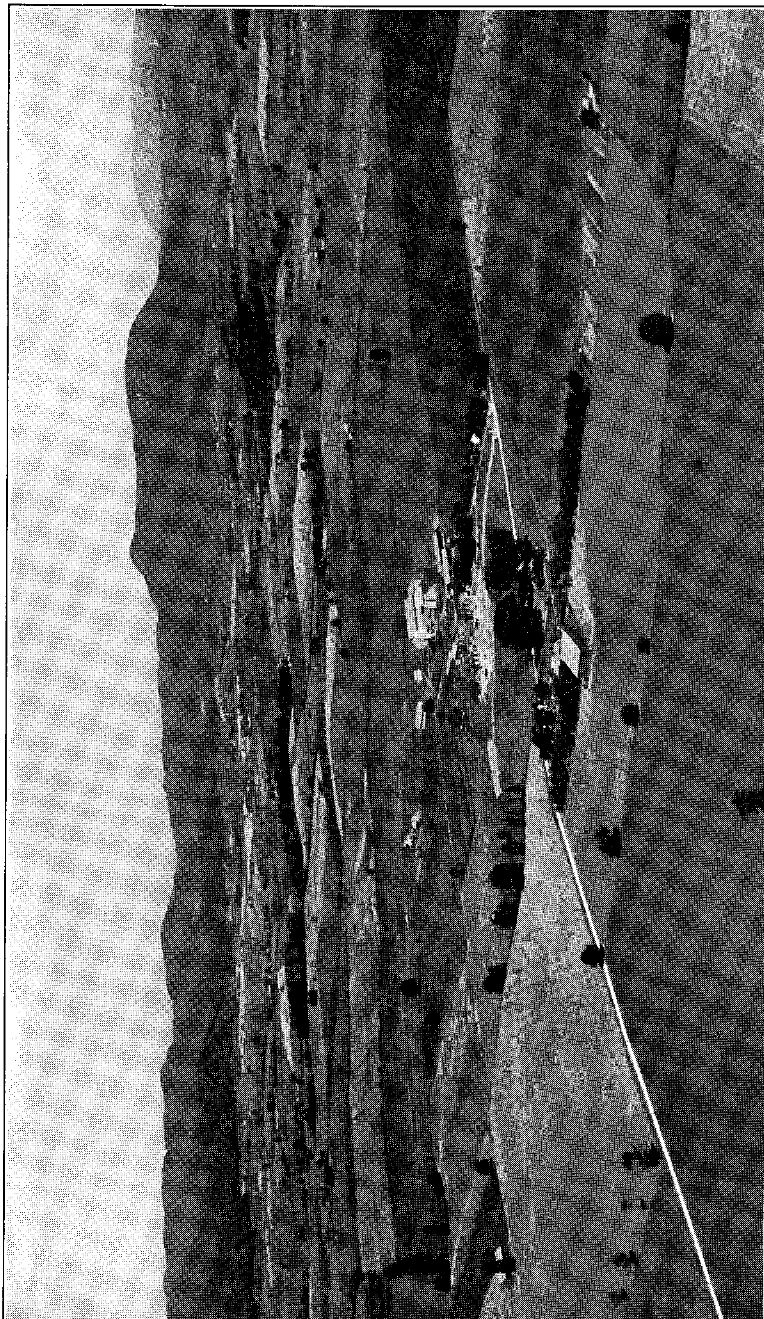
B. Contorted shale in the Elbrook formation near Kesler's Mill, east of Salem. This outcrop shows the degree of minor crumpling in the incompetent members. (See pp. 35 and 77.)



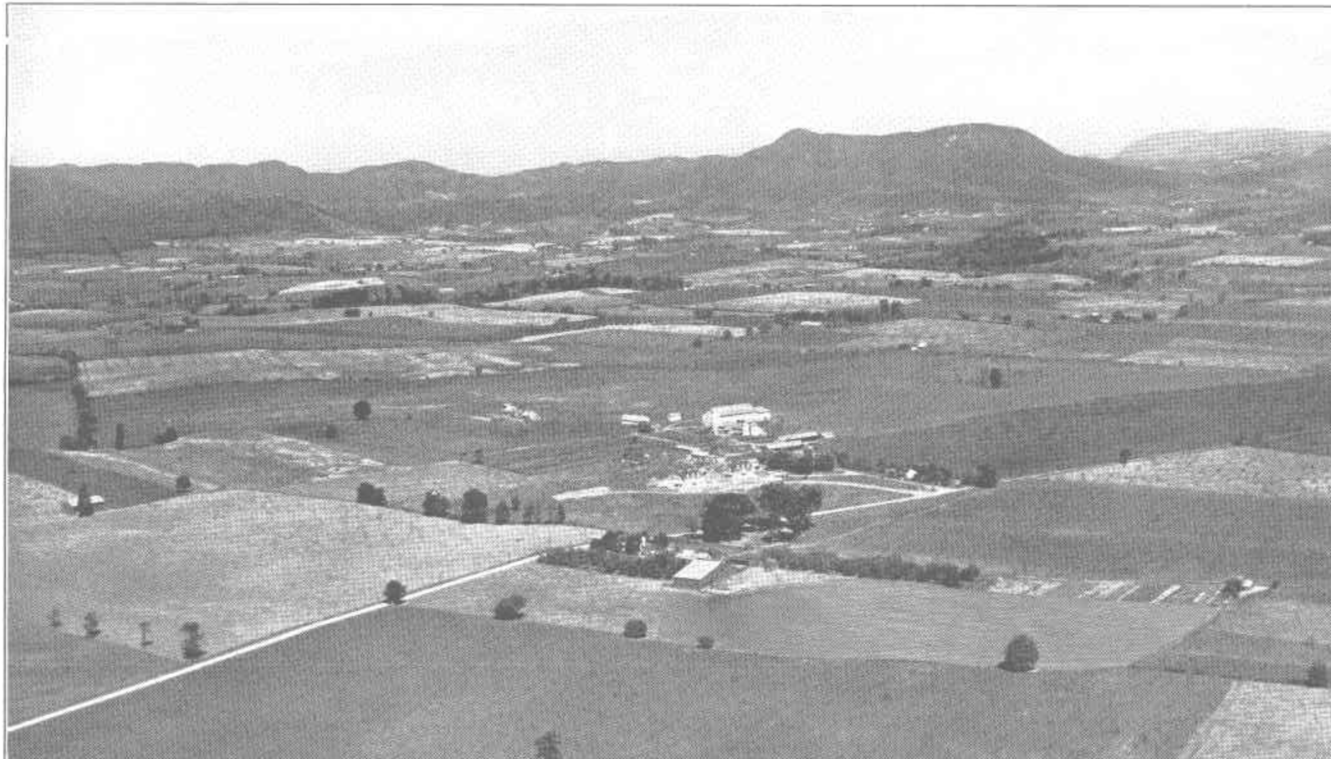
A. Small anticline in Rome ("Watauga") shale in the eastern part of Roanoke. One of the interbedded limestones has been quarried from the crest of this anticline. (See pp. 33 and 77.)



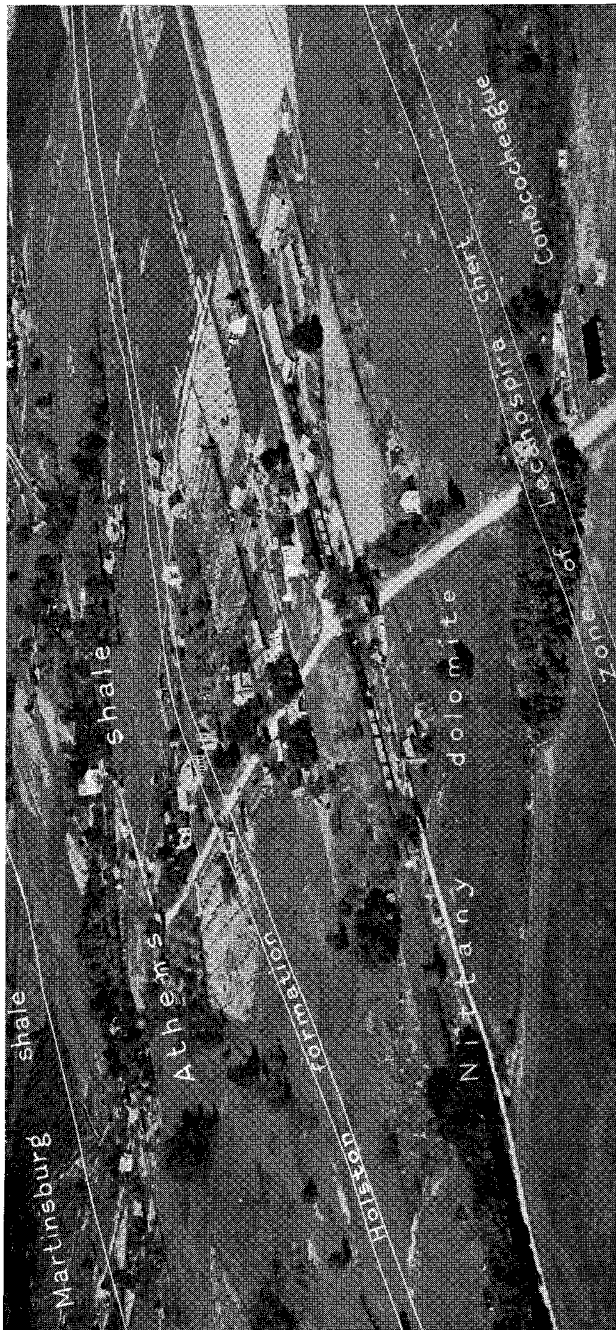
B. Contorted shale in the Elbrook formation near Kesler's Mill, east of Salem. This outcrop shows the degree of minor crumpling in the incompetent members. (See pp. 35 and 77.)



Northwest across Roanoke Valley to Tinker Mountain, showing northeastern end and southeastern limb of the Catawba syncline. The syncline pitches southwestward from Tinker Mountain. Dead Man's Mountain is in the left center of the background. The Valley floor is underlain by folded Cambrian to Devonian shales and limestones. (See pp. 14, 15, 57, and 75.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)

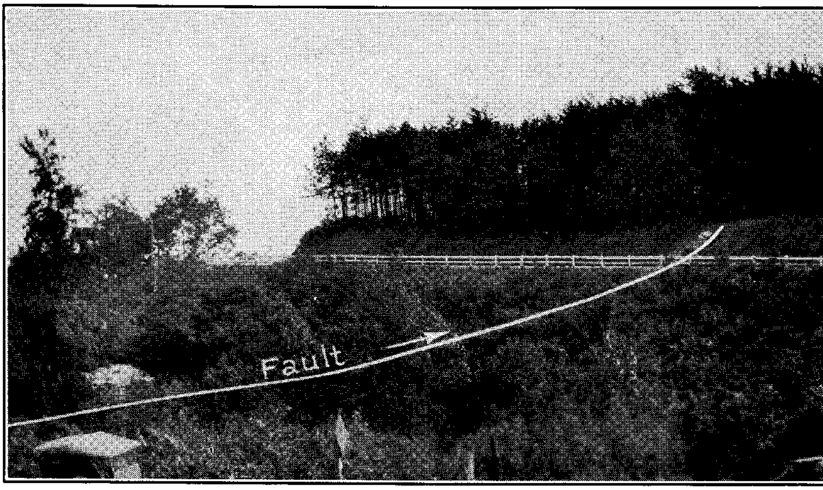


Northwest across Roanoke Valley to Tinker Mountain, showing northeastern end and southeastern limb of the Catawba syncline. The syncline pitches southwestward from Tinker Mountain. Dead Man's Mountain is in the left center of the background. The Valley floor is underlain by folded Cambrian to Devonian shales and limestones. (See pp. 14, 15, 57, and 75.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



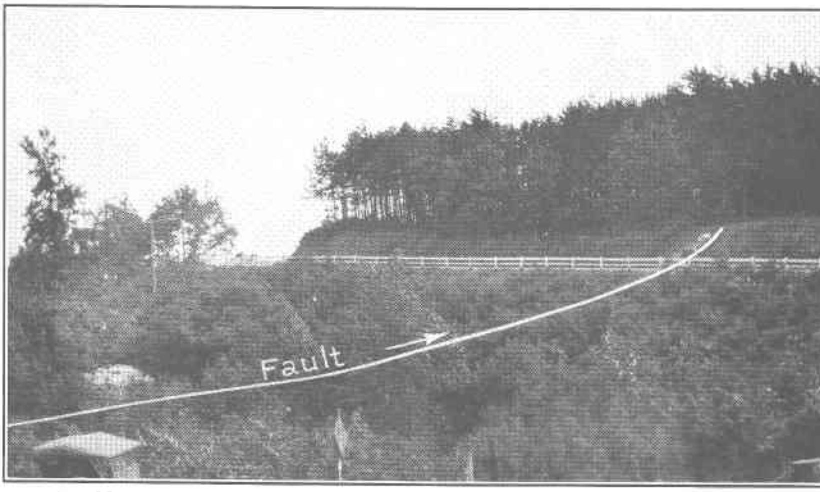
Distribution and structural relations of the formations near Cloverdale. Looking north across Cloverdale in the foreground. (See p. 83.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)

Distribution and structural relations of the formations near Cloverdale. Looking north across Cloverdale in the foreground. (See p. 83.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)

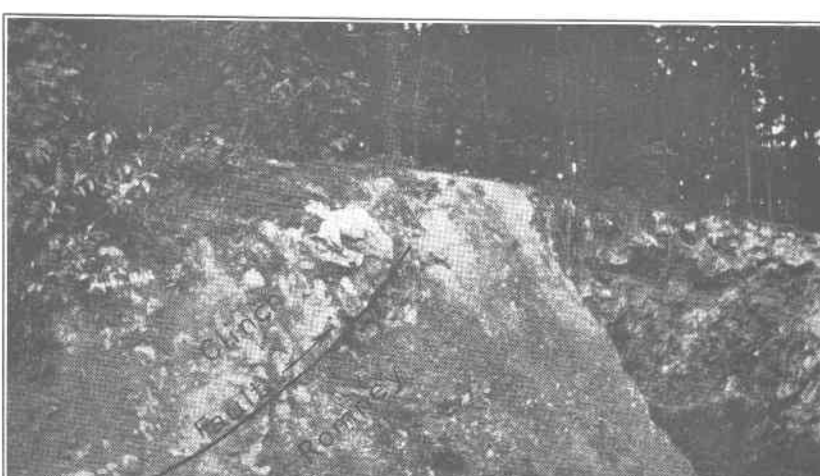


A. Northern branch of the Salem fault along the Salem-Catawba road. Clinch sandstone (on the left) has been thrust over Romney (Marcellus-Genessee) shale. View looking west.

B. Closer view of the same fault along the roadside. Note the upturning of the fault near the surface. (See p. 83.)



A. Northern branch of the Salem fault along the Salem-Catawba road. Clinch sandstone (on the left) has been thrust over Romney (Marcellus-Genessee) shale. View looking west.



B. Closer view of the same fault along the roadside. Note the upturning of the fault near the surface. (See p. 83.)

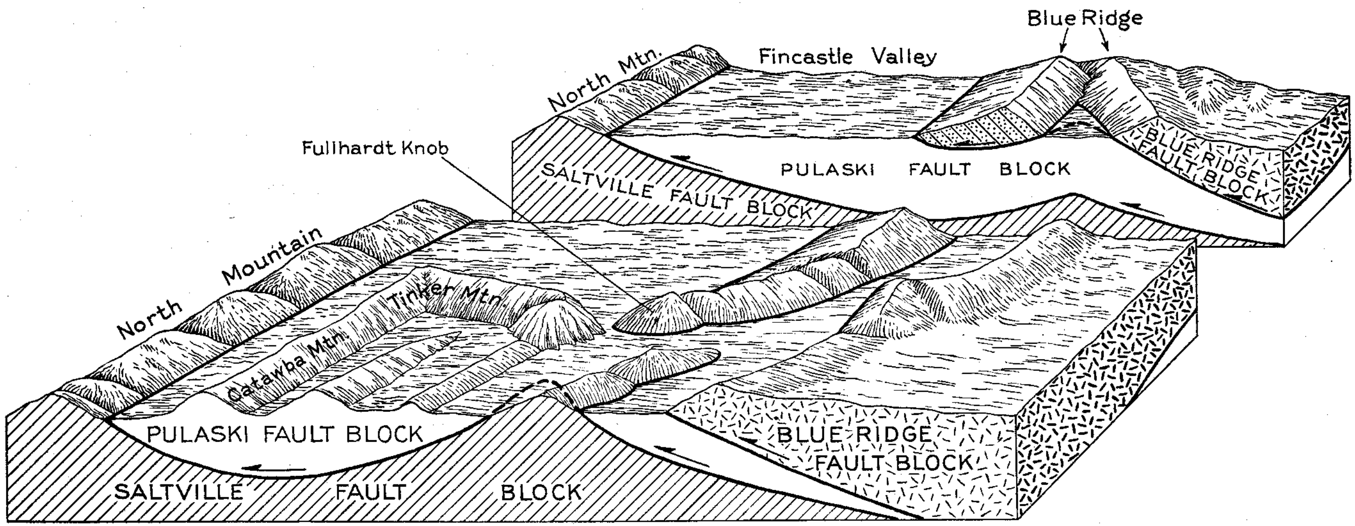


Figure 5.—Block diagram of the northeastern part of the Roanoke area showing relations of the overthrust fault blocks. Note the embayed Blue Ridge fault, giving rise to two prongs of the Blue Ridge, the Coyners-Mills mountain fenster south of Fullhardt Knob, and the Catawba-Tinker mountain rim of the Catawba syncline.

whereas 1 rod to the south there is a ledge of crystalline schist within the overthrust mass. The surface of the quartzite is strongly slickensided, and shows other evidences of faulting.

A small thrust fault branches off, or emerges, from beneath the Blue Ridge fault just east of Mill Mountain. This was traced northeastward for about 4 miles. It appears to be a fracture in the Rome ("Watauga") shale, as a result of the pressure of the overthrust Blue Ridge fault-block. The relations of the rocks at the point where this fault joins the Blue Ridge fault, are so disturbed that it is impossible to determine whether the smaller fracture actually branches off from the larger fault or whether it emerges from beneath the overthrust mass.

One of the most striking features of the Blue Ridge overthrust in this region is the western peninsula, or outlier, of the Blue Ridge fault-block which extends southward to terminate in Fullhardt Knob near Cloverdale. This is separated from the main overthrust mass by Glade Creek and Goose Creek valleys. Both valley areas were at one time covered by over-thrust crystalline rocks, but they have been so widened and deepened by erosion that they now extend below the sole (or base) of the overthrust mass, thus exposing the Paleozoic rocks over which the crystalline rocks had been thrust. (See Figs. 4, 5, and 6.) These valleys now form a great

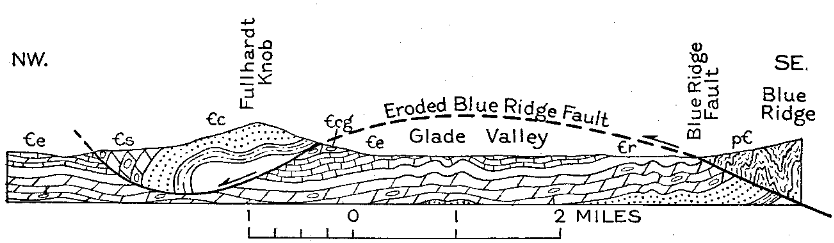


Figure 6.—Structure section showing relation of the Fullhardt Knob outlier to the Blue Ridge overthrust. p€, Precambrian; €c, Chilhowie group; €s, Shady dolomite; €r, Rome ("Watauga") formation; €e, Elbrook formation; €cg, Conococheague formation.

recess in the trace of the Blue Ridge thrust fault. In the not very remote geologic past they must have been fensters, or windows, in that fault-block. They may now be called breached fensters. The western peninsula of crystalline rocks rests upon the Valley limestones, and the synclinal structure of the northeastern end of the Catawba syncline can definitely be traced beneath this overthrust mass. The great embayment in the trace of the Blue Ridge fault south of Roanoke is probably likewise the result of continued erosion of a fenster.

The Blue Ridge overthrust is the southeasternmost of the known great thrust faults of this area. It is difficult to determine the relative age of this fault, as no rocks younger than Ordovician are overriden by the fault-block. Much farther to the southwest, where the fault crosses Little Tennessee River, the overthrust mass is supposed to override Mississippian limestones. This fact would place the time of the faulting as post-Mississippian, and the stratigraphic displacement as more than 10,000 feet. No other positive evidence of the age of this overthrust is known in the Roanoke area.

SALEM OVERTHRUST

This thrust fault was first observed by Rogers[99] in 1840 who noted that "a fault (at d) [section 12, Plate 2] at the southeast base of the Fort Lewis mountain, shows Formation II [the Cambrian-Ordovician limestones] thrown over upon VIII [Upper Devonian formations]." The fault was named by Campbell and Holden[100] from Salem, near which it passes.

The Salem overthrust extends across Roanoke County into Montgomery County to the west and into Botetourt County to the northeast. (See Fig. 4.) Its known length in the Roanoke area is about 40 miles. Its known westernmost outcrop is just west of Christiansburg, where the fault has been traced by Campbell[101] into the Berringer fenster of the Pulaski overthrust. Its relations to the Pulaski fault at this point are obscure. The Salem overthrust crosses the Christiansburg-Blacksburg road about 3 miles north of Christiansburg, and its trace continues almost eastward to old Montgomery White Sulphur Springs where the fault crosses the creek just north of the deserted hotel. At this point the Cambrian-Ordovician limestones have been thrust over the Martinsburg shale, and there appear to be several small faults parallel to, or branching from, the main fault. The fault trace swings to the northeast and extends in a nearly straight line from the Springs to Little Brushy Mountain north of Salem, passing just north of Lafayette, and flanking the base of Fort Lewis Mountain. (See Pls. 21 and 22.) At Little Brushy Mountain the fault bends slightly southward, and continues roughly parallel to the Salem-Hollins highway, crossing Carvins and Tinker creeks about 1 mile above their junction. The fault becomes lost to the northeast in the Cambrian-Ordovician limestones, although it presumably cuts through the northern end of Coyners Mountain, and extends beneath, or into,

[99]Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, New York, pp. 611-623, 1884.
[100]Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, p. 276, 1925.
[101]Op. cit., p. 51.

the Blue Ridge overthrust mass near the Lynchburg, or Grubb, iron mines in Botetourt County.

Throughout much of its extent, the Salem overthrust truncates the south rim of the Catawba syncline, and brings the Cambrian-Ordovician limestones upon the younger rocks of that syncline. (See Pl. 1.) Campbell and Holden have assumed that the horizontal displacement along the Pulaski overthrust in Montgomery County is almost 10 miles, and it seems probable that the Salem overthrust has a similar displacement.

It is difficult to date the Salem overthrust. In the Berringer fenster west of Christiansburg, the Salem fault is thought to cut the Pulaski fault, and thus to be younger, or later, than that fault. Near the Grubb iron mines, the Salem fault is supposed to disappear below the Blue Ridge overthrust mass. On these meager data, the date of the Salem overthrusting is placed between that of the Pulaski and Blue Ridge overthrusting. Figure 4 shows the traces of the faults in the Roanoke area.

PULASKI OVERTHRUST

GENERAL DESCRIPTION

The Pulaski overthrust is one of the most persistent structural breaks in the Appalachian region. It has been continuously traced for more than 200 miles, "from Pulaski southwestward to the vicinity of Timber Ridge, a small village 6 miles southwest of Greenville, Tennessee, where it apparently dies out in an anticline of Knox dolomite which plunges in a southwesterly direction under a similar structure in the Athens shale. In the opposite direction the fault has been traced from Pulaski to a point about 5 miles northwest of Fincastle, Virginia. It extends still farther toward the northeast, but the evidence available at the present time indicates that its termination will be found near James River in the vicinity of Eagle Rock. . . . .

"The southwestern termination appears to be well established, but the northeastern extremity has not been positively determined and it is possible that the fault may continue beyond [this] limit."[102]

The trace of this overthrust in the Roanoke area trends northeast along the north slope of Catawba Creek Valley. It lies at the south slope of Brush Mountain in Montgomery County, and at the Roanoke County line leaves this mountain to flank Cove and North mountains on the south. (See Figs. 4 and 5.) It continues

[102]Campbell, M. R., and others, op. cit., p. 76.
This fault has recently been traced by the writer northeastward for 40 miles into Rockbridge County.

along North and Caldwell mountains into Botetourt County, and crosses James River at Eagle Rock.

The Cambrian-Ordovician formations south of the fault have been overthrust upon all higher formations including the Price sandstone (Mississippian). The fault cuts across the Millers Cove anticline, the North Mountain syncline, and bounds the Catawba syncline on the northwest. (See Pl. 2.) It is of economic importance in that it buries most of the coal beds of the Price formation in Roanoke County.

Both the horizontal and stratigraphic displacements along this fault are great. At least 12,000 feet of stratigraphic displacement is implied, and there is evidence that the overthrust block of the Catawba syncline has been shoved northwestward at least 10 miles. The magnitude of movement in the Roanoke area is comparable with that in adjacent regions. The amount of displacement and the great length of the fault combine to make the Pulaski overthrust one of the most important structures in the central Appalachian region. It is one of the few overthrusts in the region which is known to show the phenomenon of fensters, for example, the striking fensters of Montgomery and Pulaski counties.

FENSTER OF MILLS (REEDS) AND COYNERS MOUNTAINS

Mills (Reeds) and Coyners mountains, in the Valley east of Cloverdale, and Round Hill, just north of Roanoke, are interpreted by the writer as fensters in the Pulaski overthrust mass, comparable with the Berringer and Draper Mountain fensters of the same fault in Montgomery County, about 30 to 50 miles to the southwest. Mills (Reeds) and Coyners mountains extend northeast-southwest as a continuous mountain mass about 5 miles long and about 1 mile wide. (See Pl. 23.) They rise nearly 1,000 feet above the floor of the Valley, and are surrounded on all sides by Cambrian-Ordovician limestones, with which they have no logical stratigraphic connection. The crests of both mountains are defended by resistant Silurian (Clinch) sandstone, and Romney shale containing typical fossils is found in the saddle between them. An incomplete sequence of Athens and Martinsburg shale is present along the east flanks of both mountains.

The mountains are isolated from all other outcrops of younger Paleozoic rocks; it is possible to encircle them and travel only on Conococheague and Elbrook formations. At the northern end of Coyners Mountain, limestone of Ozarkian age overlies Clinch sandstone; along the northwestern flank, the Ozarkian beds overlie Romney black shale; and on the southeastern side, Ozarkian and

Elbrook limestones rest upon Athens and Martinsburg shales. No actual overthrust contacts could be found along the flanks of Mills (Reeds) Mountain, for its base is covered with heavy soil and talus. Conditions similar to those around Coyners Mountain appear to exist, for the Cambrian-Ordovician limestones surround the mountain in the same manner, and the interval is too small for the presence of a complete stratigraphic sequence between the rocks of the mountain and those of the Valley. Furthermore, the strike of the rocks in the mountain is at variance with those of the Valley limestones. Thus the rocks of Mills (Reeds) and Coyners mountains are younger than those of the surrounding valley, and are everywhere separated from them by a fault, or faults.

Several explanations of the anomalous position of these rocks have been suggested: (1) They represent a much fractured and infolded syncline within the Valley limestones; (2) they are part of an overthrust mass which has been subsequently cut by a second fault that has obliterated the remainder of the earlier fault block; (3) they are in the uneroded remnant of a thrust block, that is, the mountains are of the klippen type; and (4) they are a part of the mass over which a fault-block has been thrust, and at this point the overthrust block has been worn through by erosion to uncover the overridden mass, that is, the area is a fenster. Each of these possibilities has been considered, but there are no available data which will positively prove one of these interpretations. The first three possible interpretations have been discarded for the following reasons:

1. If the area of Mills (Reeds) and Coyners mountains be synclinal, there should be some evidence of this syncline to the southwest. Directly along its supposed axis, and within 1 mile of the southwest end of Mills (Reeds) Mountain, is the Mundy Brothers quarry in Elbrook limestone, where the rocks are nearly horizontal, without any evidence of a synclinal structure. (See Pl. 15, B.) It would be impossible for a syncline of the necessary magnitude to infold the rocks of the mountains, and to die out in the short distance between Mills Mountain and the quarry. It would be expected also under this supposition, that other folds of like magnitude would be found with their axes parallel to this supposed syncline. No such folds are known.

2. If the rocks of these two mountains had been overthrust upon the Valley limestones and had later been partially covered by a second overthrust, the general effect would resemble the present structure of the mountains. Under this supposition there should be some trace of the second overthrust to the southwest along its supposed strike. The writer has looked for, but has not

observed, such a trace. Furthermore, the limestones surrounding the mountains apparently represent a single connected series in true stratigraphic order, and it is impossible that this condition would be duplicated by two series of thrust faults. It was suggested to the writer that the second fault might have been a gravity, or normal, fault, but this would call for tension at the place where there had previously been compression, and would presume a normal fault with the same strike as the great thrust faults of this area. No normal faults in this whole region are known to have such a strike, but, on the contrary, are all at right angles to the grain of the major structures.

3. The writer has considered the suggestion that Mills and Coyners mountains are "klippen," or outliers, of an overthrust block which have been separated from the main block by erosion. This would imply that the mass of the mountains overlies the Valley limestones, and that it was thrust there along a great fault, whose major trace is now somewhere southeast of the mountains. The only known overthrust to the southeast is the Blue Ridge fault. This overthrust mass is nowhere observed to include rocks younger than the Cambrian, and there is no evidence in the Roanoke area that any later rocks are involved in it. Unless there is below the Blue Ridge overthrust block another great thrust fault which does not appear at the surface, there is no surface indication that these mountains are outliers of an overthrust block, or klippen.

4. The writer considers that Mills (Reeds) and Coyners mountains represent a fenster in the Pulaski overthrust block which has been eroded deeply to show a part of the underlying mass. This interpretation is made for the following reasons: (a) The limestones surrounding the mountains are continuous and in regular stratigraphic sequence, apparently parts of a single structural mass; (b) there is no evidence that the mass of the mountains rests upon the limestones, but rather that the limestones overlie the rocks of the mountains; (c) a series of rocks similar to those of this area is known to be overridden by the Pulaski overthrust block not far to the northwest; (d) there is no trace of an infolded syncline, or of additional thrust faults, which would imply other interpretations; (e) fensters of this kind with similar relations are known, and have been described, within 40 miles of this area; and (f) the only fault in this area which could have produced such features is the Pulaski overthrust, which is known to show similar features in the same general region.

The present interpretation of the structure of this area therefore supposes that the southern limb of a syncline of Silurian and

Devonian rocks protrudes through the eroded Pulaski overthrust block in such a manner that the synclinal younger rocks are surrounded by Cambrian-Ordovician rocks and separated from them by the trace of the Pulaski overthrust, which is here roughly oval.

ROUND HILL FENSTER

Round Hill, north of Roanoke, is in direct line with the strike of Mills (Reeds) and Coyners mountains. (See Pl. 1.) Its crest is capped with Silurian (Clinch) sandstone which is surrounded by Elbrook limestone. The structure of this hill is likewise considered, for similar reasons, to be a fenster in the Pulaski overthrust block.

"KLIPPEN" STRUCTURE

The identification of the Mills-Coyners mountain mass as a fenster is especially interesting, in view of its position with reference to the other overthrust masses in the northeastern part of the Roanoke area. The structure of this part of the area is extremely complex, and presents certain features not known elsewhere in west-central Virginia. The most interesting one is a "klippen" structure which is readily evident in the field. "Klippen" structure designates a series of overlapping fault-blocks in which the overthrust masses, or slices, lie upon each other like shingles. This structure is made evident near Cloverdale because deep erosion has cut through several warped thrust fault surfaces.

In this part of the Roanoke area, the oldest structural unit to be identified is that of Mills (Reeds) and Coyners mountains. It has been overridden by the Pulaski overthrust block, but has later become exposed through long-continued erosion, making it a fenster. This fenster, however, lies along the middle of Glade Creek Valley, with the Blue Ridge fault on both sides of it. Glade Creek Valley is a breached fenster through the Blue Ridge overthrust, so that at this point a fenster is found within a fenster. Standing on the top of Mills (Reeds) Mountain, one can visualize the eroded Pulaski overthrust block completely surrounding the mountain, with the rocks of Mills Mountain apparently extending beneath it. To the north and to the southeast is the Blue Ridge overthrust block, which likewise once covered the site of Mills (Reeds) Mountain. Blocks of three thrust faults are therefore evident at this one point, two of which formerly extended over what is now the top of Mills (Reeds) Mountain. The general relations here are shown in Figures 4 and 5.

A significant point is that both the Blue Ridge overthrust and the Pulaski overthrust have been eroded through at about the same place, and along the same strike. These facts indicate a persistent anticlinal structure which has been imposed upon the fault surfaces subsequent to the overthrusting.

A careful discussion of the mechanics of fenster formation in this part of the Appalachian region is given by Campbell and Holden in Bulletin 25 of the Virginia Geological Survey, to which the reader is referred. The writer has recently described briefly the faults of this part of the Roanoke area.[103]

MILLER OVERTHRUST

This overthrust was first described and named by Campbell[104] as follows:

"Another fault . . . . occurs in Roanoke County only a short distance northeast of the Montgomery County line. This fault apparently branches off from the Pulaski fault just within Montgomery County. In reality the fault is on the northwest limb of an anticline that plunges sharply toward the northeast and the limestone and calcareous Sevier [Martinsburg] shale on the end of this anticline have been eroded in a great recess in the north wall of the Valley, known as Millers Cove. On account of the prominence of this cove, the fault cutting through it on the northwest side is here called the Millers fault.

"Although the field evidence is not entirely conclusive regarding the relation of the Millers fault to the Pulaski fault, the writers believe that the Pulaski fault cuts across it and the Shenandoah limestone lying to the southeast of the Pulaski fault merely overrides the belt of limestone which marks the point of the anticline in Millers Cove. This supposition is strengthened by the finding of evidence of the presence of a fault in the great mass of limestone lying between Dry Creek and the Blacksburg-Newport road. In this area Brush Mountain bends distinctly to the north and, as the supposed fault bends to the south, there is a large area of Chickamauga [Elbrook] limestone which is very cavernous and consequently has mainly underground drainage. This limestone is evidently separated from the limestone on the south by a fault and hence it seems probable that the Chickamauga [Elbrook] limestone does not belong with the great mass of the limestone in this belt, but is probably a remnant of the faulted anticline of Millers Cove which was caught and pushed forward by the Pulaski fault and so is not now directly connected with the mass to which it formerly belonged."

---

[103]Woodward, H. P., Thrust faults of the Roanoke area, Virginia (*abstract*): Geol. Soc. America Bull. 40, pp. 185-186, 1929.

[104]Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, pp. 44-45, 1925.

The Miller overthrust cuts across the northwest corner of Roanoke County along the southeast flank of Brush Mountain for a distance within the county of slightly more than 5 miles. (See Fig. 4.) It apparently comes into view from beneath the Pulaski overthrust mass just west of the Montgomery County line and has been traced northeastward into Craig County, where it crosses the Catawba-Newcastle road opposite the north end of Cove Mountain, which it sharply truncates. The fault as observed along this road is entirely in Devonian shales, but it has brought the eastward dipping Romney and Brallier shales on the south side of the fault upon southward dipping Chemung beds to the north. At the Montgomery County line, the Miller fault has brought the Elbrook formation (Cambrian) upon the Price sandstone (Mississippian), so that the stratigraphic displacement is several thousand feet.

This overthrust cuts off the north limbs of the Miller anticline and the North Mountain syncline, and the movement along the fault has thrust both of these structures against and upon the Sinking Creek anticline to the northwest. (See Pl. 1.) Data are not available to indicate the amount of horizontal displacement along this fault, but it appears that the distance of thrusting is greater toward the southwest than toward the northeast. The presence of the Elbrook limestone upon the Price formation at the Montgomery-Roanoke County line seems to indicate a horizontal movement of at least 2 or 3 miles, and probably more.

The Miller fault is similar in every respect to the other great overthrusts of the region. Its origin is discussed under regional faulting.

MINOR THRUST FAULTS

In addition to the large overthrusts which have been described in detail, there occur in the Roanoke area numerous minor thrust faults which are, for the most part, of too limited extent and displacement to be shown on the geologic map. Some of these minor faults are distinct structures, entirely separate from the large thrust faults. Others branch off from the main faults and represent lines of weakness formed during the major faulting. Still others are confined to a single formation and represent overturned folds in semi-competent beds which have been entirely displaced during folding. Many examples of this type of fault can be seen in the Cambrian quartzites, where resistant beds have accommodated themselves to the extreme folding by local fracturing and thrusting.

NORMAL FAULTS

Although the great majority of the faults of this region are of the overthrust type, some normal, or gravity, faults are found.

The normal faults are much smaller than the thrust faults, and in Roanoke County are too small to be shown on the present topographic map. They occur typically in the weaker beds, especially in the shales, and are found in the Rome ("Watauga") formation, and in the Ordovician and Devonian shales. (See Pl. 24.) The amount of displacement is small, probably much less than 100 feet. The faults dip steeply as compared to the thrust faults, the average dip of the observed normal faults being about 70°, whereas the thrust faults seldom dip more than 15° to 20°.

It is extremely difficult to trace these normal faults, because they occur generally in rocks lacking beds which can be definitely identified. The normal faults are indicated by offsets in the strike of a given outcrop, but exposures are so unsatisfactory because of the deep soil, that commonly the faults can not be traced beyond a single exposure. These faults are best shown where extensive vertical cuts have been made along railroads or streams. Several small faults can be seen along Roanoke River between the 13th Street and Wasena bridges in Roanoke. Others can be seen in the railroad cuts along Mason Creek between Green Ridge and Fort Lewis Mountain.

The Devonian rocks in the Catawba syncline are broken in many places by small normal faults, where the open folds of the large syncline are wrinkled by smaller folds. Campbell and Holden have mapped two of the small normal faults cutting and offsetting the boundary between the Athens shale and the Chazy group about 3 miles northeast of Blacksburg.[105] (See Pl. 24,A.) These faults strike about N. 15° W., almost at right angles to the main structural trends.

The age of these normal faults is not definitely known. As they appear to antedate some of the overthrusts, and to be younger than others, it is inferred that they do not belong to any single period of disturbance, but represent gravitational adjustments to the stress of overthrusting before, during, and after the major thrust faulting. It is possible that some of the normal faulting is associated with the Palisade disturbance of northeastern North America, which occurred toward the close of the Triassic period.

[105]Campbell, M. R., and others, op. cit., p. 54 and Pl. 15, A.

OTHER STRUCTURES

JOINTS

Joints are very common in all rocks of this area. As a general rule, however, they are more abundant and more closely spaced in the sedimentary than in the crystalline rocks. They trend in nearly all directions, but there appear to be two sets which are more common than the others, being, in order of abundance, northeast-southwest joints and northwest-southeast joints. Joints in the first series parallel the major faults and folds of the region, and have been developed at right angles to the dominant pressure, whereas those in the second series cut across the general strike of the larger structures. North-south and east-west joints are comparatively rare.

The majority of the joints are tight, although some have been enlarged by solution. In certain formations, such as the Elbrook and Athens formations, many of the joints are coated or filled with white calcite which emphasizes them. A few of the joints are horizontal, but the majority are inclined at angles up to 30°.

CLEAVAGE

In the early Paleozoic shaly formations, such as the Rome ("Watauga") and Athens shales, cleavage has been induced during folding of the rocks. The shale splits most easily along these cleavage surfaces. The origin of the cleavage is attributed to recrystallization and orientation of the mineral grains so that their flat surfaces are parallel throughout considerable bodies of rock. This cleavage is easily mistaken for bedding, and only a painstaking examination of a ledge of shale will differentiate bedding planes and cleavage. The strike of the cleavage is, in general, northeast, parallel to the main structural trends of the region. Most of the cleavage dips less steeply than the beds. In a few places the cleavage and bedding are parallel for short distances. Most of the exposures of Rome ("Watauga") shale in the northeastern part of Roanoke show well-developed cleavage and bedding. Good cleavage in the Athens shale is found along the Lee Highway near Cloverdale.

EARTHQUAKES

Earthquakes are sudden movements of the ground caused by displacement of the underlying rocks. They are thus surface expressions of faults and evidence of sudden disturbance of the earth's crust.

On Christmas night, 1924, slight earth tremors were felt in Roanoke. They were apparently of local origin for they were not recorded on the seismograph at Washington, D. C. The only observed effect of this earthquake was the breaking of a water pipe leading from Crystal Spring to the top of Mill Mountain. This fracture occurred about 40 feet above the spring at the base of the hill. The broken pipe was an ordinary cast-iron leader 16 inches in diameter and of three-quarter inch metal. The break cut obliquely across the pipe. The broken edges of the pipe show that the fracture was caused by wrenching or twisting, and that it produced a series of tiny chatter-marks along one side of the broken surface. The pipe was not entirely broken at the time of the earthquake but gave away about a day later.

It seems that the movement which caused the earthquake was the result of a slight slipping, caused by accumulating stress, along a minor fault at the base of Mill Mountain. The Appalachian region as a whole is not subject to many earthquakes, and it is unlikely that further movement will take place in the vicinity of Roanoke for a long time. This is the only earthquake in recent times which has perceptibly disturbed this area.

GEOLOGIC HISTORY

GENERAL FEATURES

The geologic history of a region is interpreted from all the geologic features now found in the region. In the Roanoke area the succession of ancient events which make up its geologic history are recorded chiefly in the rocks and in the topography. Each rock formation, including its mineral deposits and the overlying soil, and each feature of the present landscape afford evidence which may be interpreted in terms of the sequence of processes which produced the features, in order to decipher the successive stages in the geologic history of the area.

In the earliest geologic time (Cambrian) of which there is record in the sedimentary rocks of this general region, there was along the site of the present Appalachian Valley and Blue Ridge a long narrow strait in a geosyncline, or slowly sinking trough, which separated still more ancient lands. This Appalachian Strait was on the eastern border of a broad area of old crystalline rocks (pre-Cambrian) which was, perhaps, the nucleus of the present continent of North America. This land mass was low and undulatory, and during successive periods of the Paleozoic era it was slowly and intermittently submerged under marine waters in which sediments were deposited upon the ancient basement. The Strait was bordered on the east by another land mass of old crystalline rocks, known as Appalachia. This elongate and somewhat narrow borderland was off shore from the central continental nucleus, and it separated the Appalachian geosyncline from the open Atlantic Ocean. The borderland must have been at times moderately high, because erosion was active on it and vast quantities of rock debris were swept into the marine waters of the geosyncline by the rivers which flowed westward down its slopes. Similar quantities of rock waste were presumably carried into the open ocean on the eastern side of the borderland.

The Appalachian Strait and geosyncline were thus receiving much sediment from the old land mass, Appalachia, on the east. With the progressive subsidence of the western mainland, and the opening of straits through the eastern borderland, the trough was successively inundated by marine waters. Hence its floor was built up by accumulations of sedimentary rocks of many kinds, especially by sands and muds from Appalachia, and by marine calcareous sediments. The invading waters often brought in a great abundance and diversity of marine animals, some shells of which are the fossils now found in the shales and limestones of the region. The filling of the sinking Appalachian geosyncline with these sediments, and the subsequent building of the old Appalachian Mountains from it, constitute the history of eastern North America during the Paleozoic era.

PRE-CAMBRIAN TIME

The great lapse of time since the pre-Cambrian rocks were formed has largely obscured the details of the pre-Cambrian history of this general region. The processes of erosion and deposition must have been active during much of that time, and there is evidence of considerable volcanic activity. But the details of the succession of events have been obliterated by subsequent profound changes, and the general picture is very hazy.

A succession of sedimentary rocks must have been formed from the products of the erosion of very ancient lands. Igneous rocks, such as granite, crystallized far below the surface from intruded molten magmas, and folding and crumpling of the rocks were common. The establishment of the interior continental mainland, the Appalachian geosyncline, and the borderland of Appalachia were the concluding events of pre-Cambrian history in this general region. The Paleozoic era began with those three major structural and topographic features controlling the geologic events in this area.

PALEOZOIC ERA

CAMBRIAN PERIOD

The deposition of sands and gravels in early Cambrian time was the first major event of the Paleozoic era recorded in the Roanoke area. These sediments were derived from Appalachia and washed westward into the geosyncline. At the beginning of the period Appalachia no doubt stood as a bold borderland east of the geosyncline, but as Cambrian time elapsed it was constantly lowered as the result of sinking and long-continued erosion. The Lower Cambrian sandstones and sandy shales (Chilhowie group) are succeeded by limestones and calcareous shales (Shady, Rome, and Elbrook formations) showing that Appalachia had probably become a lowland, almost lacking stream erosion, and that the geosyncline probably had become wider. At this time the Appalachian Strait had become a great gulf. There was no marked change in physical conditions toward the close of the Cambrian period. The warm and shallow waters of the broad Appalachian Gulf gave the life of the time a rich opportunity for development, and a new fauna of marine animals was evolved. It is estimated that the duration of the Cambrian period was, perhaps, of the order of several tens of millions of years.

OZARKIAN AND CANADIAN TIME

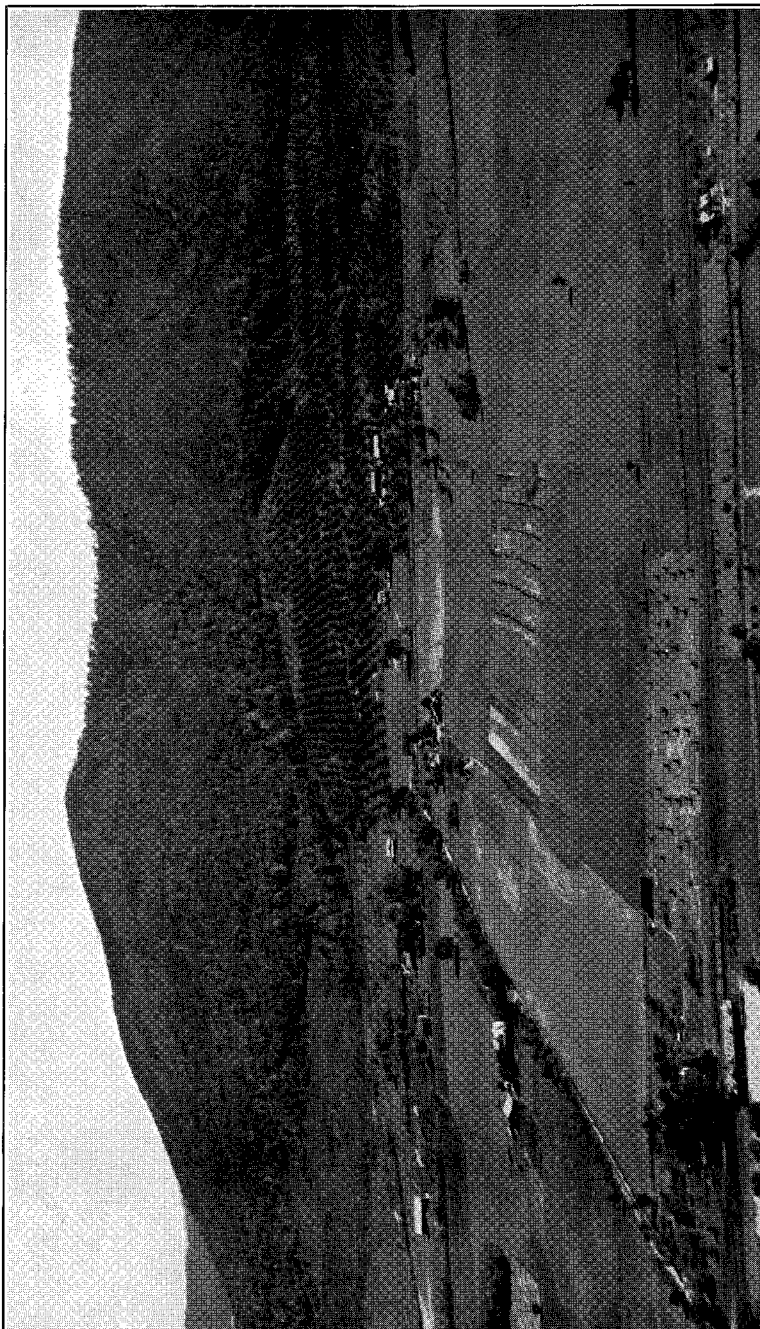
Favorable conditions for the formation of limestone continued for a very long time after the end of the Cambrian period as the calcareous sediments of the Conococheague and Nittany formations were deposited. Sands were at times swept into the sea during Conococheague time, but the sea in this area was almost free from clastic sediment during much of Conococheague and Nittany time. Although few fossils have been found in the limestones of this area, their occurrence elsewhere indicates that the sea probably contained considerable life. As shown by the absence here of thick formations of Ozarkian and Canadian age, found elsewhere in the Appalachian region, there must have been in the Roanoke area several long intervals of erosion or non-deposition between Cambrian (Elbrook) time and Ordovician (Chazy) time.

ORDOVICIAN PERIOD

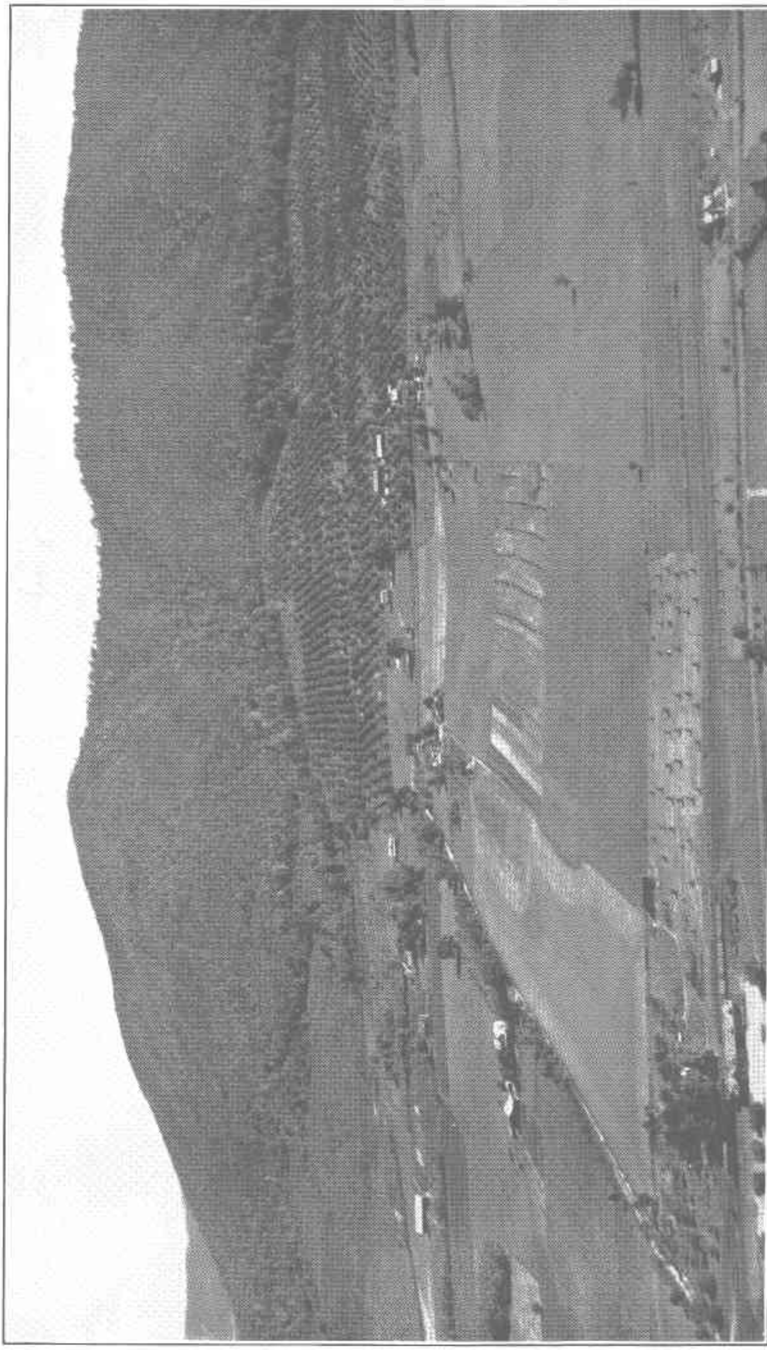
During Chazy time the deposition of dominantly calcareous sediments continued, but at times the waters were somewhat muddy. The sea was very clear during the early part of the period, resulting in the deposition of the pure calcium carbonate of the Mosheim and Holston limestones. During early Ordovician time sedimentation was interrupted because of emergence of the sea-floor, as is shown by the disconformities between some of the formations, for example, at the base of the Mosheim limestone. The inwash of muds became more pronounced in later Chazy (Athens) time. A mantle of volcanic ash settled over the area during a part of Moccasin time, giving rise to the present bentonite. Great swarms of graptolites, brachiopods, trilobites, and probably other invertebrates lived in the seas that covered the area during this time. Uplift of the borderland or shoaling of the sea brought a change in sedimentation, so that during the closing epochs of the Ordovician period the muds of the Martinsburg shale, along with numerous shells of the marine invertebrates, were deposited. Restriction of the Appalachian Gulf crowded the marine population into limited space, competitive conditions became more severe, and a great change in life followed. Hence the Ordovician and Silurian formations are distinguished by conspicuous differences in the forms of life which are preserved as fossils.

SILURIAN PERIOD

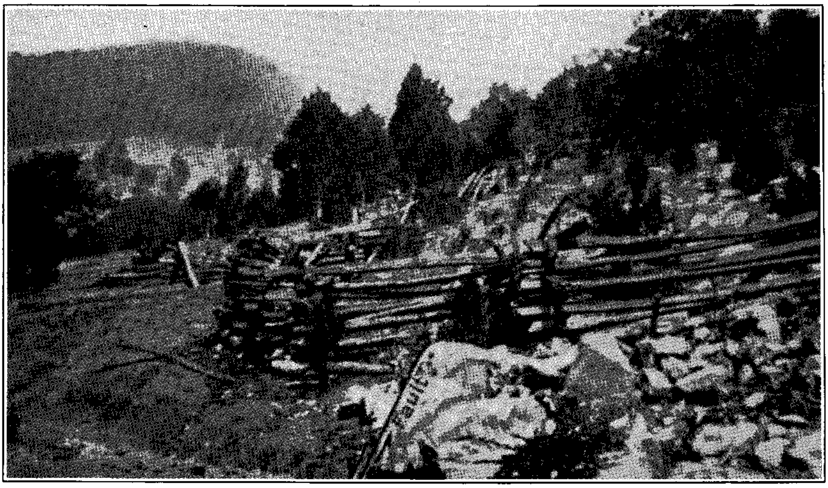
With the beginning of Silurian time, streams and wave erosion again became dominant with the resultant deposition of the Clinch and Clinton sands on the Martinsburg shale. These sands are the



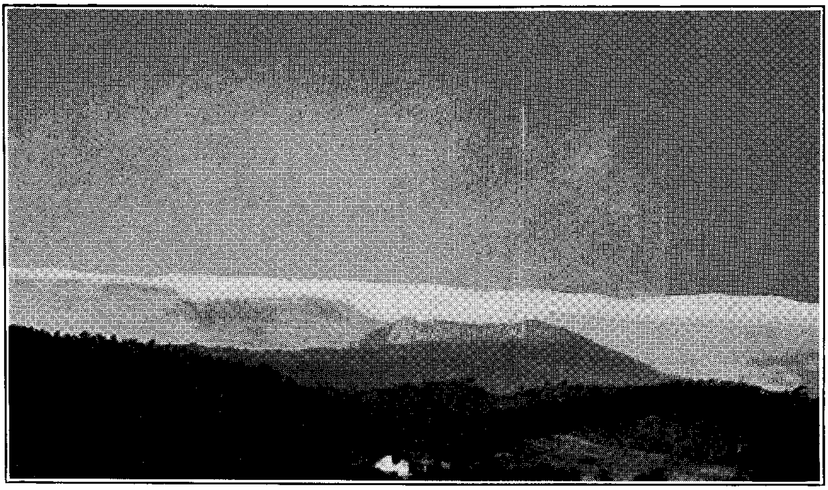
Mills (Reeds) Mountain, a fenster in the Pulaski overthrust. View looking southeast from south of Cloverdale. The ridge consists of folded middle Paleozoic formations bordered by Cambrian beds in the overriding block. (See pp. 22 and 85.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



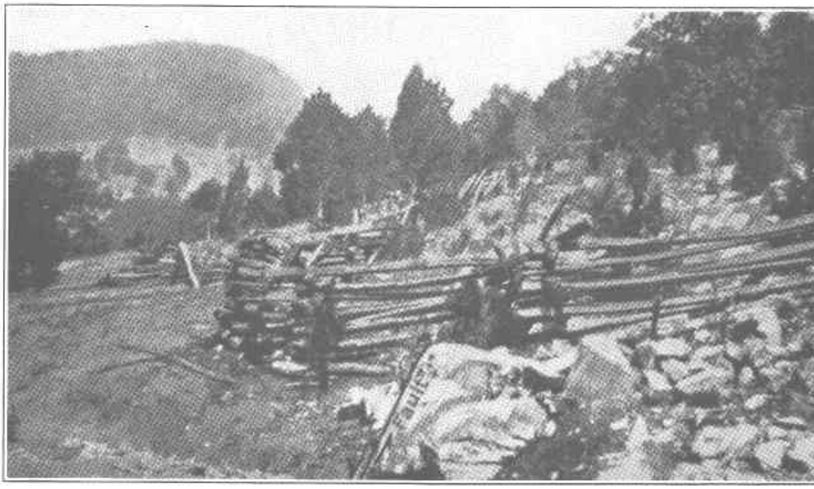
Mills (Reeds) Mountain, a fenster in the Pulaski overthrust. View looking southeast from south of Cloverdale. The ridge consists of folded middle Paleozoic formations bordered by Cambrian beds in the overriding block. (See pp. 22 and 85.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



A. Small normal fault near mouth of Mill Creek, Montgomery County. Athens shale to the left of the fault and Chazy limestone to the right. Movement along the fault has been relatively downward on the left. (See p. 91.) Photograph by M. R. Campbell.



B. North along Tinker Mountain from Dead Man's Mountain, showing offsets where the mountain is cut by faults. (See p. 91.)



A. Small normal fault near mouth of Mill Creek, Montgomery County. Athens shale to the left of the fault and Chazy limestone to the right. Movement along the fault has been relatively downward on the left. (See p. 91.) Photograph by M. R. Campbell.

B. North along Tinker Mountain from Dead Man's Mountain, showing offsets where the mountain is cut by faults. (See p. 91.)

characteristic deposits of a wave-beaten beach, which have been spread out by transient currents. The massive sandstones thus formed now represent parts of the ancient Silurian coastal plain. After millions of years of burial, the sands are again entering circulation by erosion and weathering to become part of some modern river or beach deposit. During part of Clinton time considerable ferruginous sediment was deposited in the sea that lay over central-western Virginia, from which the "fossil" hematite of the region was formed. By erosion of the material from which the Clinch and Clinton beach deposits were derived, the lands of the time had again been lowered to low plains, so that in late Silurian time little clastic sediment clouded the waters of the Appalachian Gulf. Hence the latest Silurian rocks are largely calcareous, with scattered lenses of sand.

DEVONIAN PERIOD

Conditions were much the same in early Devonian (Helderberg) time as in late Silurian time. Following the deposition of these calcareous beds another sheet of sand was spread widely by waves. Then there was deposited over a vast area the black muds of the Romney shale. These sediments accumulated in shallow waters, during a long epoch without material addition of other sediments. A great body of sandy muds was next deposited, now making up the Brallier and Chemung formations of late Devonian age. These clastic sediments are the waste of an eastern highland which was gradually uplifted and eroded during the period. This was a time when great deltas were built by the turbid flood waters of large streams. The frequent interbedding of coarse sands, sandy clays, and clays, and the cross-bedding, ripple-marks, and sun-cracks in these beds afford abundant evidence of the shifting conditions of deposition, the irregularity of currents, and the wide expanses of tidal and deltaic flats covered by shallow waters in late Devonian time. They show also the progressive erosion of the highlands in Appalachia as the period progressed. The sea in the geosyncline gradually shoaled until waves became effective in reworking and distributing the great volume of material furnished from the borderland.

MISSISSIPPIAN PERIOD

Slight submergence of the broad coastal plain developed during late Devonian time again brought the waves across the area. Sands and pebbles were swept out to form the earliest Mississippian deposits of sandstone and conglomerate (Price formation) in this region. The gravel in the Ingles conglomerate at the base of the Price formation indicates either that the land to the east was considerably elevated or that increased rainfall caused the streams to bring down large amounts of coarse material. Plants grew in coastal lagoons and swamps and their remains accumulated to form the coal beds in the Price formation. This formation is followed by red and greenish shales (Maccrady shale), and west of this area these shales are overlain by a thick widespread limestone. There is no evidence of this limestone in the Roanoke area, although it may have been deposited and later eroded away. No Paleozoic rocks younger than the Maccrady shale are known in this area.

POST-MISSISSIPPIAN TIME

From late Mississippian time to the present, the geological record in this area is largely one of crustal disturbance and erosion. This area has not again been the site of marine deposition. The results of erosion have been recorded in the peneplanes already described. The crustal disturbances have produced the folds and faults described under the heading "Structural Geology." The sequence of structural events is of interest in understanding the origin of the ancestral Appalachian Mountains, and in studying the present geologic structure of the area.

BUILDING THE APPALACHIAN MOUNTAINS

The geologic events that produced the diverse folds and faults of the Roanoke area were part of a series of disturbances which, as a final result, produced the great Appalachian Mountain system. This series of events, one of the most notable in the geologic history of eastern North America, is called the Appalachian revolution. The date of this revolution has been determined, but the details of the actual succession of events can be only approximately ascertained. In the Roanoke area no rocks later than Lower Mississippian are involved in the folds and faults because all younger rocks are absent. Hence evidence is not available in this area to determine how soon after early Mississippian time the revolution began or how long it continued. Such information must be derived elsewhere in the Appalachian region.

Study of the geologic record in the Roanoke area brings out the fact that the various folds and faults were not formed simultaneously or even continuously. The obvious impression is that the structures are either the result of more or less spasmodic forces or of a continuous force which acted spasmodically. As reflected in the rocks of this region, the Appalachian revolution must have been a continuous process extending over considerable time, but producing results that were manifested only at intervals, that is, a continuous effort with discontinuous effects. This idea is directly opposed to the early views of the Appalachian revolution, which pictured it as a cataclysmic disturbance of short duration. Studies throughout the Appalachian province have shown that the Appalachian revolution was not of sudden origin, but that it began well toward the middle of the Paleozoic era and culminated in late Pennsylvanian and Permian time. The disturbance thus extended over tens of millions of years; hence ample time was available for the succession of events recorded in the structures of the Roanoke area.

Several disturbances in other parts of the Appalachian region occurred before the Appalachian revolution, but little is known about them in this area. The exact relations of the various uplifts and warpings which caused the unconformable relations between different Paleozoic formations are rather vague. Possibly, these disturbances were premonitions of the great earth revolution which was to follow, and which produced the most important and obvious geologic structures of the region, as well as the greatest mountain system in eastern North America.

The earliest structures associated with the Appalachian revolution are the great open folds, the Catawba syncline being a typical example. These folds must have been a system of wavelike flexures of the whole eastern part of the Appalachian region. The folding began directly west of the old crystalline land mass, which furnished the material for the Paleozoic sediments, and the folds progressively involved rocks farther to the west until they died out in the Appalachian Plateaus of West Virginia and other states.

This period of folding had a special effect upon the shales immediately above and below the competent Cambrian-Ordovician limestones. These Cambrian and Ordovician shales are relatively weak, and being buttressed on all sides by resistant formations, they were contorted into a series of minor folds which show no clear relation to the great open folds. There is no adequate information as to the relative age of the numerous small thrust and normal faults. It is reasonable to consider that, throughout this time of folding and the subsequent times of faulting, many minor adjustments would be made in the various rock masses, and that they would be manifested in many small faults. The whole history of the region appears to be marked by faulting. The earthquake at Roanoke in 1924 tends to show that slight faulting continues to the present time.

Following the time of great folding, or late in its cycle, the next event appears to have been faulting, with the Miller overthrust being the first large fault in this area. During this overthrusting the Miller anticline and the North Mountain syncline were thrust northwestward against the Sinking Creek anticline. Little is known about the Miller fault, except that it passes under the Pulaski overthrust mass, and was formed prior to the Pulaski fault. It was formed later than the great folds, as they are included in the rock masses along the Miller fault, but how much later has not been determined.

The great Pulaski fault was formed after the Miller fault. It is impossible to determine the time that elapsed between the two epochs of displacement because the same series of rocks is involved. Were it not for the fact that one fault crosses the other, they might be considered simultaneous. The mass of the Catawba syncline was thrust northwestward for several miles during this disturbance, and it now rests upon the Miller anticline and the North Mountain syncline, covering part of the Miller fault. The sharp bend in Tinker Mountain just east of McAfee Knob suggests thrust-faulting subsequent to the original folding, along either the Pulaski or Salem faults, or both. It is the opinion of the writer that the acuteness of this bend was initiated at the time of the Pulaski fault, and was further accentuated by the Salem overthrust.

In Montgomery County, the Pulaski fault has been found by Campbell and Holden [106] to become involved at the southeastern end of Berringer Mountain with another fault which is considered to be the westward continuation of the Salem fault. At this point the Pulaski fault appears to be older than the other fault, although the relations are not clear. If this is true, and if the Salem fault is continued in this secondary fault, the Salem fault is younger than the Pulaski fault. So far as the writer is aware, there is no other definite evidence bearing upon the relation of these two faults. As the general tendency in this region is for the faults to be younger toward the southeast, and as the Salem fault-block overlaps the Catawba syncline, which was in motion during the Pulaski overthrusting, the evidence rather strongly suggests that the Salem fault is younger than the Pulaski fault. This point, however, has not been positively determined.

The supposed northeastward continuation of the Salem fault meets the Blue Ridge fault in Powell Gap near the Grubb iron mines, northwest of Blue Ridge Springs, Botetourt County. It appears from their traces that the Blue Ridge fault cuts across the

[106]Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, p. 51, 1925.

Salem fault. On the assumption that the southeastern faults are younger than those to the northwest, the Blue Ridge fault is considered to be younger than the Salem fault. The Blue Ridge overthrusting caused the folding and shattering of the Cambrian quartzites and further compression of the minor folds in the Cambrian and Ordovician shales.

Overthrusts later than the Blue Ridge fault are not known in the Roanoke area. This great displacement seems to have relieved the compressive stress so that further large-scale adjustments were unnecessary. There is evidence in adjacent areas that the fault planes were gently warped after the Blue Ridge overthrusting. It is reasonable to expect that a series of great movements, such as produced the major structures of this area, would not end suddenly, but would die out gradually, with the later movements becoming progressively smaller.

The geologic events which produced the structure of the rocks of the Roanoke area may be arranged approximately in their relative order, as has been attempted, but it is impossible to date accurately this series of events. The events are later than the deposition and consolidation of the Lower Mississippian rocks. The Appalachian revolution appears to have ended in other areas before the deposition of Upper Triassic sediments. Hence the major deformative movements occurred between these time limits. In Pennsylvania, the youngest rocks that were folded during the Appalachian revolution are of Pennsylvanian and Permian age. By analogy, it may be assumed that if these rocks were ever present in the Roanoke area, they would have been involved also in the folds and faults. It seems highly probable, therefore, that the crustal movements which severely folded and faulted the rocks of the Roanoke area began toward the end of the Pennsylvanian period, and continued at intervals into the Permian period but had largely ceased by the early part of the Mesozoic era.

MESOZOIC ERA

In the Roanoke area, as well as throughout all of the central Appalachian region, the Mesozoic era was a time of almost continuous erosion and destruction of the newly formed Appalachian Mountains. There is no record in this region by which to decipher the details of geologic activity, except toward the close of the era, when certain topographic features were produced. No doubt, sediments were deposited locally, but later erosion removed them. It is quite possible also that some of the characteristic land animals of Mesozoic time, such as dinosaurs, wandered into this general region but there is no record of them.

Toward the middle of the Mesozoic era, or possibly later, apparently much of this general region had been eroded by streams to a widespread, gently undulatory plain. The great anticlines and the huge overthrust blocks had been reduced mostly to a common level. The Roanoke area instead of being in a region of bold mountains was a plain not far above sea-level. This plain is now called the Summit peneplane.

This long period of crustal stability, during which the Appalachian Mountains were beveled to produce the Summit peneplane, was brought to an end by a vertical uplift of about 500 feet. The rejuvenated streams cut to this new base-level and again planed away much of the region. This peneplane was very widely developed in the Appalachian province. Residual hills, or monadnocks, were, however, scattered over it. It is now the Upland peneplane, which is generally considered to be of Cretaceous age, although it may be younger.

CENOZOIC ERA

Another vertical uplift, or series of uplifts, occurred during late Mesozoic (?) and early Cenozoic time. The Upland peneplane was dissected and broad flat-floored valleys were cut at new levels about 800 to 1,200 feet below its surface. This third erosion cycle may be represented in the Roanoke area by the "Intermediate levels," which have been previously discussed.

During early Cenozoic time (Tertiary period) further vertical uplift of about 1,000 feet was followed by a time of crustal stability during which a series of broad lowland plains was cut on the less resistant limestones and shales of the Appalachian region. These peneplanes of the fourth series are known as the Valley peneplanes. Roanoke Valley floor, at a general elevation of about 1,000 feet, is the local representative of this erosion cycle. The broad Dublin and Fincastle Valley floors were also produced at this time. They are at different elevations because they were produced in three separate drainage systems, namely, the Roanoke, the New, and the James.

This last cycle of partial peneplanation was likewise ended by vertical uplift, which to date has amounted to several hundred feet. It may still be continuing. The rejuvenated streams have become entrenched in their present relatively narrow valleys.

MINERAL RESOURCES

GENERAL FEATURES

Many of the rocks of the Roanoke area contain minerals that are of economic value under favorable conditions of occurrence and favorable markets. Few of them are being mined at present, and the mining industry is now of slight importance in Roanoke County.

The most important materials being mined and quarried are: Clay, stone for building, and crushed rock, limestone, nelsonite, and slight amounts of iron. The production of none of these is very large. Coal, iron, manganese, glass sand, barite, and cement rock are of possible economic value, but they can be profitably developed only under more favorable market conditions. Petroleum in commercial quantities will not be found here. The occurrence of gold, and possibly silver, near Roanoke is authentic, but both occur in such small amounts as to be commercially negligible. Lead, zinc, copper, and nickel have been discovered but have not proved of commercial value. The main natural resources of the area are, therefore, non-metallic substances.

A bibliography is given at the end of this section. It contains all of the important articles on the mineral resources of the Roanoke area.

METALS

IRON AND MANGANESE

That iron deposits have long been known in this area is attested by the old Back Creek furnace, about 6 miles south of Roanoke, which was operated in the latter part of the 18th century. The old Catawba furnace (Pl. 25, A) was built about 1820 on Catawba Creek, near the present site of Haymakertown, and the Cloverdale furnace, near Cloverdale, was built about 1830 and abandoned in 1849. The accessibility of the deposits and the ease of mining and smelting the ores led to early operations on a small and crude scale. As the discovery of higher grade ores elsewhere and the centralization of the iron industry have made such small operations profitless, the iron deposits of the Roanoke area are not being mined at present.

Some prospecting, but very little serious mining, was done in the region until the boom of the early eighties. The building of a railroad and the rapid growth of Roanoke led to local mining operations, which were further encouraged by the meeting at Roanoke in 1883, of the American Institute of Mining Engineers. From 1880 to 1905, many iron mines were opened and abundant pros-

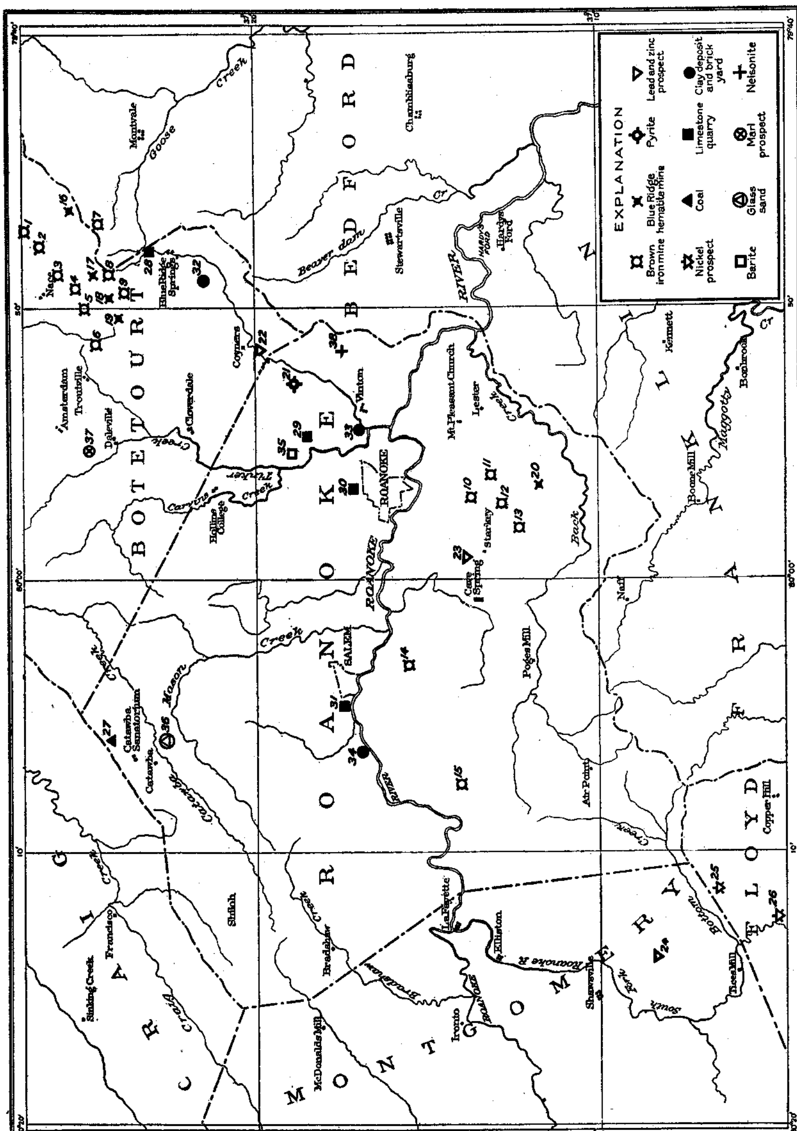


Figure 7.—Map showing location of the most important mines, prospects, and quarries in the Roanoke area.

1. Gowan bank.
2. White bank.
3. Deal bank.
4. Houston mine.
5. Stoner mine.
6. Murray mine.
7. Buford bank.
8. Upland, or Crozer, mine.
9. Lynchburg, or Grubb, mine.
10. Rorer mine.
11. Griffin mine.
12. Gale mine.
13. Starkey mine.
14. Castle Rock mine.
15. Poor Mountain mine.
16. Lemon mine.
17. Edith mine.
18. Grubb specular mine.
19. Cundiff and Dewey mines.
20. Griffin specular mine.
21. Bonsacks prospect.
22. Bonsacks prospect.
23. Martin and Wertz prospects.
24. Langhorne and Wills prospects.
25. Sugar Run prospects.
26. Lick Fork prospects.
27. Chapman prospect.
28. Blue Ridge Springs quarry.
29. Mundy quarry.
30. Roanoke city quarry.
31. Salem city quarry.
32. Webster Brick Company.
33. Adam, Payne, and Gleaves Company.
34. Salem Brick Works.
35. Reeds quarry.
36. Salem Glass Works quarry.
37. Daleville opening.
38. Hutchins mine.

pects were located, so that by 1903 several furnaces were operating at or near Roanoke. (See Fig. 7.) Soon after this flurry, workings were rapidly closed. Since 1920 no iron or manganese mine has been operated in the area around Roanoke, except near Buchanan.

The iron and manganese deposits of this general region may be classified as follows:[107]

A. Red hematite.
   1. Blue Ridge "specular" hematite.
   2. Clinton "fossil" hematite.
B. Brown iron and manganese.
   1. Cambrian deposits along the Blue Ridge.
      a. Iron and manganese in pockets in brown or variegated clays.
      b. Iron in dark-red ocherous clays at the edge of the Valley.
      c. Replacement deposits of iron and manganese in stratified bedrock.

[107]Modified after Harder, E. C., The iron ores of the Appalachian region in Virginia: U. S. Geol. Survey Bull. 380, pp. 215-254, 1909.

B. Brown iron and manganese.—Continued.
   2. Oriskany iron and manganese deposits.

C. Magnetite.
   1. Limestone magnetite in the Valley.
   2. Titaniferous magnetite in crystalline rocks.

D. Pyrite and pyrrhotite.

BLUE RIDGE HEMATITE

At, or near, the base of the Chilhowie group (Lower Cambrian) there occurs a ferruginous sandstone which is locally of suitable quality to be mined as a siliceous iron ore. It is often called "mountain specular ore"[108] from its occurrence high on the flanks of the Blue Ridge foothills. It is very siliceous and of rather poor grade, having an average iron content of from 35 to 40 per cent, with 30 to 40 per cent of silica. The combined percentages of phosphorus and manganese seldom exceed 1 per cent. This ore has been mined in Roanoke County only on Buck Mountain. Several other mines and prospects have been opened along the southwest flank of the Blue Ridge near Blue Ridge Springs. (See Fig. 7.)

The Blue Ridge hematite consists of beds of quartzose sandstone and conglomerate which have been partly replaced by hematite. The ore is dense and hard and generally deep bluish-green at depth, with the hematite giving slight color to the enclosing rocks. The material is much weathered near, and at, the surface and becomes dark-red due to oxidation of the iron. Where long exposed, much of the hematite alters to soft limonite with traces of manganese oxides in incrustations. The siliceous nature of the ore is due to unreplaced sand grains and quartz pebbles which are very abundant along some of the bedding planes. Small gray or reddish lumps of clay are found in the ore and thin lenses of shale occur in the low-grade masses.

The hematite is associated with the sandstone, quartzite, and shale near the base of the Chilhowie group, and has the same strike and dip. The beds have been much fractured and generally dip at high angles. In the belt north of Blue Ridge Springs the iron deposit persists along the strike for more than 3 miles. Only one bed of this hematite is known in the Roanoke area. It is reported to be from 4 to 12 feet thick near Blue Ridge Springs, and 2 feet thick on Buck Mountain. It was mined from open cuts and deep workings along the dip. The highly siliceous nature of the Blue Ridge hematite greatly impairs its value, and it is not probable that the deposits in this area will again be of value.

[108]Although this is called specular ore, it has no resemblance to true specularite.

The bedded nature of the hematite shows original deposition probably very similar to the deposition of the younger Clinton hematite. The associated rocks are non-fossiliferous but are probably of marine origin.

CLINTON HEMATITE

Bedded deposits of hematite are associated with the Clinton formation or its equivalent, from New York State to Alabama, but few workable deposits have been found in Virginia and none near Roanoke County. The formation is present in Roanoke County and carries small amounts of hematite which is too thin and of too low grade to be of value.

The Clinton formation crops out along the southeast slope of Catawba Mountain, where it consists of sandstone and shale with a few thin, interbedded limestones. Near its base there is a bed of red "fossil" hematite a few inches thick, which can be traced along the strike for 10 to 12 miles east of Catawba Sanatorium. This lens is between green shales. It was deposited probably as a marine sediment. The Clinton formation generally dips at rather high angles. The red iron stain is washed down the exposure for several feet, so that the actual thickness of the iron deposit is often exaggerated. The iron is called "fossil" hematite because it is composed of an aggregate of tiny shells of brachiopods, crinoid stems, and bryozoa, whose original calcium carbonate has been replaced by ferric oxide. In some places the material is granular and consists of tiny rounded quartz grains which have been coated with hematite. Blocks of this iron have been found on Little Brushy and Mills (Reeds) mountains, but none of it in place was observed.

Analyses of the Catawba hematite have been made as follows:

Analyses of Catawba iron ores[109]

(Henry Froehling, Analyst)

	1	2	3	4
Metallic iron	56.490	66.375	51.970	40.672
Phosphorus	.034	.014	.176	.156
Manganese	....	....	....	.393

1. Ore from "Beard's," on Catawba Creek, from Middle Ridge, between North and Catawba mountains.
2. From Capt. Jas. Peak's, on Catawba Creek; from same ridge as No. 1 above, but 6 miles distant.
3. From Capt. W. W. Beard's, on Catawba Creek, from continuation of Catawba furnace ore beds in North, or Catawba, Mountain.
4. From David Barnett's land on side of Catawba Mountain.

[109]Hotchkiss, Jed., Analyses of Catawba iron ores: The Virginias, vol. 5, p. 107, 1884.

BLUE RIDGE BROWN IRON AND MANGANESE

These deposits include all of the deposits of brown iron and manganese oxides at the foot or along the slope of the Blue Ridge in, and beyond, the Roanoke area. (See Fig. 7.) They include several types: (1) The so-called "mountain brown ores," (2) the limestone limonite or Valley brown ores, and (3) the deposits of manganiferous iron or purer manganese at the west foot of the Blue Ridge. For the most part they are on gravel-covered remnants of the Valley-floor peneplane on the west slopes of the sandstone foothills of the Blue Ridge. The deposits are seldom large, but are numerous. Some have been worked for more than 150 years. This report deals with three groups of mines: (1) Those surrounding Rorer mine 5 miles south of Roanoke; (2) those surrounding the Grubb, or Lynchburg, mine near Blue Ridge Springs, Botetourt County; and (3) mines near the Houston mine on the northwest slope of the Blue Ridge. (See Fig. 7.)

The brown iron and manganese are found mostly (1) just above the Erwin quartzite at the base of the Shady dolomite, (2) in residual clays from these formations, and (3) along a fault which overthrust one of the Cambrian-Ordovician limestones against the Erwin quartzite. A few deposits are known in (1) the Rome ("Watauga") shale, (2) the brecciated zones of the Erwin quartzite, (3) pockets of residual clay from the Elbrook formation, and (4) stream gravels derived from the ore-bearing formations. All of the deposits have had the same general history, and the different types represent different stages in the same processes of ore formation.

These deposits of brown iron and manganese along the west side of the Blue Ridge in this general region may be classified as follows:[110]

A. Irregular concentrations in brown or variegated clays.
   1. Pocket deposits along or upon foothills of quartzite.
      a. In Shady residual clays along slopes of monoclinal Erwin quartzite.
      b. In synclinal basins upon a floor of Erwin quartzite.
   2. Pocket deposits in fluvial clays in the Valley.
   3. Irregular masses along faults in clays of the lower Shady or other Valley limestones.

[110]Modified after Harder, E. C., op. cit.

B. Concentrations in dark-red ocherous clays at the edge of the Valley.
   1. Pocket deposits in residual clays above the Shady or Elbrook formations.

C. Replacement deposits in stratified bedrock along the slopes of foothills.
   1. Along faults and brecciated zones in the upper Erwin quartzite.
   2. In sandstone or shale of the lower Shady or Erwin formations.
   3. Along fractures in shales.

The most common type of deposit occurs in brown or variegated clays as irregular concentrations which were produced by downward moving meteoric waters. This material occurs as lumps, grains, and shapeless masses ranging from a small nodule to masses of 1,000 tons. The deposits are generally on a remnant of the Valley-floor peneplane, a few hundred feet above the present streams, and are most abundant along the quartzite foothills of the Blue Ridge. They occur in irregular broken masses in the residual clays of the lower 300 feet of the Shady dolomite, concentrated against the impervious beds of the Erwin quartzite. They are especially rich where the Erwin dips in a monocline toward the Valley. These deposits are more or less linear with their long axes parallel to the hill slope. In places they dip steeply. They have accumulated along the surface of benches and in the shales below. Much float occurs, and many of the ore bodies are very large. The ore is generally mammillary. A limestone nucleus is found in some of the larger masses, showing that the iron and manganese are replacing original calcareous material.

In a few places deposits occur well toward the top of the foothills in troughs on the Erwin quartzite. These deposits are small and some of the quartzite is partly replaced. Farther out in the Valley, where erosion has transported the weathered clays, scattered small deposits are found. At other places deposits of iron and manganese occur along faults which cut the basal Shady dolomite. This type of deposit is uncommon and is unknown in the Roanoke area.

On the lower levels of the Valley near the Blue Ridge, irregular lumps and masses of brown ore occur in dark-red clays above the Shady and Elbrook limestones. This type of deposit is shallow but somewhat richer than that associated with the quartzite. The deposits are of the same general nature as those on the foothill slopes, but they have not been deposited down to the quartzite basement. These deposits are invariably associated with dark-red clays, and the bright-colored or variegated clays are conspicuously absent. (See Pl. 25, B.) Many masses of fresh limestone occur in the ore bodies. This type of deposit is much more important in southwest Virginia than along the Blue Ridge.

The Erwin quartzite is in places crushed and brecciated, and iron or manganese replaces the broken sandstone, fills crevices in the crushed zones, and is found along bedding planes. In other places the sandy beds of the lower Shady dolomite and of some of the upper Erwin quartzite have been replaced with iron. The deposits range from highly ferruginous sandstone to quartzite barely stained with iron. In favorable locations, calcareous beds of the Rome ("Watauga") and lower Cambrian shales have been replaced with iron, which gives a low-grade deposit of brown iron alternating with thin beds of shale. No deposits of this kind are known in Roanoke County.

The brown iron deposits along the Blue Ridge consist of impure hydrated oxides of iron, often so intimately intermixed with manganese oxides that it is impossible to distinguish them in the field. The iron oxides range from limonite to goethite and carry from 35 to 45 per cent metallic iron. The manganese oxides are psilomelane, pyrolusite, manganite, and wad. The brown ores are of three general types, namely, relatively pure iron ore, manganiferous iron ore, and relatively pure manganese ore. All of the ore is non-Bessemer. The more highly manganiferous ore is unsuited for steel but is used for ferromanganese. The grade of the ore determines the manner of mining. About 1 car of ore is obtained from 5 to 25 cars of clay.

The ores around Roanoke are high in phosphorus. The most common ore is a brown earthy amorphous mixture of oxides containing considerable clay. It is purer and darker where it is associated with limestone, and becomes lighter and poorer where mixed with sand and clay. The so-called "Valley ore" is purer than the "mountain ore" and contains less manganese. Some ore is black, glossy, hard, and breaks with a conchoidal fracture. This type occurs as fillings and replacements and is less common in the clay pockets. It is in places mammillary and contains a high percentage of manganese.

The following analyses show the average metallic content of the brown ore:

Analyses of three general types of brown ore in southwestern Virginia

	1	2	3	4
Metallic iron	41.99	41.22	47.15	12.32
Metallic manganese	.81	.90	7.28	44.31
Phosphorus	.25	.93	.06	.10
Alumina	1.91	....	....	....
Silica	16.17	20.61	8.03	5.47

1. Average of all ores from 21 mines in the New River-Cripple Creek district. Holden, R. J., Iron, *in* Watson, T. L., Mineral resources of Virginia, p. 414, Lynchburg, 1907.
2. Blue Ridge limonite, average composition as mined. Op. cit., p. 416.
3. Iron ore from Houston mine. McCreath, A. S., The mineral wealth of Virginia tributary to the lines of the Shenandoah Valley and Norfolk and Western railroad companies, p. 51, Harrisburg, Pa., 1883.
4. Manganiferous iron ore from Houston mine. Idem.

The iron and manganese were originally derived from the Piedmont crystalline rocks and then deposited with the clays and limy muds that compose the shales and limestones. The metals were probably widely disseminated in the sediments, combined with carbonic acid, sulphur, or some form of silicic acid. The undecomposed shale and limestone carry ferrous silicate minerals and pyrite, and the Shady dolomite contains nodules of mixed calcium, iron, and manganese carbonates. Under the influence of descending oxidizing meteoric waters, and in part through the agency of organic acids, the carbonates were altered to hydrates and the metallic contents were transported along favorable channels and redeposited as oxides by replacement of calcareous matter in the clays. The localization of the oxides was favored by the impervious basement of quartzite and by cracks in brecciated zones. The degree of concentration was governed by the amount of the original metals in the overlying beds, which accounts for the scattered nature of the deposits. This process of concentration would operate most favorably upon an area of low relief under a warm moist climate. The epoch of Valley-floor peneplanation, when deep decay was taking place, seems to have been suitable for the deposition. These deposits are upon benches along the Valley, except some in fluvial clays which have been eroded from higher deposits.

A considerable number of workings and prospects of the brown iron are scattered through the Roanoke area, but none of them are at present important, or give promise of much future development. The mines south of Roanoke, at the edge of Roanoke Valley, are: Rorer mine, Gale mine, Griffin mine, Castle Rock and Turner mines, Iron Bluff Farm prospect, and Poor Mountain mines. Mines along the southeast side of the Blue Ridge in Glade Creek Valley are: Lynchburg, or Grubb, mine, Upland, or Crozer, mine, and Buford bank. Mines along the northwest side of the Blue Ridge in Fincastle Valley are: Houston mine, Stoner mine, Murray bank, Gowan bank, Deal bank, and White bank.

ORISKANY IRON AND MANGANESE

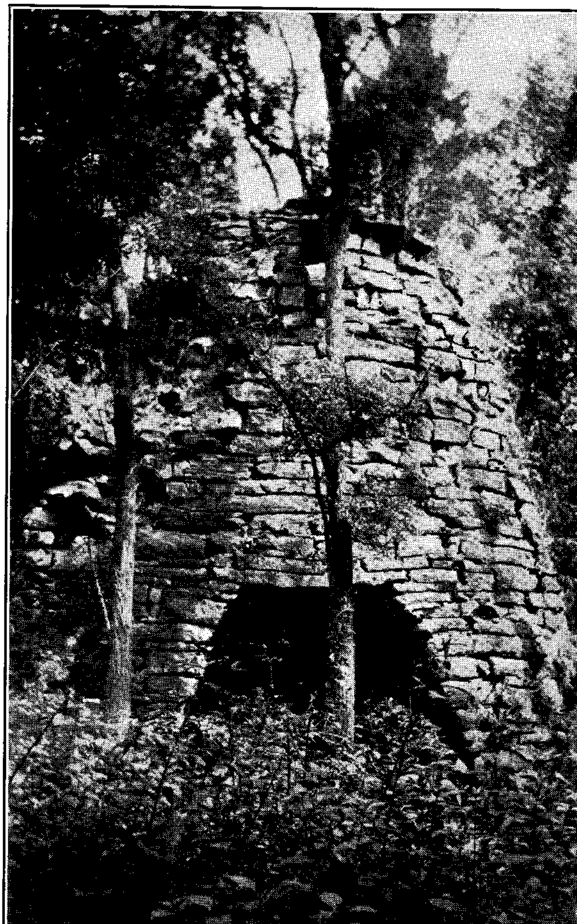
In the Roanoke area the Oriskany horizon is represented in a few places by a sandstone at the top of the Helderberg group which lies directly below the black Romney shale. In Botetourt and Craig counties this (or a similar) sandstone carries abundant brown iron and manganese. In the Roanoke area no mines or prospects have been opened at this horizon, and deposits of commercial value have not been observed.

In the adjacent counties beds of dark-brown limonite high in silica and manganese occur as irregular masses which are in places hard and solid but more commonly are cellular. The limonite is scattered through the sandstone or replaces the cherty limestone below it, and generally carries much clay and sand. The horizon crops out along the lower slopes of the Valley Ridges at one of the Valley-floor erosion levels, a few hundred feet above the present streams. The deposit commonly occurs along the strike with fairly constant thickness and high dips.

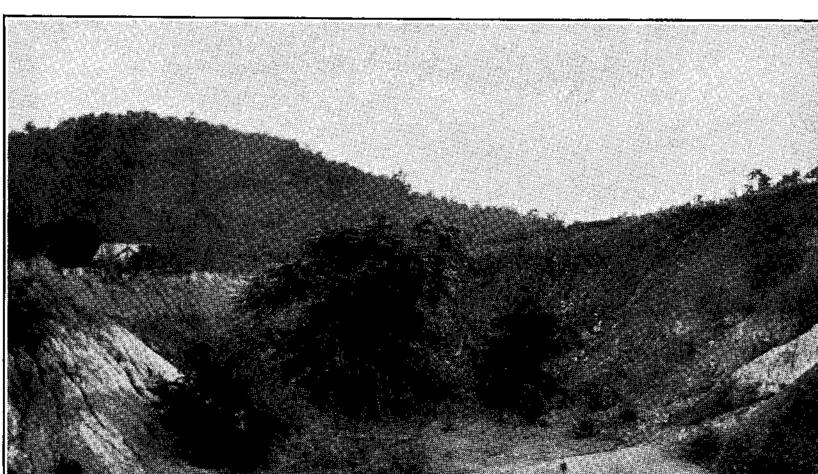
The iron and manganese have evidently been leached from higher levels by descending surface waters, and have been deposited near the bottom of the zone of surface weathering on the peneplanes. Subsequent uplift of the land has enabled the streams to cut into this floor so that the deposits now lie on benches along the mountain slopes. The deposits have been enriched further by deposition after uplift of the peneplanes. The source of the material was probably the overlying Devonian black shales which carry 4 to 5 per cent of iron.[111] It is possible that the sandstone itself is a source of the iron, as suggested by Kemp[112] and by Weld.[113] The outcrops, bedding planes, and joints of the sandstone are stained in many places with manganese oxide.

Disseminated masses of brown iron and manganese occur in the Helderberg beds in Roanoke County, for example, on Tinker, Dead Man's, and Catawba mountains. The oxides occur in cracks, in pockets, and are disseminated in a yellowish, coarse friable sandstone. At no place, however, were deposits of commercial value noted. Several workings, about 12 miles southwest of Newscastle, in Craig Valley, were operated on a small scale during the World

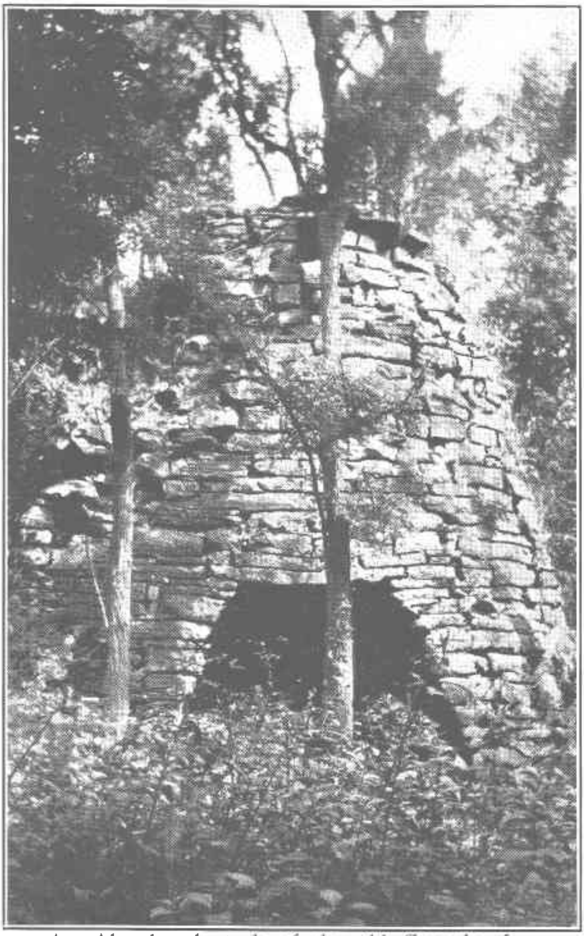
[111]Holden, R. J., Iron, *in* Watson, T. L., Mineral resources of Virginia, p. 408, 1907.
[111]Harder, E. C., The iron ores of the Appalachian district in Virginia: U. S. Geol. Survey Bull. 380, pp. 249-250, 1909.
[112]Kemp, J. F., The iron ore resources of the world: Internat. Geol. Cong., XI, Stockholm, vol. 2, p. 764, 1910.
[113]Weld, C. M., The Oriskany iron ores of Virginia: Econ. Geology, vol. 10, pp. 399-421, 1915.



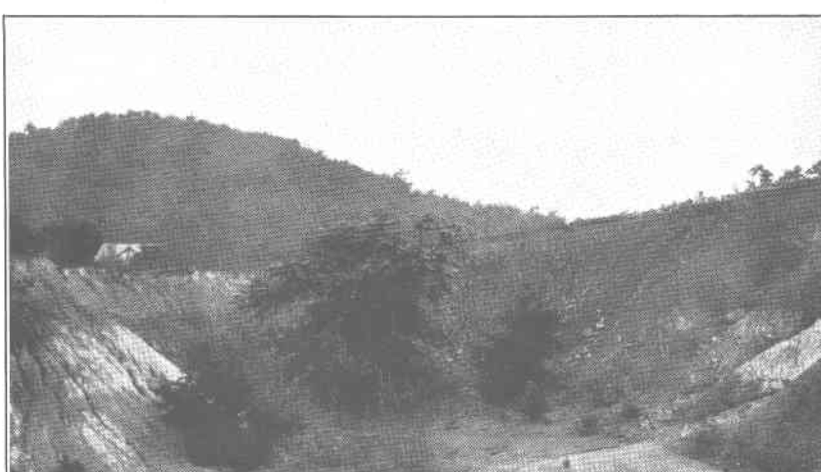
A. Abandoned stack of the old Catawba furnace. Along Catawba Creek north of Haymakertown, Botetourt County. This furnace was abandoned about the time of the War between the States. (See p. 103.)



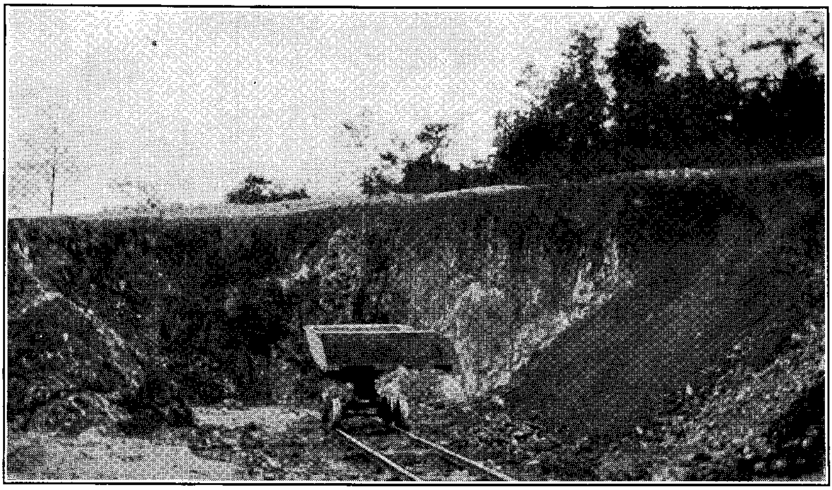
B. Abandoned open pit in residual brown iron ores of the lower Shady dolomite. Five miles south of Roanoke, along the Rocky Mount highway. (See p. 110.)



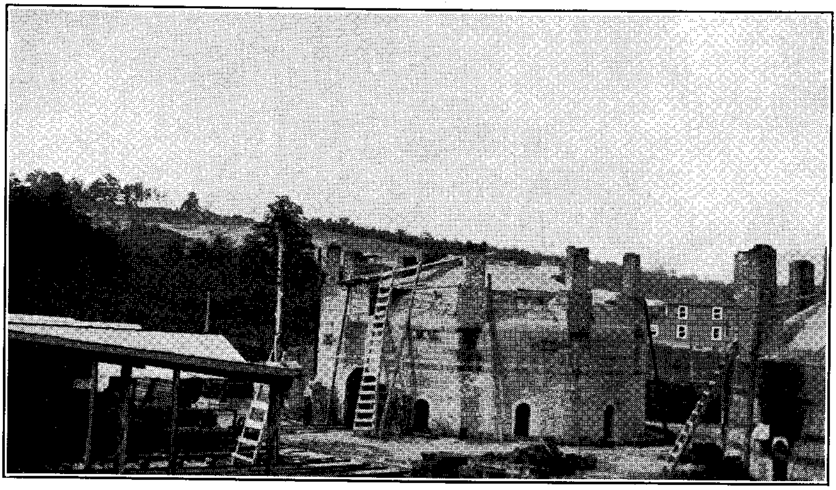
A. Abandoned stack of the old Catawba furnace. Along Catawba Creek north of Haymakertown, Botetourt County. This furnace was abandoned about the time of the War between the States. (See p. 103.)



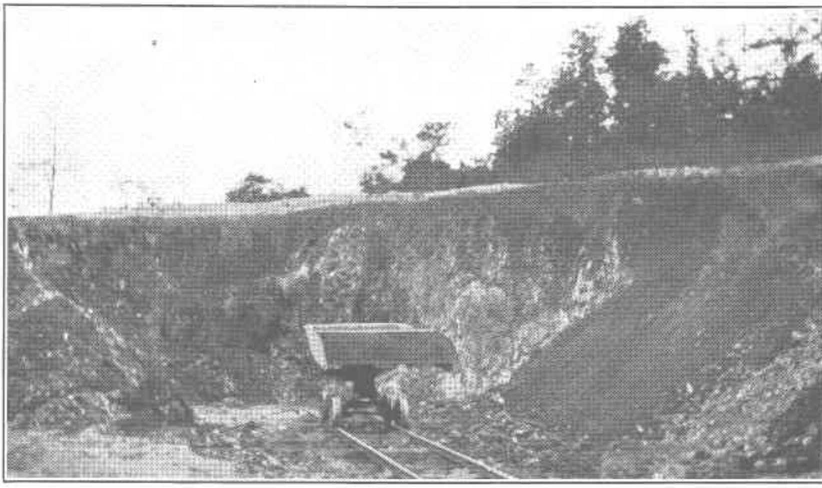
B. Abandoned open pit in residual brown iron ores of the lower Shady dolomite. Five miles south of Roanoke, along the Rocky Mount highway. (See p. 110.)



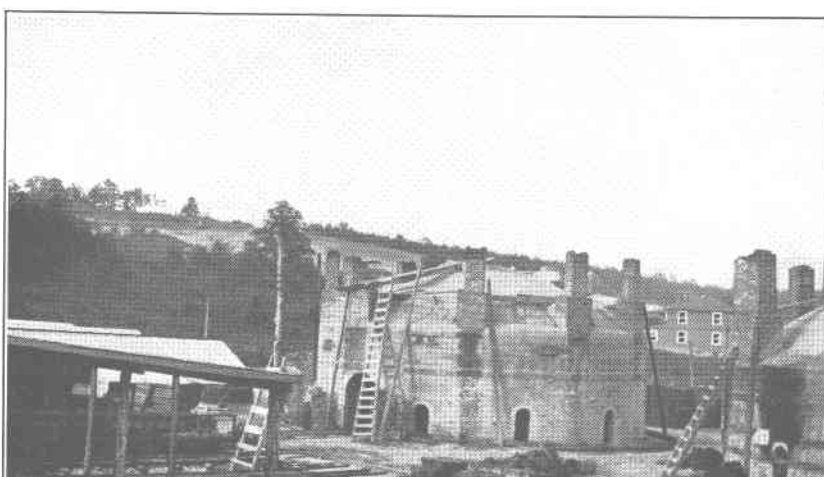
A. Clay pit of Webster Brick Company, in weathered Rome ("Watauga") shale. (See p. 127.)



B. Brick kilns of the Webster Brick Company.



A. Clay pit of Webster Brick Company, in weathered Rome ("Watauga") shale. (See p. 127.)



B. Brick kilns of the Webster Brick Company.

War but have been idle since 1924. The ore was psilomelane, manganite, and brown limonite.[114] Similar Oriskany deposits are reported to crop out on the south slope of Cove Mountain. This exposure was not visited by the writer. Numerous reports[115] have been made of cellular brown ores in the "Hudson River shales, Formation III of Rogers" [Martinsburg shale], of the Roanoke area and adjacent areas. The writer agrees with Holden[116] that "such deposits have either not been seen by the writer, or, if seen, have not been confirmed as belonging to this formation."

LIMESTONE MAGNETITE

At a few places in Virginia very small isolated occurrences of magnetite have been reported from the Valley limestones. The magnetite is associated with iron carbonate and hematite, and occurs either in beds in the limestone or near the base of the residual clays above it. It is generally of very high grade but in quantities too small for economic use. The magnetite is thought to be a secondary concentration from the overlying shales.

Specular magnetite has been reported from Roanoke County,[117] only from the "Simmons beds" of P. H. Rorer, near the Rorer mines. An analysis made in 1883 gave the composition as follows:

Analysis of specular magnetic ore from Roanoke County, Virginia

(Henry Froehling, Analyst)

	Per cent
Metallic iron	39.40
Phosphorus	.4482
Silica	40.48

No deposit of this kind was found by the writer, and the location of the "Simmons beds" is indefinite. It is supposed that the magnetite probably came from the Shady dolomite rather than from the Elbrook formation. If this is true, the occurrence is unusual, for no magnetite has heretofore been recorded from the Shady dolomite.

[114] Stose, G. W., and Miser, H. D., Manganese deposits of western Virginia: Virginia Geol. Survey Bull. 23, pp. 115-117, 1922.

[115] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, p. 222, New York. 1884.

Campbell, J. L., Geology and mineral resources of the James River Valley, Virginia, p. 57, New York, 1882.

Pechin, E. C., The iron development and ore resources of Virginia: Am. Inst. Min. Eng. Trans., vol. 19, p. 1024, 1891.

Hotchkiss, Jed., The Virginias, vol. 4, pp. 68 and 81, 1883.

Hotchkiss, Jed., op. cit., vol. 5, pp. 43, 139, and 169, 1884.

[116] Holden, R. J., Iron, *in* Watson, T. L., Mineral resources of Virginia, p. 403, Lynchburg, 1907.

[117] Hotchkiss, Jed., The Virginias, vol. 4, p. 19, 1883.

TITANIFEROUS MAGNETITE OR ILMENITE

Important bodies of nelsonite, a mixture of apatite and ilmenite, are found in the pre-Cambrian crystalline rocks east of Vinton. They are described under titanium and apatite.

PYRITE

An occurrence of pyrite with associated galena and sphalerite has been described from the Martin and Wertz properties 2¾ miles south of Roanoke.[118] The minerals are in a limestone in the Rome ("Watauga") shale. The deposit has been prospected for lead and zinc. A similar occurrence of these minerals is found near the Norfolk and Western Railway about 1 mile north of Bonsacks, Botetourt County.

PYRRHOTITE

Deposits of pyrrhotite are found in Floyd County but are not known in the area covered by this report.

SUMMARY OF IRON AND MANGANESE DEPOSITS

The early descriptions of the iron resources of Roanoke County and the reports of 40 years ago were very glowing. At present no iron or manganese is being mined in the county, and no new prospects have been opened during the last 20 years. It is barely possible that operations will begin again, if the deposits can be mined at a profit. The exposures of Clinton hematite show too meager quantities of iron for exploitation. There is no warrant for prospecting the limestone magnetite, pyrite, and pyrrhotite. Unless a greater quantity of Oriskany ore is discovered, no important operations can be expected from this type of deposit in Roanoke County. From the available information, only the limonite and hematite ores along the Blue Ridge belt hold any promise of future value, and even this is very uncertain.

The Blue Ridge hematite is known to occur on Buck Mountain, and may occur in the Poor Mountain area. The deposit is very thin and of poor grade. An average of several analyses of these deposits in this area shows the following content:

[118] Watson, T. L., Lead and zinc deposits of Virginia: Virginia Dept. Agriculture and Immigration, Geol. Survey of Virginia, Geol. Ser., Bull. 1, p. 71, 1905.

Average of analyses of Blue Ridge hematite from Buck Mountain, Roanoke County, Virginia

Metallic iron	38.84
Silica	33.89
Phosphorus	.43
Metallic manganese	.22

If this hematite is ever used it will be with different metallurgical methods than those employed at present, and it is highly improbable that the need for iron in the immediate future will require the use of this type of deposit. It is possible that this hematite may again be mined from the deposits along the Blue Ridge in Botetourt County, especially along the northwestern slope where the hematite is of better grade and more abundant, but the small quantity known in Roanoke County is scarcely to be considered as an economic reserve.

The brown deposits along the Blue Ridge belt constitute the greatest supply of iron in the Roanoke area. The presence of this iron has been proved in the area south of Roanoke and along Poor Mountain. There are still considerable quantities of the limonite which have not been mined, although few new prospects will be discovered. The greatest drawback to the present use of this material is the high phosphorus content and the general avoidance by the iron industry of medium or low-grade limonites. The Roanoke deposits have a fair composition for this type of iron, their average composition being reported as follows:

Average of analyses of limonite deposits from the Roanoke area, Virginia

Metallic iron	52.24
Metallic manganese	1.36
Phosphorus	.80
Silica	8.20

These iron deposits may become useful under either of two conditions: (1) An increase in the price of pig iron which will bring the lower grades of ore into the market, and (2) metallurgical improvements which will make possible the economical production of pig iron from low-grade ores. Until these conditions obtain, the iron deposits of Roanoke County will probably not be further worked.

Manganese probably will not be mined in this area, because no known deposits have a sufficient percentage of manganese to approach the requirements of successful production. Even the fairly rich deposits of the Blue Ridge in Botetourt County are not now being mined, and will not be mined again except under more favorable economic conditions.

LEAD AND ZINC

The Roanoke area has been prospected at five separate localities for lead and zinc, but no workable ore was found and mining was not undertaken at any of the prospects. (See Fig. 7.) The minerals which attracted attention were galena and sphalerite, closely associated with pyrite, chalcopyrite, and calcite. They occur in one of the dolomites well toward the base of the Rome ("Watauga") formation. It is not possible to determine whether the same dolomite beds carry these minerals, for the localities are widely separated and the individual beds can not be traced from one exposure to another. In each place the dolomite lies between red, purplish, and gray shales, and the whole series has been highly folded, broken, and brecciated. The shales and dolomites are veined with calcite and the rocks in many places are faulted.

The metallic minerals are closely associated with and follow the brecciated zones of the dolomite as irregular lumps and stringers. The deposits appear to be disseminated cavity fillings which have been introduced and localized by percolating waters. The intimate relations of the sulphides show that all were introduced at about the same time. The minerals are slightly altered and no secondary minerals were observed. Sphalerite is present at each of the five prospects, and galena at all except the Bonsacks prospect. Slight traces of gold and silver have been reported from the galena at two of the localities.

It is supposed that the metals were originally finely disseminated in the dolomites and shales, and have since been concentrated along lines of structural weaknesses. There is little or no replacement of the surrounding wall-rock. The date of formation of the ore minerals is unknown, but must have succeeded the period of deformation in which the country rocks were folded and crushed.

None of these prospects are being worked, and there is little possibility that they will ever be of economic value. The two most promising prospects were the Martin and Wertz openings about 2 miles southwest of Roanoke, and the Bonsacks prospect along the railroad about half a mile northeast of Bonsacks. The Langhorne property 2 miles south of Alleghany Springs, Montgomery County, was also prospected for lead and zinc.

MINOR OCCURRENCES OF METALS

Small amounts of gold, copper, nickel, cobalt, and arsenic have been reported at various places in the Roanoke area, and small prospects have been opened in a few scattered localities. Most of these occurrences are in the rugged Blue Ridge plateau of Floyd, Franklin, and Montgomery counties, and lie southwest of the Roanoke County line. None of the deposits appear to be of economic importance, and none of them are being operated at the present time.

Figure 7 shows the distribution of the prospects in the deposits of metals in the Roanoke area.

FUELS

COAL

A recent publication[119] deals adequately with the occurrence of coal in the Roanoke area, and the present discussion is taken largely from that bulletin.

The counties adjacent to Roanoke County have been coal producers of note. The Catawba field of Botetourt County and the Brush Mountain and Price Mountain fields of Montgomery County have furnished considerable coal. Although the coal-bearing series is present in Roanoke County, important seams of coal are either absent or inaccessible, so that local production has been very meager and future possibilities are very discouraging. The paucity of coal beds in this county is largely the result of the complex geologic structure of the coal-bearing formation, although it crops out in discontinuous belts totaling at least 20 miles in extent within the limits of the county.

The coal-bearing formation is the Price sandstone of Lower Mississippian age. It consists of bluish-white sandstones and conglomerates with a reported total thickness of 1,700 to 1,800 feet in Montgomery County. There are a few scattered coal seams toward the middle of the formation, the Merrimac seam being the most important. This bed is now mined at several places near Blacksburg, Montgomery County. The lower part of the formation crops out in Roanoke County in three disconnected belts: (1) Along Brush Mountain near the northwestern border of the county, (2) along North Mountain from Moomaw Gap to the north county line, and (3) along parts of the crest of Fort Lewis Mountain.

[119]Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, pp. 130-190, 273-282, 1925.

BRUSH MOUNTAIN BELT

This belt of the Price formation is a continuation into Roanoke County of the coal-bearing rocks of the Brush Mountain field of Montgomery County. The formation is exposed along the southeast slope of Brush Mountain, where it dips about 30° S. 25° E. The outcrop is cut off at the base of the mountain by the Miller fault which has overthrust the Cambrian-Ordovician formations upon Lower Mississippian rocks. The overthrust limestones cover the upper part of the Price formation, and as few coal beds are found above the line of the fault, it is supposed that important coal beds, if present, lie beneath the overthrust limestone and shale. No evidence of coal was observed in the exposed Price formation along Brush Mountain, in Roanoke County or within 2 miles of the county line, and this belt may be considered unfavorable for commercial development of coal. It has been reported by Campbell[120] that coal was once prospected in Millers Cove, but no trace of these prospects has been found. Most of the material reported as coal from this cove has been black carbonaceous Athens shale of no economic value.

Under the supposition that important beds of coal are buried beneath the overthrust Cambrian-Ordovician rocks, the question of their accessibility arises, and particularly the possibility of reaching them by deep mining. Campbell[121] has considered this point, and has concluded from the probable thickness of the overlying fault block "that it is hopeless to expect coal at a depth south of a line extending from Blacksburg to the point of Cove Mountain, northeast of Shiloh Church, but even along this line the coal may be too deep for economical mining." Considering the uncertainty of reaching any coal below the thrust block, and the scarcity of data on the exposed beds, success in such an undertaking is very doubtful, and operations are not recommended without more information than is available at present.

NORTH MOUNTAIN BELT

From Moomaw Gap northwest into Botetourt County the Price sandstone crops out in a narrow belt along the southeast slope of North Mountain. The beds strike about N. 50° E., and dip about 60° SE. The great Pulaski fault at the base of the mountain has thrust the Cambrian-Ordovician rocks upon the upper part of the coal series, and like the Miller overthrust in the Brush Mountain belt, it is so near the mountain that the upper coal seams are

[120] Op. cit., p. 281.
[121] Op. cit., pp. 138, 150.

either cut out or concealed. Campbell[122] concludes that the important Merrimac, or Langhorne, seam of Montgomery County is covered by the overthrust block of Cambrian-Ordovician formations.

Above the fault, however, and well up the slopes of the mountain, are exposed several thin beds of coal which have been prospected, chiefly by T. G. Chapman, at several localities, about three-fourths of a mile northeast of Catawba Sanatorium. The coal beds are found a short distance down the slope of the mountain from the Ingles conglomerate and are thus near the base of the Price formation. The coal occurs in several very small lenticular seams which are badly shattered and displaced, with many angular rock fragments intermixed with the coal. In the largest and best prospect, two small seams, exposed along a drift 15 feet long, are about 20 inches thick and are about 30 feet apart. Both are interbedded with thin shales and enclosed between sandstones. The containing rocks are faulted and broken, indicating that much movement has taken place. The strike here is N. 53° E. and the dip is 78° SE. The seams become thinner with depth, so that further prospecting and mining have been abandoned.[123] The Chapman property has the best showing of any prospect visited. (See Fig. 7.)

At several points along the mountain, coal "blossom" was observed, which has largely resulted from the weathering of black carbonaceous shale with only small fragments of coal being present. The known quantity of coal along North Mountain is so small as to discourage further prospecting.

FORT LEWIS MOUNTAIN BELT

Along parts of the south slope of Fort Lewis Mountain the Price formation crops out from the west line of Roanoke County to a point north of Salem. This belt is not known to contain workable beds of coal, although coal fragments have been found in these rocks. Holden[124] reports that the best occurrence he discovered in this area was ". . . . a highly pyritiferous coal bed about 8 inches thick." It was reported to the writer in 1926 that some small-scale prospecting had recently been done and that more was being considered, but this report was not verified.

Considering the good development of coal in the Price formation on Brush Mountain in Montgomery County, within 20 miles of the Fort Lewis belt, it seems strange that Fort Lewis Mountain contains no workable beds. Campbell[125] has explained this

[122] Op. cit., p. 281.
[123] Campbell, M. R., and others, op. cit., pp. 279-281.
[124] Cited by Campbell, M. R., and others, op. cit., p. 281.
[125] Op. cit., p. 281.

lack by the great Pulaski fault between the two areas. The coal series on Fort Lewis Mountain is in the Catawba syncline which has been thrust many miles to the northwest. It is possible that the Price formation in the Catawba syncline has no coal. Thus the Fort Lewis belt may represent barren Price sandstone overthrust very close to coal-bearing Price sandstone.

OIL AND GAS

There has been recently considerable speculation concerning the possibility of obtaining oil and natural gas from the rocks of Roanoke County. Added interest has arisen because of a so-called "gas well" on the Williamson road.

This well is about 1½ miles northeast of Roanoke, on the northeast side of the Williamson road (part of the Lee Highway) just south of the entrance to the Upson real estate addition. It is 119 feet deep and is pumped. The water has a sour taste, and the contained gas is noticed soon after drinking. Small quantities of gas accumulate in the vacuum tank of the pump and at times issue from the water taps in sufficient volume to burn, for a few moments, with a blue flame. It is said that an analysis shows the gas to be "natural gas," but this report was not verified by the writer. The presence of the gas in this well is unique in the area, for other wells of equal or greater depths within a few hundred feet of this well have no sign of gas. It was reported to the writer that gas was found in another well about one-fourth of a mile to the northeast, but, upon inquiry, this report was not verified. Reports of gas from Moomaw Springs northwest of Roanoke were also not substantiated.

The well on the Williamson road is about half a mile north of, and within, the southern outcrop of the Elbrook formation. It is about 400 yards east of the crest of Round Hill which is considered to be a fenster of sandstone uncovered by erosion through the Pulaski overthrust block.

If this well contains natural gas, there are at least two possible explanations of its presence. (1) The gas may be derived from the decomposition of organic matter in small pockets in the Elbrook formation. Similar occurrences are known in other regions, for example, pockets of gas are often found in the Onondaga limestone of western New York. This would explain the isolated occurrence and limited quantity of the gas. (2) As an alternative explanation, the gas may be derived from Devonian shale below the overthrust block, and may have seeped upward along fissures in the overthrust limestone and thus be tapped by this particular well. Clinch sandstone on Round Hill suggests that such conditions may exist. In neither case is there any possibility of obtaining gas in commercial quantity. As this well is beneath a gasoline filling station, and gas was not discovered in it until the station had been built, it is possible that the gas has been produced from leaking gasoline. Some effort was made to organize a company to investigate the oil possibilities of the region around the "gas well," and several leases were obtained.

Oil and gas are found in commercial amounts only under certain known geologic conditions. Unless these conditions exist in an area, it is useless to prospect there for oil and gas. The essential conditions are: (1) Sedimentary rocks, probably of marine origin, containing organic materials from which oil and gas have been naturally distilled; (2) porous rock, such as sandstone, in which the oil and gas can accumulate; (3) an impervious cap-rock to prevent the upward escape of the oil and gas; (4) a favorable structure, such as an anticline, in which the migrating oil and gas can accumulate; and (5) lack of severe deformation, which drives off the oil and gas.

The rocks of the Roanoke area have been intensely folded and faulted, and subsequent erosion has deeply dissected the region. It is highly improbable that rocks of this nature would now contain either oil or gas, for these volatile substances have had ample opportunity to escape during the deformation of the rocks, if indeed they were ever present. There does not seem to be the slightest reason to believe that petroleum will be discovered in Roanoke County, and it is very improbable that natural gas will be found in quantity to warrant even local development.

OTHER NON-METALLIC RESOURCES

LIMES AND CEMENTS

A comprehensive discussion of the cement resources of Virginia west of the Blue Ridge has been given by Bassler,[126] but few data are given about the occurrences of these materials in the Roanoke area. The reader is referred to this report for information about the nature and use of limes and cements in general, and the possibility of their development in adjacent areas. The rocks used by the lime and cement industry are chiefly limestone, dolomite, and shale of various compositions. In the Roanoke area the formations that are possible sources of rock for lime and cement are: (1) Cambrian limestones, (2) Ozarkian and Canadian limestones, (3) Ordovician limestones, and (4) Devonian limestones.

[126] Bassler, R. S., Cement resources of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 2A, 1909.

TABLE 2.—*Analyses of limestones from the Roanoke area, Virginia*

Horizon	Shady	Watauga	Elbrook					Conococheague	Nittany		Mosheim		Athens	
Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
$CaCO_3$	53.34	...	51.91	63.12	53.44	54.16	44.64	52.50	46.46	66.43	94.48	95.36	46.20	67.03
CaO	...	30.06	29.4	35.68	30.26	...	...	...	...	...	53.5	53.5	...	37.54
CaO_2	...	43.98	35.92	41.0	44.86	...	...	...	...	...	42.2	41.9	...	...
$MgCO_3$	46.02	...	27.93	23.79	39.83	39.86	37.53	34.34	37.38	24.21	2.32	0.21	34.16	1.85
MgO	...	18.41	13.36	10.90	19.05	...	...	...	...	...	1.11	0.1	...	0.88
SiO_2	0.45	trace	16.2	6.13	1.17	4.24	14.36	...	...	...	1.37	2.49	12.68	23.56
Al_2O_3	1.05	0.43	3.71	3.39	2.63	1.12	2.48	0.84	1.33	0.88	1.51	2.17	4.00	5.48
Fe_2O_3	...	0.93	2.77	2.14	1.15									
Na_2O	...	0.21	...	...	...	...	...	...	...	...	...	...	...	...
K_2O	...	0.24	...	...	...	0.10	...	...	...	...	...	...	...	...
P	0.01	...	...	...	...	...	...	...	...	...	...	...	...	...
S	0.14	...	...	...	...	0.11	...	...	...	...	...	...	0.93	...
H_2O	...	3.30	...	...	...	...	1.00	...	...	...	...	...	2.00	...
Insol. Residue	...	2.90	...	...	...	...	...	3.48	14.93	8.18	...	...	...	...
	101.01	100.47	101.36	99.95	99.32	95.69	100.01	91.16	100.12	100.70	99.69	100.69	99.97	97.92
Sp. Gr.	...	...	2.70	2.82	2.66	...	...	...	...	...	2.76	2.87	...	...

1. Limestone reported from quarry northeast of Buchanan; P. Salom, analyst. Hotchkiss, Jed., The Virginias, vol. 6, p. 62; 1885.
2. Massive limestone, 2¾ miles southeast of Roanoke; W. E. Barlow, analyst. Watson, T. L., Lead and zinc deposits of Virginia: Virginia Dept. Agr. and Immigration, Geol. Survey of Virginia, Geol. Ser., Bull. 1, p. 72, 1905.
3. Gray massive limestone, Salem city quarry; C. W. Kinzer, analyst. Kinzer, C. W., A chemical interpretation of the limestones of the Roanoke and Catawba valleys: Unpublished thesis, Roanoke College, Salem, Va., p. 13, 1924.
4. Massive gray limestone, 2 miles east of Salem; C. W. Kinzer, analyst. Idem.
5. Gray limestone, Cavern Hill near Glenvar; C. W. Kinzer, analyst. Idem.
6. Limestone, Blue Ridge Springs quarry; P. Salom, analyst. Hotchkiss, Jed., op. cit.
7. Limestone, Catawba Creek near Stone Coal Gap; W. B. Rogers, analyst. Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, p. 344, New York, 1884.
8. Limestone from near Blacksburg; W. B. Rogers, analyst. Idem, p. 170.
9. Limestone, Davidson farm, 1 mile east of Blacksburg; J. R. Eoff, Jr., analyst. Watson, T. L., op. cit., p. 74.
10. Limestone, Bell quarry, 3 miles southwest of Blacksburg; J. R. Eoff, Jr., analyst. Idem.
11. Dove-colored limestone, 1 mile east of Catawba Sanatorium; C. W. Kinzer, analyst. Kinzer, C. W., op. cit.
12. Dove-colored limestone, near Keslers Mill, 2 miles east of Salem; C. W. Kinzer, analyst. Idem.
13. Shaly limestone, 3 miles north of Roanoke; W. B. Rogers, analyst. Rogers, W. B., op. cit., p. 393.
14. Limy shale, Catawba Valley, near Catawba; W. M. Thornton, Jr., analyst. Bassler, R. S., The cement resources of Virginia west of the Blue Ridge, p. 136, 1909.

CAMBRIAN LIMESTONES

The limestones of the Shady and Rome ("Watauga") formations are extensively quarried for lime and crushed stone, but have not been used for cement rock. In general these limestones are too dolomitic for use in the manufacture of Portland cement, and no observed exposures show material sufficiently pure for use as natural cement. The most accessible outcrop of the Shady dolomite is along the Blue Ridge from Troutville to Buchanan, where it is parallel to and less than 1 mile from the Norfolk and Western Railway. If cement rock could be developed from the Shady, this belt would offer good transportation facilities. The Rome ("Watauga") formation is exposed along the railroad from Troutville to Buchanan and in Roanoke Valley at Roanoke. An analysis of limestone from each of these formations is given in Table 2. The high percentage of magnesia greatly impairs the value of these rocks for cement.

The Elbrook formation contains abundant limestone, but the beds are very thin and argillaceous. The formation as a whole lacks pure limestones of the quality necessary for cement rock. Elbrook limestones are quarried in many places in the Roanoke area, but the rock is used mainly for road material. Analyses of typical limestones of the Elbrook formation are given in Table 2. Samples 3-5 represent the purest members of the Elbrook exposed near Salem and Glenvar. (See Pl. 15.)

OZARKIAN AND CANADIAN LIMESTONES

The greater part of the combined thickness, more than 2,500 feet, of the Conococheague formation and the Nittany dolomite, consists of limestone and dolomite. None of these beds, however, are known to be of a quality suitable for cement rock. The dolomites contain too much magnesia for Portland cement, and the limestones are too impure for natural cements. It is somewhat surprising that such an extensive series of calcareous beds should contain no workable cement rocks in the Roanoke area, but at only a very few places are cement rocks obtainable from the Ozarkian or Canadian formations. Analyses of limestones from these formations in the Roanoke area are given in Table 2. The limestones have been extensively quarried for furnace flux, lime burning, and for road material, and are entirely suitable for these purposes.

ORDOVICIAN LIMESTONES

The purest limestone in this area is the Mosheim limestone which is fine-grained, blue or dove-colored limestone containing about 95 per cent calcium carbonate. The color and composition are remarkably uniform wherever the limestone is exposed. Its thickness in Catawba Valley is about 30 feet. The lower 7 feet, however, is conglomeratic, so that here the pure limestone is about 23 feet thick. The formation crops out in a narrow belt along Catawba Valley, just south of the Catawba Sanatorium, and it can be traced along the strike for several miles. It thickens toward the west and thins toward the east. The formation is present south of the Salem fault and is exposed near Keslers Mill, on Mason Creek, northeast of Salem. This southern exposure of the Mosheim limestone is meager, being cut off by a fault.

Analyses of this rock from Catawba Valley and from Keslers Mill are given in Table 2. The lime content is very high and little silica and magnesia are present. This limestone is suitable for Portland cement. It is impossible to tell from the analysis of a rock whether it is suitable for the manufacture of natural cement, but it is probable that the Mosheim limestone is not sufficiently argillaceous. With admixture of material from shales near-by, it might prove satisfactory. The outcrops of this formation are not far from the Catawba Branch of the Norfolk and Western Railway, and could be quarried advantageously in Catawba Valley.

The Athens shale is adjacent to the Mosheim limestone in Catawba Valley. The shale is not suitable for use as cement rock, but could be used with the Mosheim limestone in the manufacture of natural cement. Analyses of this shale from outcrops near the Mosheim limestone are given in Table 2, samples 13 and 14.

DEVONIAN LIMESTONES

The Helderberg group, which overlies the Clinton sandstone, contains a thin limestone at the base, which is exposed about 1 mile south of Newcastle, Craig County. This limestone, or its equivalent, is reported to have been used for cement rock near Clifton Forge, Alleghany County. It was not tested in the Roanoke area, but it does not seem to have the physical characters essential to cement rocks. No quarries are known in the formation in this area, and the limestone appears to be too variable and inaccessible for economic use.

SUMMARY

The Roanoke area is fortunate in containing a supply of material which can be used for cement and lime. The writer recommends the Mosheim limestone for Portland cement. A good place for a quarry would be in the Salem Valley near Keslers Mill, on Mason Creek, northeast of Salem. The formation is better exposed in Catawba Valley, near the Catawba Sanatorium, but it is not as close to transportation as that at Keslers Mill. It is possible that cement material occurs in the Shady and Elbrook formations, and that prospecting in them may yield favorable results. The limestones of the Rome ("Watauga"), Conococheague, and Nittany formations seem less promising.

CLAYS AND SHALES

CLASSIFICATION

Several deposits of clays and shales in this area are suitable for the manufacture of brick and tile and, in several places, they have been commercially developed. (See Fig. 7.) The clays of the Roanoke area may be classified as follows:[127]

A. True sedimentary clays or shales.
   1. Rome ("Watauga") shales.
   2. Elbrook shales.
   3. Athens shales.
   4. Romney and Brallier shales.
   5. Mississippian shales.

[127]Modified after Ries, H., and Somers, R. E., The clays and shales of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 20, pp. 4-8, 1920.

B. Residual clays.
   1. Of the crystalline rocks.
   2. Of the Shady dolomite.
   3. Of the Elbrook formation.
   4. Of the Conococheague and Nittany formations.

C. Transported clays on flood plains.

TRUE SEDIMENTARY CLAYS OR SHALES

General statement.—Some shales are usable for the manufacture of clay products and hence may be considered as clays. Shales are transported clays which have been deposited in beds in this area, chiefly as marine sediments. Consolidation has temporarily destroyed the original plasticity, but the shales may regain this property when very finely ground and mixed with water. Shales are of much greater extent than most surface clays, but the difficulties of working them often offset this advantage. Where these shales are weathered, the clayey nature becomes partially restored; hence the amount of weathering is an important factor in the usability of shales for the manufacture of clay products. Some shales may be ground and used to good advantage with true residual clays. Where the shales contain thin lenses of limestone and sandstone which can not be thrown out during mining, the cost of handling is much greater than for residual clays, and generally prevents their use. Many shales are very gritty or calcareous, which impairs their quality.

Rome ("Watauga") shales.—The Rome ("Watauga") formation has a wide area of outcrop and its beds are in many places suitable for use as clays. Thick beds of good shale are seldom found without interbedded limestone and gritty beds which make clay operations very difficult.

These shales are worked, at several places near Roanoke, for clays. The Adams, Payne, and Gleaves Company is operating a brickyard east of Roanoke, between Roanoke River and Tinker Creek. The shales here are very argillaceous, brick-red, and dip steeply eastward. They are artificially mixed with clays taken from the adjacent flood plain, and are used near-by at the kilns of this company. The red shales lie on the southeast side of a small thrust fault which is visible in the cliff along the railroad. The company has made a cut into the hill, and has followed the shales for about 50 feet in a large pit which it is operating by a steam shovel. Calcareous layers, 1 foot or more thick, occur in the soft shales, but they can be avoided in mining. The clay burns red and is used for the manufacture of common brick.

Ries and Somers[128] report and describe workable clay shales at two localities about one-fourth and three-fourths of a mile east of Bonsacks where there are numerous outcrops of the red, yellow, and grayish shales of the Rome ("Watauga") formation. These shales do not grind up to a plastic mass when fresh, but they weather to a yellowish and gray smooth clay of good plasticity. The clay three-fourths of a mile east of Bonsacks requires about 40 per cent water of plasticity and has 8.6 per cent air shrinkage. At Cone 010 this clay shows no fire shrinkage but has a high absorption of 26.3 per cent. At Cone 05 it gives a good brick with 6.4 per cent fire shrinkage and 14.3 per cent absorption. The clay burns red and can be used for common brick. An exposed thickness of 6 feet is reported for the clay of workable grade.

At a locality along the Lynchburg Highway midway between Coyners and Blue Ridge Springs, the Webster Brick Company is working clay shales of the upper Rome ("Watauga") formation. This is the most extensive clay operation in this area. The plant manufactures ordinary brick which is used for building in Roanoke. (See Pl. 26.) The shale dips steeply to the southeast and strikes N. 80° E. The fresh shale is less satisfactory than slightly weathered rock, and a mixture of both is used. The brickyard lies a short distance from the Norfolk and Western Railway, and is connected with it by a short spur line. A chemical analysis of the shale clay here is given by Ries and Somers.[129]

Analysis of shale clay from Webster, Botetourt County, Virginia

SiO_2	51.08
Al_2O_3	22.05
Fe_2O_3	10.43
CaO	None
MgO	2.28
K_2O	5.92
Na_2O	0.20
Loss on ignition	7.36
	99.32

Similar shales suitable for brick clays occur along the wagon road near Lithia, Botetourt County. The shale requires 18 per cent water of plasticity, and the air shrinkage is low, being 3 per

[128]Op. cit., pp. 60-61.
[129]Op. cit., p. 59.

cent. "The clay has a rather short heat range, but it burns to a hard brick of rather low absorption at Cone 05. The color after burning is red."[130]

Elbrook shales.—The lower part of the Elbrook limestone contains shale beds which might be used for brick clay. The formation crops out in a wide belt across the area, but most of the exposed rock is limestone. Ries and Somers examined shales from this formation about 2 miles north-northwest of Blacksburg, and found them to be of fair quality. If the shale were mixed with residual clay from the limestone near-by, it could be used for brick. The Elbrook formation is not a promising source of clay shale.

Athens shales.—The Athens shale is conspicuously exposed in this area, but the beds are of poor quality for clay products. The shale crops out, in a belt along Catawba Valley, from Ironto, Montgomery County, to Tinker, Botetourt County, but it is here too gritty and calcareous for use. An outcrop of this shale east of Fincastle shows clay shale of fair grade, but lacking sufficient plasticity even when ground. Residual clay from the Athens shale is satisfactory and may be mixed with the fresh shale.

Romney and Brallier shales.—Certain types of Devonian shales may be ground and worked with water to form clays of good quality. They can seldom be used in fresh condition. Many of them are highly carbonaceous and hence not usable, although some of the softer shales may be very satisfactory. The Romney shales crop out in the Roanoke area on the slopes and floors of Carvins, Mason, and Bradshaws coves, and along the north slopes of Coyners and Little Brushy mountains. In general they are dark-colored, with smooth feel, and weather to a clayey mass. They are in many places too carbonaceous for making clay products. Shales of Devonian age are being worked from a cut at the west end of Little Brushy Mountain. The shales have been highly deformed and are much crushed and broken. Their color is much lighter than is common. In many places they are brick-red on their outcrops. The material has been used since 1922, by the Salem Brick Company, for common and face brick. It burns at Cone 02 or 2, and the total shrinkage is 10 per cent. The shales are mixed either with flood-plain or residual clays which are found near-by.

Mississippian shales.—It has been reported that good fire clays occur with the coal beds along North Mountain near the old Ca-

130 Ries, H., and Somers, R. E., op. cit., p. 30.

tawba furnace, and that these clays are favorable for use in manufacturing fire brick, stove linings, pipes, and tiles.[131]

Shales of the Maccrady formation are utilized for brick manufacture in Montgomery County. These shales are not known in the Roanoke area.

RESIDUAL CLAYS

Much of the Roanoke area is covered with a mantle of residual soil and clay which has resulted from the decay of rocks directly below the surface. The thickness of this residual mantle varies greatly but rather commonly reaches 100 feet. The nature of the mantle rock depends largely upon the kind of bedrock from which it has been derived.

Clays derived from the crystalline rocks.—The crystalline rocks east and south of the Blue Ridge fault have been deeply weathered into a heavy blanket of residual clays, which are generally thick, deep-red, and extremely ferruginous. The high percentage of iron renders them unfit for the manufacture of most clay products, and none of these clays are being worked in Roanoke County. In other areas these clays locally contain white streaks of high-grade kaolin, but occurrences of this kind have not been observed in the Roanoke area.

Clays derived from the Shady dolomite.—A small deposit of residual clay from the Shady dolomite occurs at the old Rorer limonite mines south of Roanoke. The clay is brown, iron-stained, and contains pockets and streaks of gray clay which is plastic and buff-burning. The good clay does not appear to be in sufficient quantity to warrant operation of the deposit, but might be sold to steel works or used in saggers if, upon careful prospecting of the area, more clay of this quality were found.[132]

A considerable quantity of this type of clay is found in the abandoned ore pits at No. 4 mine of the Houston Iron Company, 1 mile southeast of Nace, Botetourt County. The ferruginous clay is associated with a gray mottled clay (locally called fire clay) and with small deposits of pisolitic bauxite. These clays were tested by Ries and Somers,[133] who state that it is questionable whether they could be used alone for clay products and that "there is not enough of either clay to warrant establishing a plant at the mine."

---

[131]Hotchkiss, Jed., The Virginias, vol. 4, p. 161, 1883.
[132]Ries, H., and Somers, R. E., op. cit., p. 36.
[133]Op. cit., p. 46.

Clays derived from the Elbrook formation.—The Elbrook formation is widely distributed in the Roanoke area and decay of its beds in many places furnishes clays of good grade. Ries and Somers[134] have described, as follows, a deposit of residual clay at the old Lynchburg, or Grubb, iron mines. The iron is surrounded by a reddish residual clay through which are scattered streaks and patches of white and gray clay of very fine, dense texture, and with a porcelaneous luster. Some of these pockets are 10 to 15 feet in diameter, and the contacts with the reddish clays are very sharp. The writer was informed in 1926 by the superintendent of the Webster brickyards that an attempt had been made to use this material for the manufacture of brick. It was reported that the clay made a satisfactory brick and fired red. The ferruginous clays in which the iron is found are very plastic and, after firing, give a curious ringing sound. At Cone 010 the absorption is 28.4 per cent. At Cone 05 the material shows the high fire shrinkage of 10.3 per cent, although the absorption has dropped to 9.4 per cent. The clays are not now being worked.

A small deposit of residual clay from the Elbrook formation is being worked about 2 miles southwest of Salem, in a low ridge along the Salem-Christiansburg road. The exposed deposit is about 15 feet thick, and is covered with stream gravel and sand. The clays are red and yellow, but the red clay is too sticky for use. The residual clay is handmixed with the flood-plain clays which occur near-by, and is used for the manufacture of soft-mud brick. It has been worked by the Salem Brick Works. The pits were temporarily abandoned in 1922 in favor of the Devonian clay shales which occur about 1½ miles to the north.

Clays derived from the Conococheague and Nittany formations.—The clays of these formations were well distributed and are exposed at several places in sufficient quantity for clay production.

Ries and Somers[135] report that just east of Daleville "there is a good exposure of a smooth, red residual clay" of good plasticity, derived by the weathering of a hard, blue-gray limestone. They describe it as follows: This clay, mixed with 33 per cent of water, gave a material that had 9 per cent air shrinkage, burned red, and was steel hard at Cone 05. At Cone 010 its fire shrinkage was 1.3 per cent and its absorption was 24.1 per cent, while at Cone 05 the fire shrinkage was 9.3 per cent and the absorption was 9.6 per cent. This strong increase of shrinkage is characteristic of many residual clays derived from limestones. This clay would be good for common brick or tile.

[134] Op. cit., p. 47.
[135] Op. cit., p. 46.

Ries and Somers[136] report a long cut in these clays along the Norfolk and Western Railway, about one-eigth of a mile west of Hollins Station. They state that the clay is very plastic, yellow and red, and contains considerable chert. It has 37 per cent water of plasticity and its air shrinkage is 7.5 per cent. Its fire shrinkage at Cone 010 is zero, and its absorption is 24.1 per cent, which is too high for general use. At Cone 05 the clay fires red and is steel hard. Its fire shrinkage at Cone 05 is 3.3 per cent and its absorption is 17.6 per cent. The clay could be used for common brick but should be fired above Cone 010.

TRANSPORTED CLAYS ON FLOOD PLAINS

Clays of this type occur in scattered areas along the flood plains of the larger streams in the Valley lowlands. Their outcrops are seldom extensive and the material is greatly contaminated with stream deposits which are so commonly interbedded that handling of the clays is very difficult. The clay is more plastic and has a higher tensile strength than the residual clays, but some of it is very sandy. The flood-plain clays can be used to good advantage with clays of other kinds, and the mixture is excellent for brick and drain-tile. Two deposits of this kind are being worked in Roanoke County for the manufacture of common and soft-mud brick.

The Adams, Payne, and Gleaves Company has operated a brickyard along the flood plain of Roanoke River, near Tinker Creek, east of Roanoke. Open excavations with steam shovels exposed a blue, sandy, very plastic clay which fires red and gives brick with 11 per cent absorption. At the end of the pits near the kilns, away from the river, there is a very sticky clay whiich has not been used. The clays are worked in a stiff-mud machine. Physical tests were made at the Engineering Experiment Station at Blacksburg. The breaking load of the fire clay was 1,190 pounds, with a modulus of rupture of 507 pounds. The crushing strength per square inch was 4,072 pounds.[137]

The Salem Brick Works have used a flood-plain clay along Roanoke River, about 2 miles west of Salem. The clay was mixed with a limestone residual clay for the manufacture of soft-mud and common brick.

---

[136] Op. cit., p. 48.

[137] Topham, A. J., The natural economic resources of Roanoke County, Virginia: Unpublished thesis, Roanoke College, Salem, Virginia, 1923.

ILMENITE AND APATITE

Roanoke County contains deposits of ilmenite and apatite which may be of considerable economic value as sources of titanium and phosphorus. The deposits were described by Watson and Taber[138] from whom this discussion is largely taken.

The deposits are found about 2 miles east of Vinton, and 4 miles east of Roanoke, at the foot of the Blue Ridge, which is here very low. The minerals occur in crystalline rocks along Wolf Creek Valley near the main road leading east from Vinton. The crystalline rocks are part of a great fault-block which has been thrust from the east upon the Cambrian-Ordovician rocks of the Valley. The trace of this fault is north and south, and it is about 2¼ miles west of the mineral deposits. These minerals were first observed in 1890 by local parties, and some ore from shallow openings was shipped to furnaces at Roanoke. This material was rejected because of the high phosphorus and low iron content. The area was later prospected, about 1905, by H. M. Engle of Roanoke. Watson and Taber examined the region in 1910. In 1926 a single open cut was being worked by C. H. Hutchins of Vinton. (See Fig. 7.) The earlier shafts, pits, and open cuts were abandoned and grown over with brush.

The ore consists of an igneous rock high in titanium and phosphorus, which has been called nelsonite by Watson.[139] Nelsonite consists of an intimate association of apatite with ilmenite or rutile, or both. The Roanoke County nelsonite is an ilmenite nelsonite containing little or no rutile. The rock is very dark blue-gray, fine-grained to porphyritic, and generally shows foliation due to metamorphism. The ground-mass consists of very fine grains of ilmenite, and the phenocrysts are apatite, some of which is in hexagonal crystals up to 5 centimeters in diameter. The ratio of ilmenite to apatite is variable, and the two minerals are equally abundant in some specimens. A few silicate minerals occur as accessory minerals, chief of which are biotite, unstriated feldspar, occasional quartz, hornblende, and pyroxene. Epidote is a common accessory and appears to be of secondary origin. The intimate relations of the ore minerals suggest contemporaneous formation, for each shows inclusions of the other. The outlines of the apatite crystals are somewhat stronger than those of the ilmenite, suggesting that the apatite crystallized slightly earlier than the ilmen-

[138] Watson, T. L., and Taber, Stephen, Geology of the titanium and apatite deposits of Virginia: Virginia Geol. Survey Bull. 3A, pp. 235-247, 1913.

[139] The rock was named by Watson, T. L., Mineral resources of Virginia, p. 300, Lynchburg, 1907, but was not described. A detailed description is given by Watson, T. L., and Taber, Stephen, in Bulletin 3A of the Virginia Geological Survey, pp. 100-155, 1913.

ite. The rock is generally much weathered and its surface is pitted because of removal of the apatite phenocrysts.

The nelsonite appears to be in numerous dikelike bodies in a hypersthene-quartz syenite, although the exact contacts of the nelsonite and the syenite were not observed because of the deep residual soil which covers the area. The ore bodies strike N. 65° E., and may be traced by float in the soil. Some of them have been followed for one-fourth of a mile, and one was observed to be at least 50 feet wide.

The country rock is a greenish-gray, coarse-grained to porphyritic syenite which is strongly gneissoid. It is deeply weathered and exposures are very unsatisfactory. The fresh rock contains orthoclase and plagioclase, pyroxene, a little biotite and garnet, and a small amount of quartz. The phenocrysts are orthoclase crystals, some of which are several centimeters long. Under the microscope the rock is seen to carry apatite, pyrite, ilmenite, and titanite as accessory minerals. The syenite has been strongly metamorphosed and gneissoid structure is pronounced. There is associated with the syenite a coarsely crystalline pegmatitic rock composed of bright green epidote, pink feldspar, and white quartz. This rock is also much weathered and the feldspar is partly kaolinized. Apatite, titanite, biotite, and pyrite occur as accessory minerals. The quartz and feldspars are intergrown, and much of the quartz shows strain shadows. One deeply weathered diabase dike was observed by Watson along the road near the Hutchins farmhouse.

The igneous and metamorphic rocks are of pre-Cambrian age, and belong to the crystalline area of the Blue Ridge. As the actual contact of the nelsonite and the enclosing rock was not observed, it is impossible to determine whether the ore occurs as segregations within the syenite or in dikes of later age. By comparison with the larger and better known bodies of nelsonite in Amherst and Nelson counties, Watson[140] considers the nelsonite in Roanoke County to be a magmatic segregation similar to the segregation of titaniferous magnetites in gabbros.

MINOR NON-METALLIC RESOURCES

ASBESTOS

Asbestos is a silicate mineral which is characterized by fibrous structure. The asbestos of commerce is generally derived from one of the fibrous varieties of amphibole. Serpentine or chrysotile asbestos is also used in industry. The most common occurrence

[140]Watson, T. L., and Taber, Stephen, Geology of the titanium and apatite deposits of Virginia: Virginia Geol. Survey Bull. 3A, pp. 246-247, 1913.

of asbestos minerals is in igneous and metamorphic rocks, and in the Roanoke area in the Blue Ridge crystalline rocks.

Asbestos was formerly mined by the American Asbestos Company about 12 miles south of Bedford and 25 miles east of Roanoke. The mines have been closed for more than 15 years. Two varieties of asbestos were mined from vertical dikelike masses that are parallel to the schistosity of the metamorphic rocks. The asbestos occurred in fibers up to 18 inches long.

Amphibole asbestos has been reported from Roanoke County, but not in commercial quantities. The writer has observed small masses of asbestos or "slip-fibre" along shearing planes in the crystalline rocks of the Blue Ridge, but the deposits were very limited. Small masses of fibrous minerals occur along bedding-planes and fault-planes in the limestones of the area. They may be observed in the Salem city quarry. This material attracts the interest of the quarrymen but is of no commercial value.

BARITE

Barite (heavy spar or barytes) is composed of barium sulphate and is a heavy white mineral with glistening cleavage. Several small deposits are known in this area, especially near Thaxton, Bedford County. Barite is commonly found in granular, earthy, or porous masses often intimately associated with the limestone country rock in which it occurs. It is also found as veins in crystalline rocks.

In Bedford County the barite occurs about 3 miles northwest of Thaxton and 14 miles east-northeast of Bonsacks, at the southwest base of Taylors Mountain. It is in a fissure in a schistose granite porphyry. The deposit was prospected on a small scale as early as 1866, and was reopened along a small cut in 1906. This open cut was about 20 feet deep, and extended for 450 feet along the strike of the fissure. The barite is crystalline, white to blue-gray, and contains small grains of galena and sphalerite. Watson[141] considers the barium to have been derived from the feldspar of the granite porphyry. No other occurrence of this type is known near Roanoke County.

Deposits of barite, found in the outcrops of the Elbrook formation about 2 miles north-northeast of Roanoke, have been worked in a small way on Frank Reed's farm along the old Franklin road just east of Tinker Creek. (See Fig. 7.) A small prospect was opened also on the west bank of Tinker Creek along the Hollins road near the old toll-gate. Open cuts were made several years

[141]Watson, T. L., Geology of the Virginia barite deposits: Am. Inst. Min. Eng. Trans., vol. 38, p. 724, 1908.

ago on the Reed farm and some barite was shipped for use in the sugar industry. The barite occurs on the surface of the limestone and in its residual clays as irregular nodules and porous replacements with a marked development in pockets. The barite is both dense and cavernous, and is greatly contaminated with limestone and clay. The ore was mined from shallow open cuts. It seems probable that the barium was derived from the Elbrook limestone and was concentrated at the surface as replacements and cavity fillings along fracture zones. The transporting agent probably consisted of shallow circulating meteoric waters. Pure barite and impure barite have been reported from North and Mills (Reeds) mountains.[142]

BENTONITE

The term bentonite is applied to certain clayey rocks which have been derived from the decomposition of volcanic ash. The material is sometimes used for refining petroleum and other fluids by filtration. It is a product of weathering and differs from ordinary clay in that it contains much water and has low plasticity. Chemical analyses are of slight aid in determining whether the material is of commercial value.

A bed of bentonite about 2 feet thick occurs in this area about 80 feet above the base of the Martinsburg shale. It has been observed at several places, especially along Catawba Mountain. This deposit is not of commercial value because of the small amount of available material and its inaccessibility.

CONSTRUCTION MATERIALS

Sand and gravel for concrete are in great demand in Roanoke. Sand of good grade has been dredged with scoop-buckets from the bed of Back Creek south of Buck Mountain. Larger flood-plain deposits of sand and gravel, which occur along Roanoke River, have been worked by two companies between Roanoke and Salem. The Roanoke Wash Sand Company has been one of the largest operators. Its plant was two miles east of Roanoke along the river. The sand was pumped through pipes, from the river bed, and loaded into cars on the Virginian Railway. Another company near-by was chain-dredging the river and loading sand on boats from which the sand was distributed by trucks.

Roanoke County contains an abundance of stone which may be used for construction work of all kinds, from rough street work to polished interior decoration. The crystalline rocks of the pre-

[142]A general discussion of the deposits of barite in Virginia is given by Watson, T. L., op. cit., pp. 710-733.

Cambrian area are admirably suited for many uses, but have not been developed to any considerable extent. The schists of the crystalline belt are often suitable for street work, and have been extensively quarried for this purpose near Rocky Mount. Abundant quarries have been opened up for crushed stone in the various limestones of the region, and the Shady, Rome ("Watauga"), and Elbrook formations all produce limestone of good grade for crushed rock. The stone used in the Second Presbyterian Church of Roanoke is limestone quarried, in the county, from the Elbrook formation. The Chilhowie quartzites, the Silurian sandstones, and the Price sandstones are all of good quality for rough construction work but have been little used. The College Lutheran Church of Salem is constructed of Clinton sandstone quarried from Catawba Mountain near Salem.

GLASS SAND

For the manufacture of glass, a relatively pure quartz sand is used which may be obtained from either quartzose sand, sandstone, or quartzite. This sand must be free from clay, iron, or any other impurity which will discolor or cloud the glass. Where the impurities are mineral grains other than quartz, they may be screened out. Where they occur in the quartz grains, the sand is unsuitable for glass manufacture. The grains should be uniform in size, and should range between 30 and 120 mesh when free, or should be ground to this degree of fineness.

Near Roanoke there are several formations which should be considered as possible sources of glass sands. The Chilhowie group contains many siliceous beds, but they are usually too impure to meet the rigid requirements of the glass industry. The Clinch and Clinton sandstones, where pure, are admirably suited for the glass industry and furnish deposits of good sand, either as fresh rock or as weathered accumulations. A Clinton sandstone was used for glass manufacture by the Salem Glass Company, of Salem. Some of the sandstones of the Price formation are of the desired quality but, in general, are too clayey or carbonaceous for glass manufacture.

In Catawba Valley, about 9 miles northeast of Salem, there are deposits of fine white sand of Clinton age which were utilized by the Salem Glass Company, at Salem. (See Fig. 7.) The sand was transported from Catawba by a short railroad which connects with the main line of the Norfolk and Western Railway at Salem. The sand was mined from one of the purer members of the Clinton formation on the south slope of Catawba Mountain. Analyses of the sands are as follows:

Analyses of sand from southern slope of Catawba Mountain, Roanoke County, Virginia[143]

	1	2
SiO_2	98.78	96.99
Al_2O_3	.27	.01
Fe_2O_3	.41	.02
MgO	----------	.07
CaO	----------	.80
Na_2O, K_2O		1.60
Water and organic material		.31
	99.46	99.80

1. Sandstone from Catawba Mountain, 9 miles north of Salem. Courtesy of Salem Glass Company, Inc., Salem, Va.
2. Catawba Valley sand (Massanutten-Tuscarora [Clinch] sandstone), 9 miles from Salem, Virginia. (H. H. Hill, analyst.)

MARL

Marl deposits of commercial value do not occur in this area. A small deposit, owned by Messrs. Ikenberry and Thomas, was formerly worked about half a mile northwest of Daleville. (See Fig. 7.) It is about 15 feet thick, and is irregularly deposited on the floor of an old lake less than an acre in extent. A small crusher was used, but it has been idle since 1920. The marl was used for fertilizer. It contains great numbers of fossil leaves and shells of fresh-water animals. Another small deposit of marl is found near the Lynchburg, or Grubb, iron mines near Blue Ridge Springs. Marl has been found also along Catawba Creek on the old McCormick farm about 6 miles southwest of Catawba Sanatorium.

OCHER

Commercial ocher is ordinarily hematite or limonite in pulverized or earthy form, more or less admixed with clayey material. Natural ochers are commonly red, brown, or yellow, depending upon the chemical composition and the amount of clay present. Ocher is found under widely variable conditions, resulting from several kinds of processes. The most common mode of occurrence is in irregular masses and lumps resulting from the decomposition and alteration of limonite or hematite. In the Roanoke area the

[143]Watson, T. L., Glass-sand resources of Virginia: Am. Ceramic Soc. Jour., vol. 2, p. 797, 1919.

ocherous clays are largely associated with the deposits of brown iron along the Blue Ridge. The main uses of ochers are in the manufacture of paints and pigments.

No deposits of ocher have been worked in the Roanoke area, but a cursory examination of ocherous material at several of the brown iron mines showed it to be present. Ocher was observed at the Lynchburg, or Grubb, iron mines, Rorer mine, and Gale mine, and ocherous clays of fine texture, brown color, and good body were noticed about 1½ miles south of Salem. Dr. W. S. Sayers, of Roanoke, showed the writer specimens of ocher from Pulaski, Montgomery, and Roanoke counties which were being tested for commercial use.

Figure 7 shows the location of the more important developments of non-metallic mineral deposits in the Roanoke area.

SUMMARY OF THE MINERAL RESOURCES

More than a score of different mineral resources have been discovered in the rocks of this area. Some of them have been mined or prospected and thus have proved of commercial value. Many, however, have failed to show sufficient quantity for profitable extraction or a quality suitable for present use. The materials described fall into four classes:

A. Minerals now being utilized.
B. Minerals of probable future value.
C. Minerals of possible future value.
D. Minerals not known to be of economic value.

MINERALS NOW BEING UTILIZED

The materials of this class are nelsonite, clays and shales, construction and crushed stone, and sand and gravel. Each of them is being mined in the Roanoke area under conditions which presumably provide for a profitable return. The writer believes that larger operations will be similarly successful, provided that the supply of materials and the demand for them are maintained. It would appear that the resources of clay, nelsonite, crushed stone, sand, and gravel are of sufficient size and quality to warrant further investigation. Haphazard development, however, should not be undertaken, and further operations should be attempted only with a thorough understanding of the geologic relations of the deposits and adequate knowledge of the limitations which may later be imposed by lack of demand, failure of supply, and exhaustion of material of good quality. Additional development of the clays for brick manufacture, and of the nelsonite for titanium and for phosphate may be possible. Demands for crushed stone, sand, and gravel can easily be met by the additional development of the abundant supply of these materials.

MINERALS OF PROBABLE FUTURE VALUE

The materials of this class include limestone for lime and cement, glass sand, and ocher. None of them are being mined now, although they occur in deposits which would be of undoubted economic value under favorable market conditions. The writer suggests that commercial development of these deposits be considered, because the geological conditions of their occurrence are such as to warrant an adequate supply of suitable materials. The Mosheim limestone could be used for cement manufacture, particularly in the vicinity of Catawba Post Office, and possibly near Keslers Mill. These deposits lie near the Catawba Branch of the Norfolk and Western Railway. The deposit of glass sand on Catawba Mountain, although once worked, still has abundant reserves of good sand. Many of the ocherous clays of the area are suitable for the manufacture of paints or pigments.

MINERALS OF POSSIBLE FUTURE VALUE

The materials of this class include iron, manganese, coal, barite, marl, arsenic, and millstones. None of them are now being mined, nor is it probable that profitable mining of them could be undertaken at present. The future development of the iron and manganese reserves of this area depend entirely upon outside factors which have already been discussed. There is a fair supply of iron in the area, but of such grade that profitable extraction is impossible at present. It is not possible to prophesy the ultimate value of these deposits. They offer, however, the best opportunities for future mining operations in the area, and may be considered the most valuable mineral reserves of the region.

Coal, barite, marl, and arsenic are present in the area, but in deposits of unknown amount. The chances are strongly against the future value of such deposits, although small-scale operations may be practicable under exceptional conditions. The Price sandstone contains lenses suitable for the manufacture of millstones if the demand should become greater.

MINERALS NOT KNOWN TO BE OF ECONOMIC VALUE

Materials not known to be of economic value may be grouped into two minor divisions: (1) Materials whose occurrence in deposits of economic value is highly improbable; and (2) materials whose occurrence in deposits of economic value is not expectable. The writer discourages attempts toward the development of oil and gas, or gold and silver deposits in this area. The geologic conditions preclude any commercial accumulation of these materials.

Copper, lead, zinc, nickel, cobalt, graphite, talc, asbestos, and bentonite are not known to occur in commercial quantities. It is hazardous to predict that none of these materials will ever be of economic value in this area. It should be emphasized, however, that the geologic relations of the observed deposits, so far as now known, are entirely against the chances of their commercial development. It may be safely asserted that prospecting for the above materials will meet with discouraging results. It may seem that these substances should not be discussed in a report on the mineral resources of the area, as none of them show promise of profitable development, but negative information is often as valuable as positive information, and it is as important to discourage profitless work as it is to encourage profitable work.

It is probable that future mining operations in this area will be largely of mineral resources which have been described above, although it is possible that other resources will be found, or that new uses will create demands for materials which have slight value at present. It is hoped that new developments will be encouraged by improvements in methods of mineral preparation, through extension of transportation facilities, and by the normal increase of market demands, so that other mineral deposits in this area will be brought into the field of practical operation.

SELECTED REFERENCES

BASSLER, R. S., The cement resources of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 2A, pp. 135-136, 1909.

BOYD, C. R., Resources of southwest Virginia, showing the mineral deposits of iron, coal, zinc, copper, and lead, New York, 1881.

CAMPBELL, J. L., Geology and mineral resources of the James River Valley, Virginia, U. S. A., New York, 1882.

CAMPBELL, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, pp. 273-282, 1925.

CATLETT, CHARLES, Iron ores of the Potsdam formation in the Valley of Virginia: Am. Inst. Min. Eng. Trans., vol. 29, pp. 308-317, 1900.

------------, Cement resources of the Valley of Virginia: U. S. Geol. Survey Bull. 225, pp. 457-461, 1904.

CURREY, R. O., The copper and iron region of the Floyd-Carroll-Grayson plateau of the Blue Ridge in Virginia, etc.: The Virginias, vol. 1, pp. 62-64, 70-71, 74-77, 80-81, 95, 1880.

ECKEL, E. C., The Oriskany and Clinton iron ores of Virginia: U. S. Geol. Survey Bull. 285, pp. 183-189, 1906.

ECKEL, E. C., Portland cement resources of Virginia: U. S. Geol. Survey Bull. 522, pp. 350-359, 1913.

FONTAINE, W. M., Notes on the geology and mineral resources of the Floyd, Virginia, plateau: The Virginias, vol. 4, pp. 167, 178-180, 185-192, 1883.

HARDER, E. C., The iron ores of the Appalachian region in Virginia: U. S. Geol. Survey Bull. 380, pp. 215-254, 1909.

————————, Manganese deposits of the United States: U. S. Geol. Survey Bull. 380, pp. 255-277, 1909.

————————, Manganese deposits of the United States, with sections on foreign deposits, chemistry, and uses: U. S. Geol. Survey Bull. 427 [Virginia], pp. 37-42, 46-72, 1910.

HESS, F. L., Nickel in 1915: U. S. Geol. Survey Mineral Resources, 1915, part 1, pp. 756-757, 1917.

HOLDEN, R. J., Iron: *in* Watson, T. L., Mineral resources of Virginia: Virginia-Jamestown Exposition Commission, pp. 402-428, 442-447, 1907.

HOTCHKISS, JED., [Sundry articles, editorials, and other items]: The Virginias, vols. 1-6, Staunton, Virginia, 1880-1885.

KEMP, J. F., The iron ore resources of the world: Internat. Geol. Cong., XI, vol. 2, pp. 793-797, Stockholm, 1910.

KINZER, C. W., A chemical interpretation of the limestones of the Roanoke and Catawba valleys: Unpublished thesis, Roanoke College, Salem, Virginia, 1924.

MCCREATH, A. S., The iron ores of the Valley of Virginia: The Virginias, vol. 4, pp. 94-96, 1883.

————————, The mineral wealth of Virginia, Harrisburg, 1883.

PECHIN, E. C., The iron development and ore resources of Virginia: Am. Inst. Min. Eng. Trans., vol. 19, pp. 1016-1035, 1891.

RIES, HEINRICH, and SOMERS, R. E., The clays and shales of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 20, 1920.

ROGERS, W. B., A reprint of annual reports and other papers on the geology of the Virginias, New York, D. Appleton and Co., 1884.

STOSE, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, pp. 118-124, 1919.

STOSE, G. W., and MISER, H. D., Manganese deposits of western Virginia: Virginia Geol. Survey Bull. 23, pp. 108-119, 1922.

STOSE, G. W., and SCHRADER, F. C., Manganese deposits of East Tennessee: U. S. Geol. Survey Bull. 737, 1923.

TOPHAM, A. J., The natural economic resources of Roanoke County, Virginia: Unpublished thesis, Roanoke College, Salem, Virginia, 1923.

WATSON, T. L., Lead and zinc deposits of Virginia: Virginia Department of Agriculture and Immigration, Geol. Survey of Virginia, Geol. Ser., Bull. 1, pp. 21-22, 71-74, 1905.

————————, Mineral resources of Virginia: Virginia-Jamestown Exposition Commission, pp. 251-252, 301-302, 319-320, 530, 1907.

————————, The occurrence of nickel in Virginia: Am. Inst. Min. Eng. Trans., vol. 38, pp. 683-697, 1908.

————————, Geology of the Virginia barite deposits: Am. Inst. Min. Eng. Trans., vol. 38, pp. 710-733, 1908.

————————, Glass-sand resources of Virginia: Am. Ceramic Soc. Jour., vol. 2, no. 10, pp. 794-803, 1919.

WATSON, T. L., and TABER, S., Geology of the titanium and apatite deposits of Virginia: Virginia Geol. Survey Bull. 3A, pp. 235-247, 1913.

WEEKS, J. D., Manganese: U. S. Geol. Survey Mineral Resources, 1885, pp. 303-356, 1886.

WELD, C. M., The Oriskany iron ores of Virginia: Econ. Geology, vol. 10, pp. 399-421, 1915.

ANONYMOUS, Mining notes: Eng. and Min. Jour., vol. 41, 1886; vol. 42, p. 156, 1886; vol. 46, p. 159, 1888; vol. 52, p. 463, 1891.

WATER RESOURCES

GENERAL STATEMENT

This report was begun while the writer was surveying the area immediately around the city of Roanoke, in the interests of the Roanoke Water Works Company, and the writer is indebted to this company for permission to use here some of the information obtained at that time.

Surface and ground waters constitute, for most areas, a most important but much neglected natural resource. Water is essential to all forms of life and to all communities, and a steady supply of pure water is one of the most fundamental needs of civilization at any place. Water is one of the few resources which is constantly being renewed by natural processes at a rate which makes a new supply available, and hence the importance of a knowledge of surface and ground-water conditions is often underestimated, or but slightly understood.

SURFACE WATER

Roanoke River is the largest river of this area. Its two main branches, North and South forks, unite just west of Roanoke County. The length of the river across the county is about 28 miles. The elevation of its surface at the west limit of the county is 1,220 feet; at Salem, 1,000 feet; at Roanoke, 925 feet; and at the east limit of the county, 880 feet. Its total fall is thus about 340 feet or nearly 12 feet to a mile. The rate of fall varies, however, in different parts of its course, from a few feet to at least 40 feet to a mile. The velocity of the stream is variable but nowhere high. The Roanoke and its tributaries drain at least 240 square miles in Roanoke County. The remaining area drains into James River through Craig and Catawba creeks.

A summary of 28 years of record of daily discharge of the Roanoke River at Roanoke shows that 83 second-feet was available 90 per cent of the time and 231 second-feet was available 50 per cent of the time from a drainage area of 388 square miles.[144]

The maximum recorded stage of the river at Roanoke from 1896 to 1930 was 14.34 feet on August 6, 1901, with a discharge of 16,900 second-feet. The minimum stage and discharge was zero on the morning of December 23, 1909, when the flow was retarded by freezing.

Records of daily discharge prior to September 30, 1927, are published in Bulletin 31 of the Virginia Geological Survey, "Water Resources of Virginia," pages 254-270, and in the Water-Supply Papers of the United States Geological Survey.

[144]Data from Virginia Bureau of Water Resources and Power, 1931.

The Roanoke is not navigable in this area. In 1815 the Roanoke Navigation Company was organized in Salem with the object of improving the navigation of Roanoke River from Weldon, North Carolina, to Salem, Virginia. The company succeeded in bringing one bateau through to Salem, but the company was disrupted and the attempt to navigate the river commercially has never again been undertaken.

The river has an average width of about 100 feet in Roanoke County and, for the greater part of its course, flows through loose valley fill with little bedrock exposed. The banks are generally rather low, and are lined with a heavy growth of willows and brush which protects them from scour except in time of floods. The region is subject to heavy rains which produce floods that rise very rapidly and subside as quickly. The river overflows only at extreme stages.

Several large tributaries enter the Roanoke in this area, of which the most important are Tinker, Back, and Glade creeks. They add materially to the flow of the main river, and they have volumes adequate to produce considerable water power if properly utilized. Craig and Catawba creeks drain the extreme northern part of the area. Catawba Creek is the more important, and its volume could readily be used for power. These streams are fed by smaller tributaries, many of which are intermittent. Others are permanently maintained by springs near their sources. The area as a whole is well watered, both as to amount and disposal of surface drainage, and there are few parts which lack surface water.

Relatively slight use has been made of surface water in this area. Roanoke River has several desirable sites for power plants, but at present only one is being utilized. The Roanoke Railway and Electric Company has a dam about 4 miles east of the city (Pl. 27), and is developing from 1,500 to 2,000 kilowatts per hour from it. The larger tributaries afford good sites for smaller plants. Several roller-mills derive their power from these streams.

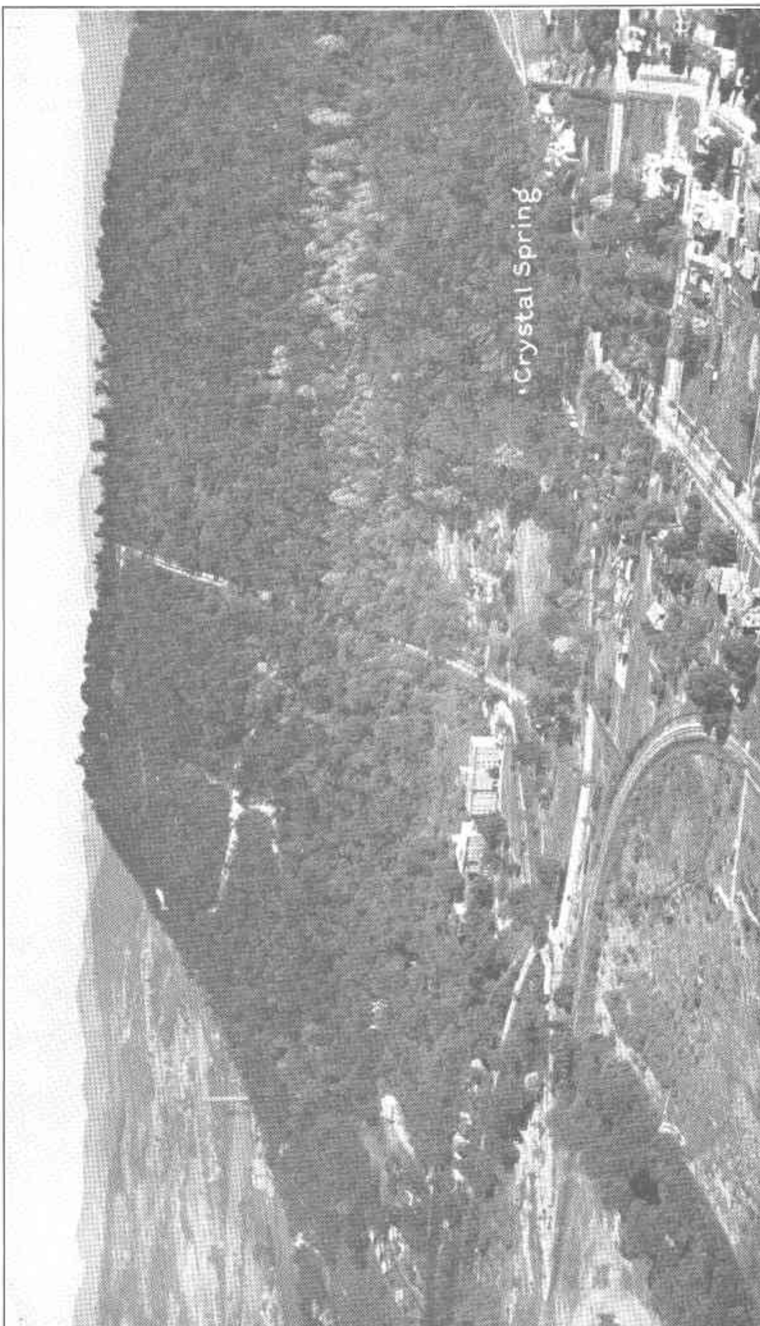
The Roanoke carries sewage and other wastes from Roanoke, Vinton, and Salem, so that its water is unfit for domestic use.

Three surface storage reservoirs are completed, or in process of completion, in this area. These store surface waters for domestic purposes and are maintained by the Roanoke Water Works Company to supply Roanoke and Vinton. They impound the waters of mountain streams several miles from the city. The Beaverdam Creek and Falling Creek reservoirs are about 6 miles northeast of Roanoke on the south slopes of Stewarts and Weaver knobs, and are about 800 feet above Roanoke. These reservoirs are connected by a tunnel through the mountain spur separating

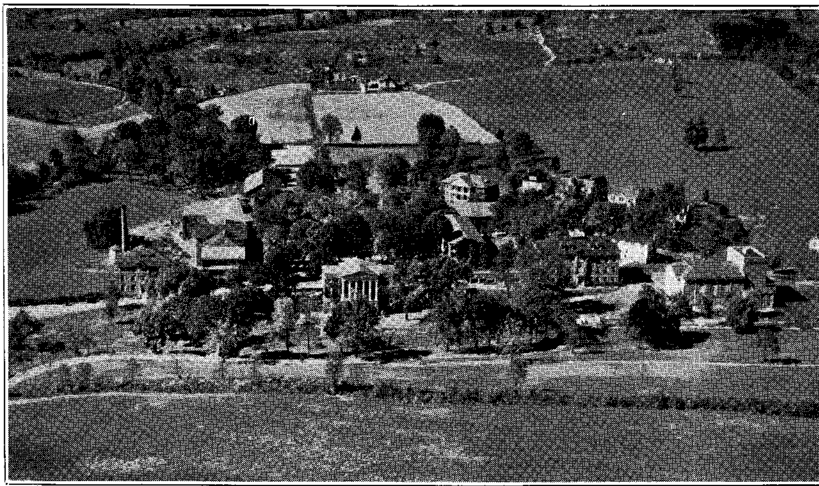
The Roanoke Railway and Electric Company's dam across Roanoke River, about 4 miles east of Roanoke. The area is underlain by pre-Cambrian crystalline rocks. (See p. 144.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)

The Roanoke Railway and Electric Company's dam across Roanoke River, about 4 miles east of Roanoke. The area is underlain by pre-Cambrian crystalline rocks. (See p. 144.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)

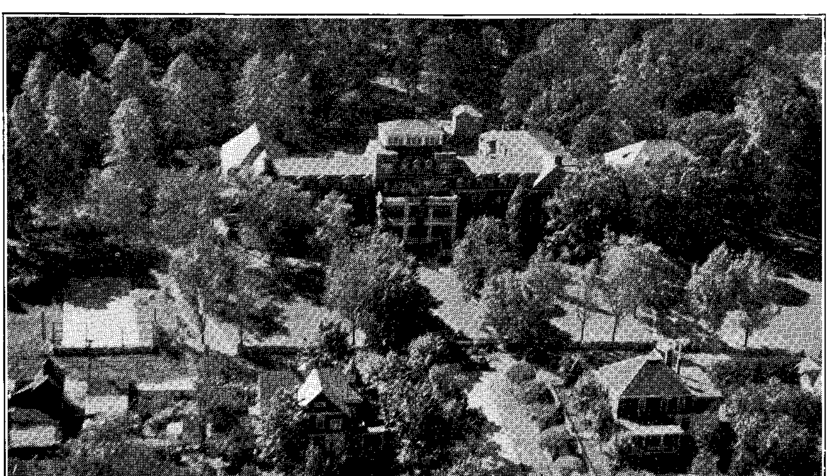
West slope of Mill Mountain showing location of Crystal Spring. (See p. 147.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



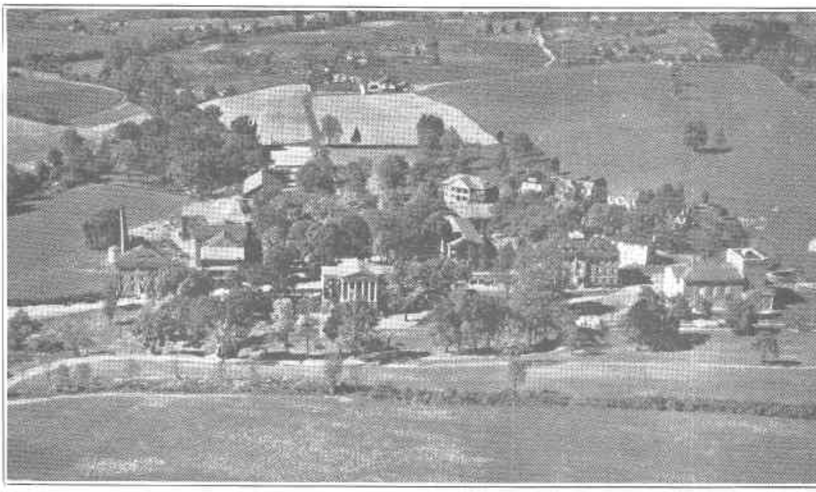
West slope of Mill Mountain showing location of Crystal Spring. (See p. 147.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



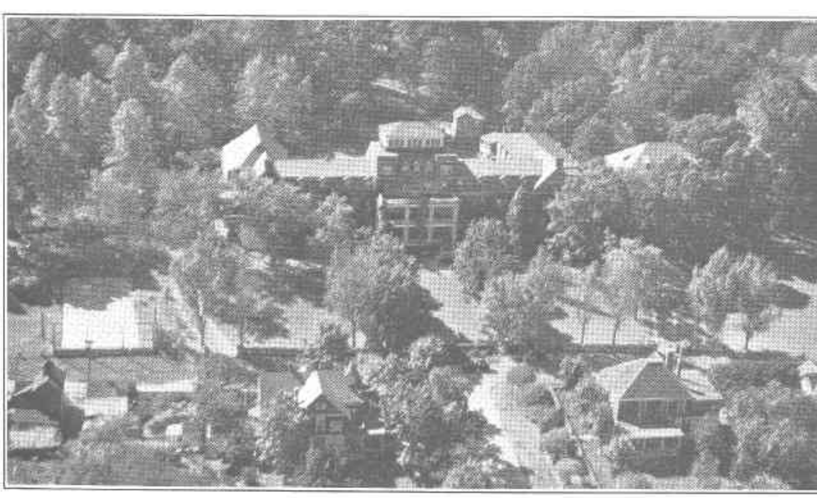
A. Hollins College campus showing location of Botetourt Springs. The springs are in the center of the view behind the central college building. Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



B. Catawba Sanatorium and Roanoke Red Sulphur Springs in Catawba Valley. The springs are behind the main building. (See pp. 149 and 150.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



A. Hollins College campus showing location of Botetourt Springs. The springs are in the center of the view behind the central college building. Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)



B. Catawba Sanatorium and Roanoke Red Sulphur Springs in Catawba Valley. The springs are behind the main building. (See pp. 149 and 150.) Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.)

the creek valleys. Their combined capacity is about 550,000,000 gallons. The water is carried to Roanoke and Vinton by pipe line.

The Richmond Development Corporation has constructed an open-storage reservoir in the south end of Carvins Cove, Botetourt County, just north of the Roanoke county line. A concrete dam has been built across the narrow notch in Smith Ridge where Carvins Creek cuts through the resistant Clinch sandstone. (See Pl. 3.) This dam is about 80 feet high and its crest is about 1,170 feet above sea-level, or about 200 feet above the average elevation of Roanoke. The dam is almost 300 feet long and will impound several square miles of water. The drainage basin of the reservoir has an area of about 18 square miles, and it is estimated that the capacity of the reservoir will be about 6,000,000,000 gallons. Four and one-half billion gallons are expected to be available at present pressure without pumping, and the average flow is calculated to be about 15,000,000 gallons per day. A 36-inch pipe line will carry the water to Roanoke.

GROUND WATER

GENERAL FEATURES

Ground water is the water contained in the outer zone of the earth's crust wherein the permeable rocks are saturated under hydrostatic pressure. For practical purposes, the term ground water is limited to the water directly beneath the land surface, which was derived from the surface by downward percolation. The upper surface of the ground water is called the water table. Its distance from the surface depends upon variable factors, such as local topography, amount of soil and vegetation, climate, and the porosity and structure of the rocks.

The amount of ground water is governed by (1) the amount of rainfall, (2) the nature of the local topography, (3) presence or absence of vegetation, and (4) the character, condition, and thickness of the soil. As the ultimate source of ground water is rainfall, it is to be expected that the flow of springs and wells would fluctuate with changes in the amount of rainfall. This fluctuation is readily observable even in the largest springs, although it varies with the amount of water in the ground and the distance it has to travel. In general, a dry spell of from 2 to 4 months will largely stop the flow of most wells and all but the very largest springs, and even their flow will be materially lessened.

The ideal conditions for an abundant supply of ground water are ample but slow precipitation upon a level or gently rolling area which is covered with loose sandy soil. The conditions in

Roanoke Valley are very favorable for the accumulation of ground water. The rainfall is about 48 inches annually and is fairly evenly distributed throughout the year. The valley is relatively flat, and the rainfall easily sinks into the porous rocks to the water table, which has the same general form as the surface topography. The water table rises rapidly after heavy rains and then gradually sinks again as the water drains away.

Ground water is primarily controlled by gravity and molecular attraction, or capillarity, as it moves through openings in the rocks, such as (1) joints and faults in all rocks, (2) solution cavities in limestone, and (3) the pore spaces between the sand grains and pebbles in sandstone and conglomerate. Water which comes from limestones generally has found its way along bedding planes or joints which have been enlarged by solution by the moving water. The most common place of rapid solution is at the intersection of a prominent bedding plane and a more or less open fault zone or joint. Water in limestone generally flows in well-defined channels to which it gains access either by seepage through the rocks, or directly through surface sinks.

SPRINGS

A spring occurs where water issues naturally from the ground and flows or lies in pools which are continuously or intermittently replenished. The essential factors in the location of springs are a supply of ground water and structure of the rocks that allows it to escape to the surface. As the feeding ground of springs is limited and their ultimate source is rainfall, their flow is materially lessened after long periods of dry weather. If the spring contains either unusual amounts of mineral substances in solution, or perceptible amounts of unusual minerals, it is called a mineral spring. Others are called common springs, and they are variously classified as to volume, temperature, location, behavior, and other characteristics. The most convenient economic classification is according to volume, which is generally measured in second-feet. A second-foot of water corresponds to the flow of one cubic foot per second. This is 448 gallons, or 12 barrels, of water per minute, and about 646,000 gallons in a day.

The location of the important springs in the Roanoke area is shown on Figure 8. Only a few springs here produce a second-foot of water, and they are considered to be exceptionally large. Average springs in this area have a flow of from 600 to 60,000 gallons per day, or about 0.001 to 0.1 second-foot.

Most of the springs in Roanoke County have a steady flow from a rock or gravel outlet, and fluctuate only with seasonal changes. The so-called "flowing spring" of the Catawba Valley has a periodic flow and its rhythmic action is supposed to be due to a natural siphon in the rock below. At Big Cook Spring, near Bonsacks, sand at the outlet is agitated by the flow of water which "boils" from several small outlets.

Most of the larger springs in the Roanoke area are along or near a fault zone, especially where limestone or dolomite is cut by a fault at fairly shallow depths. The trace of a fault is nearly always marked by a spring or by a line of springs. The mere presence of springs, however, is not positive evidence of a fault.

COMMON SPRINGS

Crystal Spring.—This spring is just east of Wellington Avenue at the base of Mill Mountain, in the southern part of Roanoke. (See Pl. 28.) It is the largest spring in the vicinity of Roanoke and is an important contributor to the city water supply. The volume of the spring is about 7 second-feet or 4,500,000 gallons of water daily. The flow in past years is reported to have reached 6,000,000 gallons daily. All of the water from this spring is utilized by the Roanoke Water Works Company for domestic purposes in Roanoke, being pumped to a reservoir on top of Mill Mountain and thence distributed by gravity flow.

Moomaw Springs.—These springs are just beyond the Roanoke city limits, not far north of the intersection of Lafayette Boulevard with the county road. They are about 100 yards from the road along the south side of Lick Creek Valley. They issue from rather low ground, with no rock exposures, but there is a cliff of Elbrook limestone a short distance to the west. The limestone contains large caverns in the face of the cliff. There are two main springs, each being of considerable size. The larger flows about 2 second-feet of water, and the smaller about half a second-foot, totaling about 1,600,000 gallons of water daily. The flow from the larger spring is not retained but finds its way into Lick Creek. The flow of the smaller spring is used to maintain a small fish pond in the valley flats.

Other springs.—Other important large common springs in the Roanoke area are Big Cook Spring near Coyners, Muse Spring near Vinton, River Spring near Vinton, Smith Spring in Vinton, Lake Spring in Salem, Cave Spring at Cave Spring, and Big Spring near Shawsville.

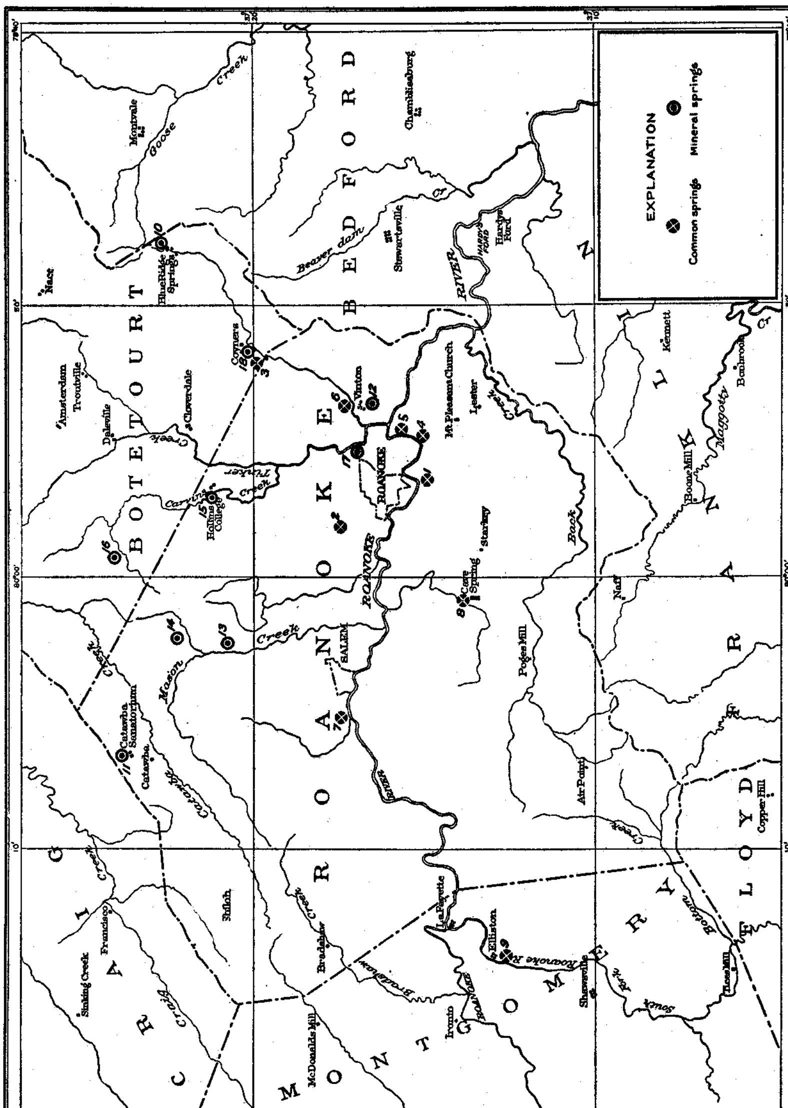


Figure 8.—Map showing location of the important springs in the Roanoke area.

1. Crystal Spring.
2. Moomaw Springs.
3. Big Cook Spring.
4. Muse Springs.
5. River Spring.
6. Smith Spring.
7. Lake Spring.
8. Cave Spring.
9. Big Spring.
10. Blue Ridge Springs.
11. Roanoke Red Sulphur Springs.
12. Virginia Etna Spring.
13. Smiths Lithia Spring.
14. Bennetts Sulphur Spring.
15. Botetourt, or Johnsons, Springs.
16. Cove Alum Spring.
17. Franklin Mineral Spring.
18. Coyners Springs.

MINERAL SPRINGS

Mineral springs contain unusual amounts or unusual kinds of mineral matter. They are generally classified, according to the presence or predominance of various mineral substances, as alum, lithia, chalybeate, sulphur, calcic, and saline. It is claimed that the waters of many springs possess valuable medicinal or therapeutic properties, and it is possible that certain of these waters have beneficial properties. Some of the mineral springs of this area, notably Roanoke Red Sulphur Springs, have long been famous as watering places, and their waters are still held in high esteem by local users. (See Fig. 8.)

Blue Ridge Springs.—These springs, formerly called Bufords Gap Springs, are in Glade Creek Valley at the foot of Porters Mountain, Botetourt County, about 9 miles northwest of Roanoke. They have five separate outlets. Their combined flow is 375 gallons of water in an hour. The waters are calcic and saline, and their temperature varies from 53° to 70° Fahrenheit. The springs are in the Elbrook limestone near its contact with the Rome ("Watauga") shale. The structure is controlled by fractures and small faults in the limestone caused by the great overthrust of the crystalline rocks of Porters Mountain upon the sedimentary formations. The springs are the site of the Blue Ridge hotel which has been operated as a health and summer resort.

Roanoke Red Sulphur Springs.—These springs are on the property of the Catawba Sanatorium, about 9 miles north of Salem, along the south base of North Mountain. (See Pl. 29.) The springs are about 2,100 feet above sea-level. They derive their name partly from reddish deposits and partly from a supposed resemblance to the old Red Sulphur Spring of Monroe County, West Virginia. There are four springs here, consisting of chalybeate (iron) and sulphur waters. Their combined flow is 1,280 gallons in an hour. The temperature of the water varies between 53° and 60° Fahrenheit. The waters are mild and pleasant and have been famous for their supposed medicinal value. They are now held in high esteem for therapeutic qualities by the patients of Catawba Sanatorium.

Virginia Etna Spring.—This so-called lithia spring is in Vinton along the Roanoke-Vinton road a few rods east of the bridge over Tinker Creek. The spring is along a small overthrust fault in the Rome ("Watauga") shale and it emerges from one of the crushed limestones. The spring is about one-quarter of a mile northwest of the Blue Ridge fault. A bottling plant is located over the spring and the water is exported for its medicinal value.

Other mineral springs.—Other important mineral springs are Cove Alum Springs, Coyners Springs, Bennetts Sulphur Springs, Franklin Mineral Springs, Smith's Lithia Spring, and Botetourt Springs. (See Pl. 29 and Fig 8.)

SURFACE INDICATIONS OF UNDERGROUND DRAINAGE

Like most areas in the Valley of Virginia, the Roanoke area shows evidences of abundant underground drainage, such as sinks, sink-holes, and caverns, which occur in the various belts of limestone, especially in Roanoke and Catawba valleys.

A sink is a surface depression which results from solution of the rocks. The term sink-hole is restricted to depressions which result from the collapse of caves, and in which there is a visible hole leading downward into an open cavity. Although only one sink is shown on the old reconnaissance topographic map of the area, there are at least 100 which are more than 30 feet deep and some are much larger. Numerous sinks along the Lee Highway north of Roanoke are along a belt of the Elbrook formation. The Conococheague formation is also marked by numerous sinks, the largest being in Catawba Valley about 5 miles northeast of Catawba Sanatorium.

The largest sink-hole in this area is the locally famous Murder Hole in Catawba Valley north of Little Ridge, about half-way between Catawba and Haymakertown. It is in the Conococheague formation near the crest of Little Ridge. It represents the partial collapse of a large chamber. The hole leads vertically downward into a cavern 300 feet deep and more than 50 feet in diameter. As the opening is encountered without warning, the sheer drop into the cave is a natural feature of much local interest, and many curious people visit the spot. Stalactites are hanging from the roof of the chamber. It is said that the cave has several side chambers which have never been explored.

The largest cave in the region, the Dixie Caverns, is along the Lee Highway about 7 miles southwest of Salem. This cave is on the property of E. J. Givens and has been developed by J. Gillespie and N. Beck. It has been known for 50 years and was first opened to the public in 1922. More than half a mile of continuous caverns has been developed, and electric lights have been installed. The cave extends down to the present water level and for 85 feet above this level. The deepest point is about 250 feet below the crest of the hill. The largest chamber in the cave is about 40 feet in diameter and more than 60 feet high. There is good evidence of a similar cavernous area in the same hill about 250 feet to the west, but this has not been developed. The caves occur in the Elbrook formation which dips about 30° ESE.

Other small caves are found in the area, but none of them have been explored to any extent or opened to the public. The best known are Moomaw Cave on the property of John Moomaw near Moomaw Springs, Bushong's Cave along the Salem-Hollins road north of Roanoke, and the cave at Cave Springs. Each cave represents channels of underground drainage which have become enlarged by solution, and the sinks and sink-holes represent collapsed or incipient solution cavities.

CONTAMINATION

It is obvious that the underground circulation through the limestones of this area must be very free and easily open to contamination from the surface. Many of the sinks are filled with waste of all kinds and in some places sewage is diverted into them. Great care should be exercised in using water for domestic purposes from the springs of a limestone region. R. J. Holden, of Virginia Polytechnic Institute, Blacksburg, has been conducting a series of experiments to ascertain the channels of underground circulation in Montgomery and Pulaski counties, by putting fluorescein into the larger intakes of ground water, and then testing the various springs and wells in the neighborhood for its presence. It is thus possible to determine the larger channels of circulation.

SUMMARY OF GROUND-WATER CONDITIONS

The abundance of springs in the Valley of Virginia is due to the prevalence of limestone and to its crushed and broken character, whereby ground water moves readily and has free access to the surface. Most of the springs in the Roanoke area issue from limestones and most of the larger springs are along faults.

The variety of mineral substances in the waters of different springs results from local differences in the composition of the rocks and from different lines of circulation. The great variation in the flow of the springs indicates differences in the size of the solution channels and in opportunity for escape to the surface.

Solution channels in this area probably do not extend to great depths, and it may be assumed that most of the underground circulation takes place within 300 feet of the surface. Drilling of wells beyond this depth is not recommended. The writer is of the opinion that a considerable quantity of uncontaminated water may be obtained from wells located along favorable structures, and that the most favorable locations are a short distance southeast of faults which are known to cut the water-bearing limestones.

GLOSSARY

(By the Virginia Geological Survey)

Technical terms are here defined briefly in the sense in which they are used in this report. For more extended discussion the reader is referred to standard text-books on geology.

Accessory minerals. Minerals which occur in small and unimportant amounts in a rock.

Accordant. Peaks and ridges which are approximately at the same elevation.

Alga (algae). A primitive kind of plant, e. g., seaweed.

Alluvial. Deposits made by streams.

Alluvial fan. A fan-shaped deposit on land at the mouth of a valley.

Amorphous. Not crystalline.

Anticline. An arch or upfold in rocks.

Apatite. A mineral composed mainly of calcium and phosphorus. An important constituent of nelsonite.

Appalachia. The great land mass, at times mountainous, that existed in Paleozoic time where now are the Piedmont province, Coastal Plain, and the western part of the Atlantic Ocean. It furnished the gravels, sands, and muds that make up the clastic rocks of the Blue Ridge and the Valley.

Appalachian Valley. The province between the Blue Ridge on the east and the Appalachian Plateaus on the west. It includes the Valley of Virginia on the east and the region of alternating mountain ridges and valleys ("Allegheny Mountains") on the west. Also called Valley and Ridge province.

Areal map. A geologic map showing the distribution of bedrock formations at the surface and below the mantle rock.

Arenaceous. Sandy; containing considerable sand.

Argillaceous. Clayey; containing considerable clay or silt.

Arkose. A sandstone or conglomerate composed largely of undecayed feldspar.

Arthropod. A member of the highest developed class of invertebrate animals. Crabs are a living form. Trilobites are a common fossil form in the early Paleozoic rocks of the region.

Asbestos. A fibrous mineral of complex silicate composition. Used for its heat-resisting qualities.

Axis. A line formed by the intersection of the two sides of a fold. It is the crest of an anticline and the bottom of a syncline.

Baselevel. The lowest level to which land can be eroded by streams and running water.

Bauxite. A mineral composed of hydrated alumina. The principal source of aluminum ore.

Bedding plane. The surface between two adjacent beds of sedimentary rock.

Bedrock. Solid rock. It underlies all loose surface materials. The kinds are igneous, sedimentary, and metamorphic.

Bentonite. Plastic clayey rock which swells greatly upon wetting. It is composed of altered volcanic ash.

Biotite. Dark-brown to black mica.

Borderland. An intermittently rising land-mass along the border of a continent; e. g., Appalachia.

Brachiopod. A mollusk-like form of invertebrate having a bivalve shell of unlike parts.

Brecciated. Broken into angular fragments which have been cemented.

Calcareous. Containing considerable calcium carbonate; limy.

Calcite. A mineral composed of calcium carbonate ($CaCO_3$). It is colorless to white, has perfect cleavage, and effervesces in acid.

Cambrian. See Paleozoic.

Canadian. See Paleozoic.

Cenozoic. The latest era of geologic time. It is subdivided into the Tertiary and Quaternary periods, the latter including the present. The time of the great development of mammals and modern plants.

Cephalon (cephala). The headshield of a trilobite.

Cephalopod. A kind of invertebrate; a mollusk.

Chalcedony. A waxy translucent variety of quartz.

Chalcopyrite. A mineral composed of copper-iron sulphide. Copper pyrites. Resembles pyrite but is much softer.

Chert. A very hard dull substance resembling flint, which occurs in limestone. It is composed of silica.

Clastic. Composed of particles of other rocks.

Cleavage. The property of a mineral or metamorphic rock whereby it splits readily along a smooth surface, e. g., in slate.

Coarse topography. An incompletely dissected surface, or one in which the erosional features are on a large scale.

Conchoidal. Having a concave, shell-like fracture.

Conformable. Describes adjacent parallel beds of sedimentary rock, the materials of which were deposited, in general, more or less continuously.

Conglomerate. A sedimentary rock composed of cemented gravel.

Conodont. A small toothlike fossil.

Correlation. Determining the rocks at different places to be of the same age, or to belong to the same formation.

Cretaceous. The last period of the Mesozoic era, and the rocks formed during that time.

Crinoid. A marine form of invertebrate, attached to the sea floor by a long stem. The stem is composed of cylindrical segments, often called "Indian beads."

Cross-bedding. Oblique arrangement of thin layers of sand or gravel within a bed. Often mistaken for true bedding-planes.

Crystalline rock. A rock composed of minerals which have crystallized from the parent material. It commonly refers to igneous and metamorphic rocks.

Delta. A fan-shaped alluvial deposit made by a stream where it empties into a body of water.

Dendritic drainage. Arrangement of streams in a branching pattern like the limbs of a tree.

Devonian. See Paleozoic.
Dike. A sheetlike body of igneous rock which cuts across bedrock.
Dip. Maximum inclination of beds or fault planes to the horizontal.
Disconformity. The contact between two parallel adjacent beds where uplift and erosion, or non-deposition, have occurred between the deposition of these beds.
Displacement. Amount of movement along a fault.
Dolomite. A limestone containing considerable magnesium carbonate ($MgCO_3$).
Drusy. Cavities or surfaces lined with small crystals.
Earthquake. A sudden trembling of the earth's crust caused by internal forces.
Epoch. A division of a period.
Era. The longest division of recorded geologic time.
Erosion. Wearing away of rocks by geologic processes.
Erosion cycle. The succession of events, and the time involved, during the erosion of a region from its initial form to baselevel.
Facies. A variety of the same formation or fauna.
Fault. A fracture in rock along which there has been displacement.
Fault-block. A mass of rock displaced along a fault.
Fauna. An assemblage of animals that lived at one time or in one place.
Feldspar. A group of very common minerals in igneous and metamorphic rocks, containing alumina, silica, and potash or lime and soda. See orthoclase, plagioclase.
Fenster. An area of rocks below an overthrust fault-block, exposed by erosion through the fault-block.
Ferruginous. Containing iron.
Fissile. Having the ability to split readily.
Flint. A fine-grained, very hard substance composed of silica. Commonly dark-gray to black. Breaks with sharp edges and conchoidal fracture.
Float. Fragments of a rock or an ore-body found at a distance from the parent outcrop.
Flood plain. Part of a valley floor that is flooded. It is covered with alluvial deposits.
Fluvial. Pertaining to a river.
Fold. An upwarp or downwarp in rocks; caused by pressure.
Formation. A unit of geologic mapping consisting of "rocks of uniform character or rocks more or less uniformly varied in character."
Fossil. Remains or traces of ancient plants or animals embedded in sedimentary rocks; e. g., shells, tracks.
Fossiliferous. Containing fossils.
Galena. A mineral composed of lead sulphide. It is black, heavy, and has perfect cubic cleavage. An important ore of lead.
Gastropod. A kind of invertebrate; a mollusk; a snail.
Geosyncline. A large downfold or trough in the earth's crust.
Glabella. Middle part of the headshield of a trilobite.
Gneiss. A banded crystalline metamorphic rock, having some cleavage.
Goniatite. A kind of coiled cephalopod.

Gradient. Rate of descent of a stream or a slope.

Granite. A granular crystalline igneous rock composed of quartz, feldspar, and other minerals.

Graphite. A mineral composed of the element carbon (C). It is black, soft, and marks on paper.

Gravity fault. See normal fault.

Great Valley. See Valley of Virginia.

Ground water. Underground water, which fills cavities in the rocks.

Group. An assemblage of two or more closely related formations. (As used in this report.)

Horizon. A definite ("key") zone in a formation, or in a series of rocks.

Hornblende. A mineral of complex silicate composition. It is dark-green to black, glassy, and hard.

Igneous rocks. Rocks which have been formed by the cooling and hardening of molten rock materials.

Ilmenite. A mineral composed of iron and titanium oxides. It is iron-black and has a brownish-red to black streak. A source of titanium.

Indurated. Hardened by pressure or addition of cementing substances; e. g., shale is indurated mud.

Intermontane valley. A valley between mountains, e. g., Catawba Valley.

Intrusive. Igneous rocks which have formed underground.

Invertebrate. An animal lacking a backbone. Common forms are worms, clams, snails, crabs, and insects.

Joint. A crack or fracture in rock.

Jurassic. The second period of the Mesozoic era.

Klippen. Outlying masses of an overthrust block, separated from it by erosion.

Laminae. Very thin layers of sedimentary rock.

Limb. One side of a fold.

Limestone. A sedimentary rock composed largely of calcium carbonate ($CaCO_3$). It is produced by algae and invertebrates and by precipitation from solution in water.

Limonite. A hydrated iron oxide; dark-brown to nearly black color; gives a yellow-brown streak. "Brown hematite."

Magma. Molten rock materials in the earth's interior.

Manganite. A hydrated manganese oxide; steel-gray to iron-black color; gives a dark-brown streak.

Magnetite. Magnetic iron oxide; black color; heavy.

Mantle rock. Loose surficial material above bedrock, e. g., gravel, sand, clay.

Marble. A calcareous metamorphic rock produced by the recrystallization of limestone. A crystalline limestone.

Marine. Pertaining to the ocean. Marine sediments were deposited in oceanic waters.

Mastodon. An extinct kind of elephant-like mammal. Common in the United States during the last glacial epoch (Pleistocene). Perhaps contemporaneous with the early Indians.

Maturity. The stage in the dissection of a region by streams when the land is well cut up into hills and valleys.

Meandering. Pertaining to streams that wind in broad curves, e. g., Back Creek.

Mesozoic. Next to the last great era (Cenozoic) of recorded geologic time. Follows the Paleozoic era. Includes the Triassic, Jurassic, and Cretaceous periods. The time of the development of the great reptiles and of the first hardwood forests.

Metamorphic rocks. Igneous or sedimentary rocks greatly altered by heat and pressure; e. g., slate is metamorphosed shale and marble is metamorphosed limestone.

Metamorphism. The processes of great alteration of rocks, as by pressure and heat, whereby the resultant rock is unlike the parent rock.

Meteoric. Ground water which has been derived from the surface.

Mississippian. See Paleozoic.

Mold. The imprint of a fossil shell upon the sediment that surrounds or fills it.

Monadnock. A hill that remains upon a peneplain (peneplane), either because the rock is more resistant to erosion than the surrounding rock or because it was far from the main streams.

Monocline. Beds of rock dipping in one direction.

Mud-cracks. See sun-cracks.

Nelsonite. A granular igneous rock composed chiefly of ilmenite and apatite, and generally containing rutile.

Nodule. A small irregular to roundish lump of a substance in a rock; e. g., chert in limestone.

Normal fault. A fault along which the hanging wall (block above the fault) has moved relatively downward.

Ocher. A powdery or earthy claylike iron oxide; used for pigments.

Ordovician. See Paleozoic.

Ore. Material mined for its mineral content.

Orthoclase. A variety of feldspar containing potash, alumina, and silica; white, gray, or pink color; glassy luster; scratches glass.

Outcrop. An exposure of rock at the surface.

Outlier. Part of a formation separated from the main mass of the formation by erosion.

Overthrust. A fault along which a fault-block under compression has been thrust upward and over the lower fault-block.

Ozarkian. See Paleozoic.

Paleozoic. The third great era of recorded geologic time. The time of great development of invertebrates, fish, and fernlike plants. The era is subdivided commonly into seven periods: Cambrian (oldest), Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian. Some geologists use the terms Ozarkian and Canadian for the later Cambrian and the earlier Ordovician, respectively. The time terms are also used to designate the rocks formed during the same periods, as the Cambrian system of rocks was formed during the Cambrian period.

Pegmatite. A very coarse-grained dikelike igneous rock, similar to granite.

Pelecypod. A kind of invertebrate; a mollusk; a clam.

Peneplain (peneplane). An almost flat surface of great extent which has been formed at, or near, baselevel by erosion by running water. The almost finished product of an erosion cycle.

Pennsylvanian. See Paleozoic.

Period. A major division of an era, characterized by a cycle of physical and organic changes.

Permeable. Having a texture that permits the movement of ground water.

Permian. See Paleozoic.

Phenocryst. A large crystal in an igneous rock surrounded by smaller crystals.

Physiography. The description and interpretation of the surface features of the earth.

Pisolitic. A texture characterized by rounded concretionary grains about the size of peas.

Plagioclase. A group of feldspars containing soda, lime, alumina, and silica.

Pleistocene. The geologic time, or epoch, just before Recent time; the glacial epoch.

Pliocene. The last epoch of the Tertiary period.

Plunging. Applies to the axis of a fold which dips, as at the ends of all folds.

Porphyritic. A texture of igneous rocks characterized by large crystals in a finer ground-mass.

Pre-Cambrian. (1) All recorded geologic time before the beginning of the Paleozoic era. (2) Very old crystalline rocks.

Province. A region characterized by the same, or closely similar, features; e. g., the Blue Ridge province.

Psilomelane. A mineral composed of hydrated manganese oxide; black color. A common ore of manganese.

Pygidia. The tail shields of trilobites.

Pyrite. A mineral composed of iron sulphide; "fool's gold;" brassy-yellow color; hard (scratches glass).

Pyroclastic. Igneous rocks which have been erupted explosively from a vent in the earth's crust and thus are fragmental.

Pyrolusite. A mineral composed of manganese oxide; iron-black color; soils the fingers.

Pyroxene. A mineral of complex silicate composition. Resembles hornblende.

Pyrrhotite. A mineral composed of iron sulphide; magnetic pyrites, brownish bronze color; black streak. Some contains nickel.

Quartz. A very common mineral composed of silica (SiO_2); colorless to white; very hard (scratches glass).

Quartzite. A metamorphosed sandstone. The grains of quartz sand have been firmly cemented by silica which has recrystallized around them.

Quartzose. Containing much quartz.

Quaternary. Second period of the Cenozoic era, consisting of Pleistocene and Recent time.

Recent. Geologic time since the glacial epoch, including the present.

Rejuvenation. Pertaining to streams which have had their gradients, and therefore their velocities and erosive powers, increased.

Relief. Difference in elevation in an area. Irregularities of the surface.

Residual soil. Soil produced by decay of the underlying rock.

Resistant rocks. Rocks which disintegrate slowly under the attacks of erosive agents, such as streams. In this area they are chiefly quartzites, well-cemented sandstones, and crystalline rocks.

Revolution. Great deformation of the earth's crust, caused by internal forces, whereby extensive mountain systems are upheaved.

Rill-marks. Tiny channels left on a sandy beach by the undertow.

Ripple-marks. Small furrows, or troughs and ridges, made in sand by waves and currents in shoal water.

Rutile. A mineral composed of titanium dioxide; red, red-brown to black color; hard (scratches glass). A source of titanium.

Sandstone. A sedimentary rock composed of cemented grains of sand which is commonly quartz.

Schist. A foliated crystalline metamorphic rock which has distinct cleavage.

Schistosity. Pertaining to foliated metamorphic rocks; having the cleavage of schist.

Second-foot. A flow of one cubic foot of water in one second; about 646,000 gallons per day.

Sedimentary rocks. Rocks which are in beds and are composed of (1) particles of other rocks, (2) organic remains, or (3) materials deposited from solution in water. Most fossils are found in them.

Seismograph. A delicate instrument which records earthquakes.

Series. Two or more formations which make up a major division of a system of sedimentary rocks.

Shale. A sedimentary rock composed of particles of clay and mud pressed and cemented together.

Siliceous. Containing silica (SiO_2).

Silurian. See Paleozoic.

Sink. An enclosed depression formed by solution of limestone.

Slate. Metamorphosed shale. It is characterized by well-developed cleavage.

Slickensides. Smoothed and polished surfaces of fault-blocks.

Sole. The lower surface of an overthrust fault-block.

Sphalerite. A mineral composed of zinc sulphide; commonly yellow, brown to black color; resinous luster. An ore of zinc.

Stratified. In beds or layers.

Stratigraphy. The description and interpretation of the succession and relations of rocks.

Strike. A horizontal line on a bed of rock; the trend of a fold.

Structure. Arrangement of rocks in the earth's crust.

Structure section. A vertical section showing the rocks as they would appear in the wall of a deep cut.

Subsequent streams. Streams not dependent on the original topography but whose development has been controlled by the difference in the resistance of the underlying rock.

Sun-cracks. Shrinkage cracks produced in muds as the water evaporates.

Syenite. A granular igneous rock similar to granite but lacking quartz.

Syncline. A downfold or trough.

System. All the rocks formed during a geologic period, e. g., Cambrian system.

Talc. A mineral composed of magnesium and silica. Has a greasy feel, is very soft, and is easily cut.

Talus. A pile of coarse angular rock fragments at the base of a cliff or along a slope below the cliff.

Terrace. A benchlike flat above a stream; part of a former valley floor.

Tertiary. The first period of the Cenozoic era; just prior to Quaternary time.

Titaniferous. Containing titanium.

Titanite. A mineral containing titanium, calcium, and silica.

Topography. The surface form, or shape, of the land.

Trace. The intersection of a (fault) plane with the surface.

Trellis drainage. Streams arranged more or less at right angles, resembling a trellis. Indicates alternating belts of resistant and weak rocks.

Trilobite. An extinct crablike kind of invertebrate (Arthropod), characteristic of Paleozoic time.

Unconformity. The contact of two formations, which shows uplift and erosion before the upper formation was deposited.

Valley of Virginia. The broad elongate lowland, or series of valley-like lowlands, just west of the Blue Ridge. The eastern part of the Appalachian Valley in Virginia. It includes Roanoke Valley .

Valley Ridges. The narrow linear mountain ridges west of the Valley of Virginia, e. g., Catawba Mountain.

Volcanic ash. Fine fragments of igneous rock erupted from a volcano.

Wad. An impure manganese oxide. It is black, soft, and soils the hands.

Water gap. A narrow passage cut by a stream through a ridge, e. g., Goshen Pass.

Water table. The upper surface of the zone saturated with ground water.

Weak rocks. Rocks which offer slight resistance to erosion, e. g., shale.

Weathering. The slow action of geologic agents at or near the surface whereby rocks decay and disintegrate.

Wind gap. An abandoned water gap.

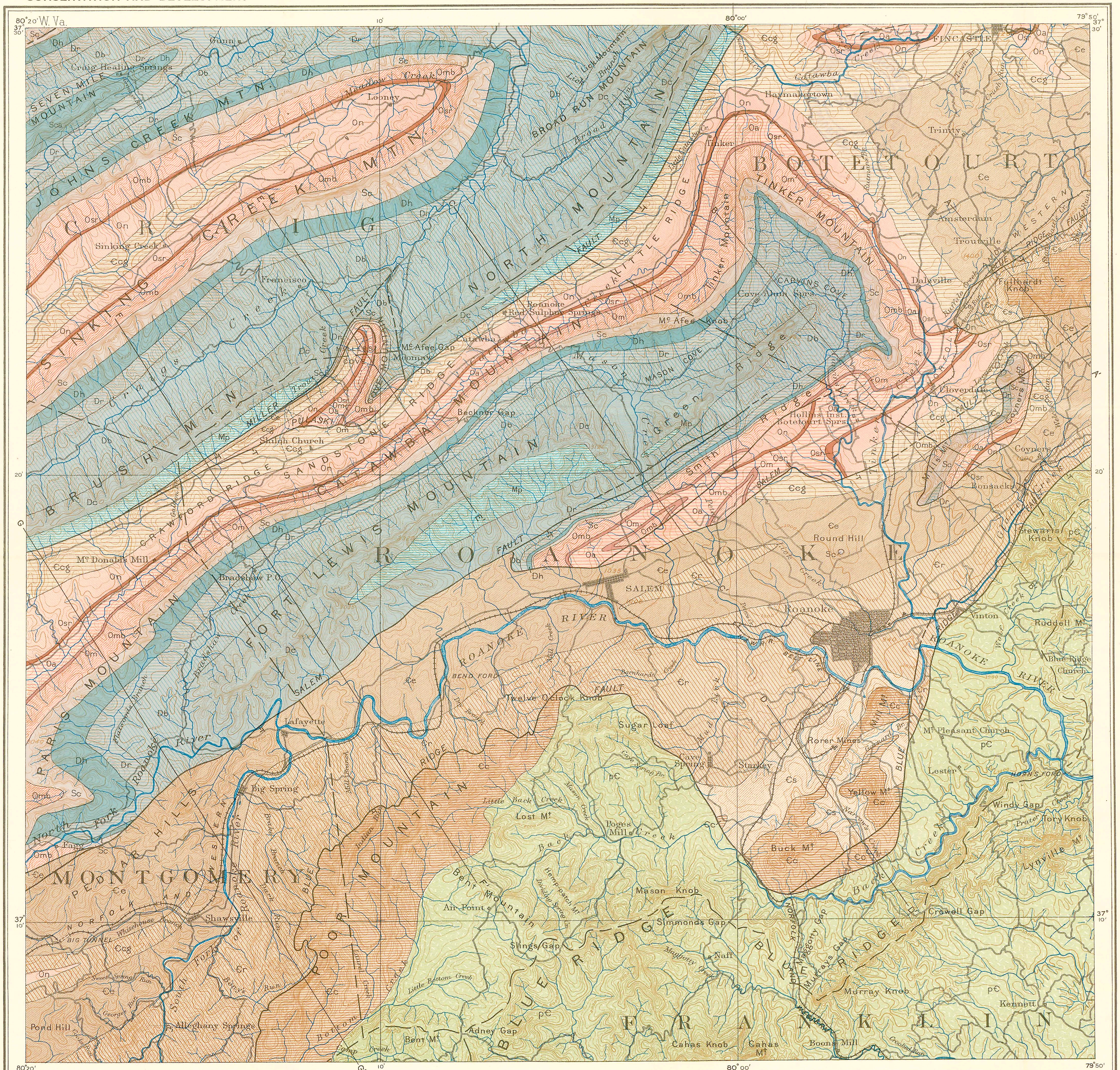
Youth. An early stage in the erosion cycle characterized by partial dissection of the land. "Most of the erosion of the land remains to be done."

INDEX

STATE COMMISSION ON
CONSERVATION AND DEVELOPMENT

VIRGINIA GEOLOGICAL SURVEY
ARTHUR BEVAN, STATE GEOLOGIST

BULLETIN 34 PLATE 1



A. Hoen & Co. Lith.

GEOLOGIC MAP OF THE ROANOKE AREA, VIRGINIA

Scale $\frac{1}{125,000}$

0 1 2 3 4 5 6 Miles

Contour Interval 100 feet

Base from United States Geological Survey maps of Christiansburg and Roanoke quadrangles. Surveyed in 1885-6-7.

Geology by Herbert P. Woodward
Surveyed in 1926-27

EXPLANATION

SEDIMENTARY ROCKS

MISS.

Mp — Price formation
(*Mainly sandstone with red shale in upper part and thin beds of conglomerate; contains some beds of coal; of Osage age.*)

DEVONIAN

Dc — Chemung formation
(*Shale, sandstone, and thin beds of conglomerate.*)

Db — Brallier shale
(*Greenish-gray shale and interbedded thin flaggy sandstone; of Portage age.*)

Dr — Romney shale
(*Dark-gray to black fissile shale; of Onondaga, Hamilton, and Marcellus age.*)

Sca Dh — Helderberg group
(*Gray-brown friable sandstone and blue cherty limestone; includes Cayugan on Seven Mile Mtn.*)

SILURIAN

Sc — Clinch and Clinton formations
(*Clinton formation above is white and red sandstone and green and buff shale. Clinch sandstone below is gray quartzitic sandstone and conglomerate with some thin beds of shale; of Medina age.*)

ORDOVICIAN

Omb — Martinsburg shale
(*Calcareous and sandy shale, thin sandstones, and thin beds of impure limestone; of Trenton, Eden, and Maysville age.*)

Om — Moccasin formation
(*Gray-brown sandstone and vari-colored shale; of upper Black River age.*)

Oa — Athens shale
(*Dark-gray to black shale and thin beds of limestone; of middle Chazy age. Includes crystalline Whitesburg limestone at base.*)

Osr — Stones River group
(*Dark-colored knotty Lenoir limestone above and pure dove-colored Mosheim limestone below. Includes locally light-gray crystalline Holston limestone at top.*)

CANADIAN

On — Nittany dolomite
(*Massive light-gray to blue dolomite having abundant jagged chert on outcrop; of Beekmantown age; probably includes beds of Bellefonte age at top.*)

OZARKIAN

Ccg — Conococheague formation
(*Limestone, dolomite, and calcareous shale, with some beds of calcareous sandstone; black slabby chert on outcrop. Includes Copper Ridge facies in Catawba Valley.*)

CAMBRIAN

Ce — Elbrook formation
(*Thinly bedded bluish-gray limestone and dolomite with interbedded calcareous shales; of middle and late Cambrian age.*)

Cr — Rome ("Watauga") formation
(*Red, purple, and green shale with thin interbedded bluish limestones and some calcareous sandstone; of early and middle Cambrian age.*)

Cs — Shady dolomite
(*Dark bluish-gray massive dolomite and calcareous shale; of early Cambrian age.*)

Cc — Chilhowie group
(*Massive quartzite [Erwin] above; shale conglomerate, quartzite, arkose, and hematite beds [Hampton and Unicoi] below; of early Cambrian age.*)

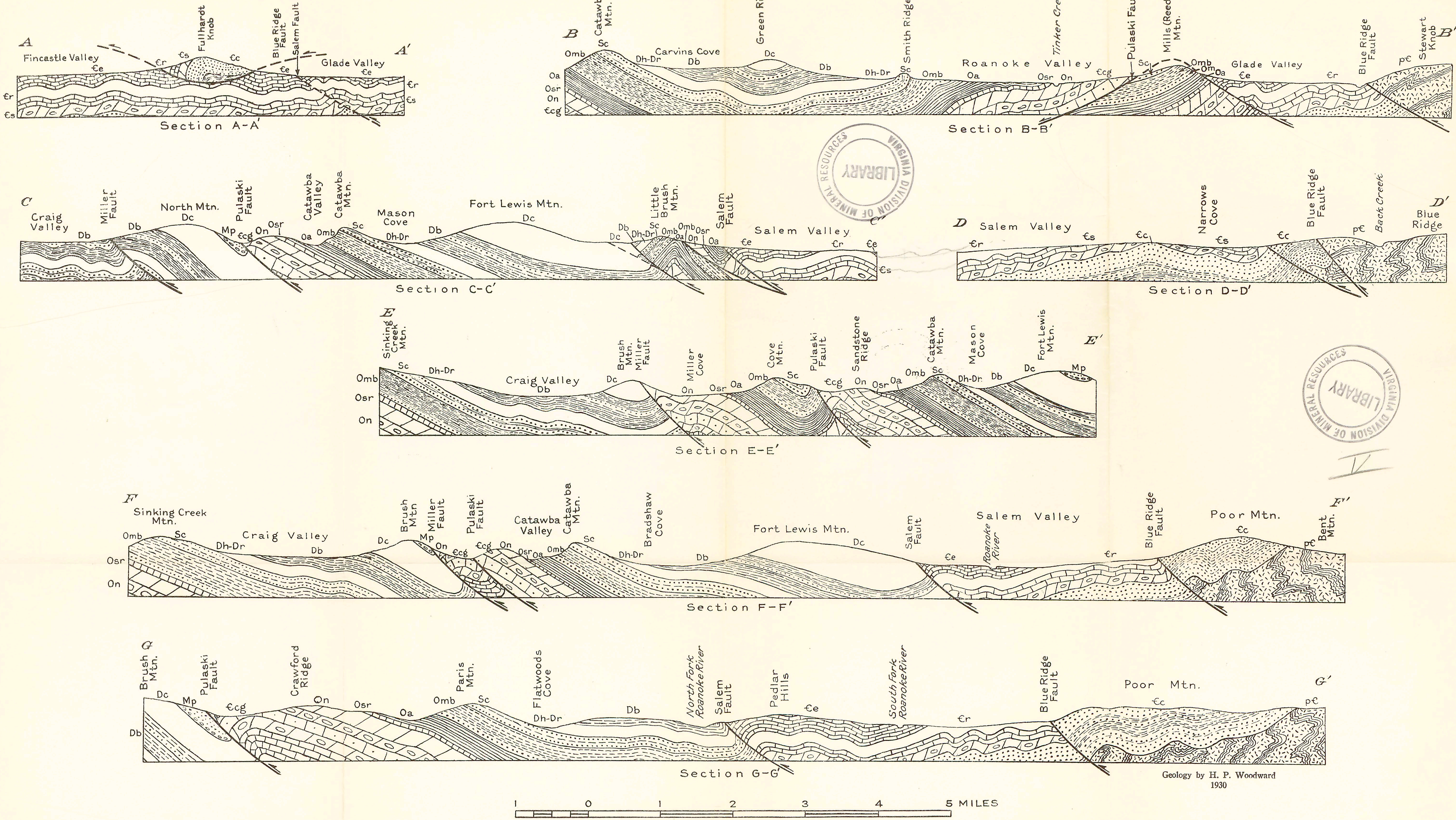
UNCONFORMITY

PRE-CAMBRIAN

pC — Metamorphic and igneous rocks
(*Undifferentiated metamorphic and igneous rocks, including schists, gneisses, granites and gabbros.*)

Faults

T — Overthrust side of thrust fault



Geology by H. P. Woodward
1930

GEOLOGIC STRUCTURE SECTIONS ACROSS THE ROANOKE AREA, VIRGINIA

Mp, Price formation; Dc, Chemung formation; Db, Brallier shale; Dr, Romney shale; Dh, Helderberg group; Sc, Clinch-Clinton group; Omb, Martinsburg shale; Om, Moccasin formation; Oa, Athens shale; Osr, Stones River group; On, Nittany dolomite; Ꞓcg, Conococheague formation; Ꞓe, Elbrook formation; Ꞓr, Rome ("Watauga") formation; Ꞓs, Shady dolomite; Ꞓc, Chilhowie group; pꞒ, Precambrian rocks.

Note: For explanation of formations and location of sections see Plate 1.