COMMONWEALTH OF VIRGINIA

DEPARTMENT OF CONSERVATION AND DEVELOPMENT

VIRGINIA DIVISION OF MINERAL RESOURCES

JAMES L. CALVER, Commissioner of Mineral Resources and State Geologist

Bulletin 72

Geology and Mineral Resources of the Gossan Lead District and Adjacent Areas in Virginia

By

ANNA J. STOSE and GEORGE W. STOSE

CHARLOTTESVILLE, VIRGINIA

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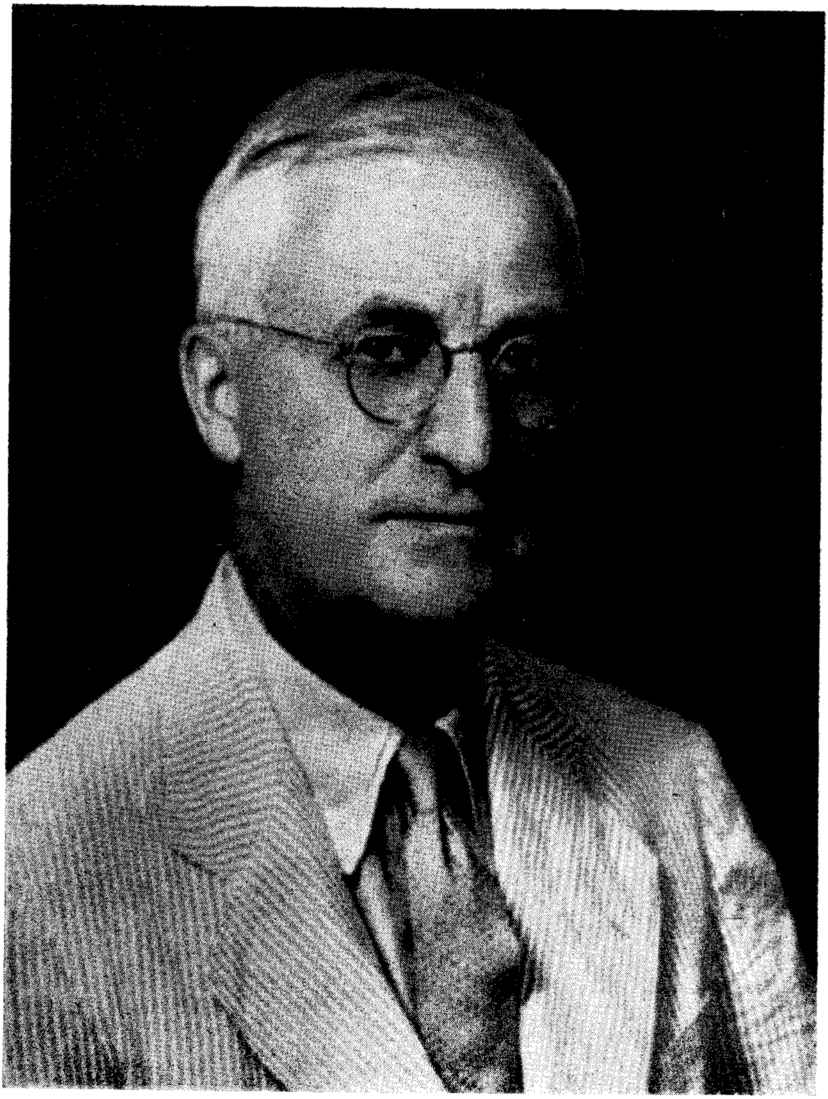

DR. GEORGE W. STOSE

Dr. George W. Stose

GEORGE W. STOSE HAS BEEN ONE OF THE NATION'S GREAT GEOLOGISTS FOR A PERIOD OF MANY DECADES. IT IS DEEMED APPROPRIATE AT THIS TIME TO INCLUDE HIS PHOTOGRAPH AS THE FRONTISPIECE TO THIS VOLUME WHICH REPRESENTS THE RESULTS OF YEARS OF FIELD WORK BY HIM AND HIS WIFE, ANNA JONAS STOSE.

DEPARTMENT OF CONSERVATION AND DEVELOPMENT

RAYMOND V. LONG, *Director,* Richmond

BOARD

LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND DEVELOPMENT
DIVISION OF MINERAL RESOURCES

LEXINGTON, VIRGINIA, FEBRUARY 23, 1957.

To the Department of Conservation and Development:

GENTLEMEN:

It is an honor and pleasure to transmit and recommend for publication as Bulletin 72 of the Division of Geology the text, geologic maps, plates, and figures of a report on *Geology and Mineral Resources of the Gossan Lead District and Adjacent Areas in Virginia,* by Dr. Anna J. Stose and Dr. George W. Stose. The latter was for many decades a geologist on the United States Geological Survey; he is now retired. Anna J. Stose was employed by the Division of Geology from 1926 to 1945. She contributed the geology east of the Great Valley to the 1928 State Geologic Map and is author of several reports published by the Division of Mineral Resources.

This report was prepared as a cooperative project of the U. S. Geological Survey and the Virginia Division of Mineral Resources. The authors did their first geological work in the area in 1928; they visited the area again in 1930. In 1932 Anna J. Stose began a detailed study of the area and continued field work during the field seasons of 1932 to 1939. George W. Stose did detailed field work on the Paleozoic rocks of the area during the field seasons of 1933 to 1939.

The Gossan Lead District is located in southwest Virginia, and is included, for the most part, in Carroll and Grayson counties. The area mapped is on the Galax, Independence, Max Meadows, Speedwell, and a small part of the Mouth of Wilson topographic quadrangles of the U. S. Geological Survey.

The area covered by the report has not been mapped previously. It contains several diverse series of sedimentary, metamorphic, and igneous rocks which have a complicated structure and contain valuable minerals.

Hence it is an area of exceptional scientific interest and economic importance. The following have been produced in the District: barite, building stone, copper, garnet, iron, kyanite, lead, limestone, manganese, pyrrhotite (sulphur), quartz, rutile and ilmenite, soapstone, and zinc. Much of the mineral wealth of the District is now derived from mining pyrrhotite at Iron Ridge, near Galax, and zinc and lead around Austinville.

Currently there is great interest in prospecting for a wide variety of economically valuable minerals in the Gossan Lead District. Publication of Bulletin 72 will be a most significant and valuable contribution to exploration for and development of Virginia's mineral resources.

It is recognized that it is a bit unusual to include a photograph of one of the authors as a Frontispiece, but because this is his last report, due to his present fatal illness, it was considered appropriate to recognize in this way Dr. George W. Stose's long devotion to geology, and to Virginia geology in particular.

Manuscript, maps, plates, and figures were given to the undersigned on September 7, 1956 for final editing and supervision of printing and publishing.

Respectfully submitted,

MARCELLUS H. STOW
Geological Consultant
to the Director.

Approved for publication:

Virginia Department of Conservation and Development,
Richmond, Virginia, February 27, 1957
RAYMOND V. LONG, *Director.*

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*Plates 1, 60, and 61 are in pocket. All other plates are at end of volume.

PLATE

Geology and Mineral Resources of the Gossan Lead District and Adjacent Areas in Virginia[1]

By Anna J. Stose[2] and George W. Stose[3]

ABSTRACT

The Gossan Lead district is located in southwest Virginia, and is included, for the most part, in Carroll and Grayson counties. Galax is the largest town in the district while Independence, the next largest, 18 miles west of Galax, is the county seat of Grayson County. The district is served by the Norfolk and Western Railway, which extends to Galax.

The district, which lies chiefly on the Blue Ridge plateau and which has a general upland altitude, ranging from 2,500 to 3,000 feet, is bounded on the southeast side by the Blue Ridge escarpment and on the northwest side by Iron Mountain. The Point Lookout—Buck Mountain range stands prominently above the general surface of the plateau. The district is drained by New River, which flows across it from southwest to northeast.

The Gossan Lead district contains rocks, many of which have been intensely metamorphosed, of both sedimentary and igneous origin which range in age from early pre-Cambrian to middle Cambrian. The relatively earlier pre-Cambrian rocks are an injection complex, made up of an old sedimentary gneiss and a diorite both of which are injected and metasomatically replaced by later granites. This complex is mapped as twelve rock units. These older rocks are exposed in the Elk Creek anticline, one of the major structural features of the district.

The southeastern part of the district is underlain by schists and gneisses, probably of late pre-Cambrian age, which are thrust northwestward over the injection complex.

On the northwest limb of the Elk Creek anticline this injection complex is overlain by volcanic and sedimentary rocks that comprise the Mount Rogers volcanic series, of late pre-Cambrian age. Tuffs, conglomerate, sediments and rhyolite lava flows, make up this series. Lower Cambrian quartzose rocks overlie the Mount Rogers volcanic series and overlap the injection complex. The quartzose series, comprising eight

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[1] The geologic field work and the preparation of this report were in co-operation with the U. S. Geological Survey.
[2] Geologist, Virginia Geological Survey.
[3] Geologist, U. S. Geological Survey.

mapped units, is overlain by Lower Cambrian dolomite, limestone, and shale, which are exposed chiefly in the Great Valley in the northern part of the district.

All the rocks of the district are closely folded and are broken by thrust faults. The geologic structures in the district are parts of structures which extend from Roanoke, Virginia, southwestward into Tennessee. Several major overthrust faults cross the district, and fault blocks, formerly widely separated, are crowded together and overlap one another. In one of these blocks the Elk Creek anticline brings the pre-Cambrian injection complex to the surface in the core of the fold. This deformation occurred during the late Paleozoic orogeny.

Most of the mineral wealth of the district is derived from the mining of pyrrhotite at Iron Ridge, 4 miles north of Galax. This mineral is mainly used in the manufacture of sulphuric acid. Pyrrhotite is associated with quartz veins that contain pyrite, rutile and ilmenite. The rocks of the district also contain veins of massive spessartite, veins of quartz with kyanite and rutile, and veins of barite. In the northwestern part of the district, mines of zinc and lead are grouped around Austinville, Ivanhoe, and Bertha. Most of the ore-bearing solutions were introduced into rocks during the last stages of the late Paleozoic orogeny.

INTRODUCTION

LOCATION OF DISTRICT

The district covered by this report, which will be herein referred to as the Gossan Lead district, embraces all of the Galax, and Independence quadrangles in Virginia and an irregular area at the north, in the southern part of the Max Meadows and Speedwell quadrangles (Fig. 1).

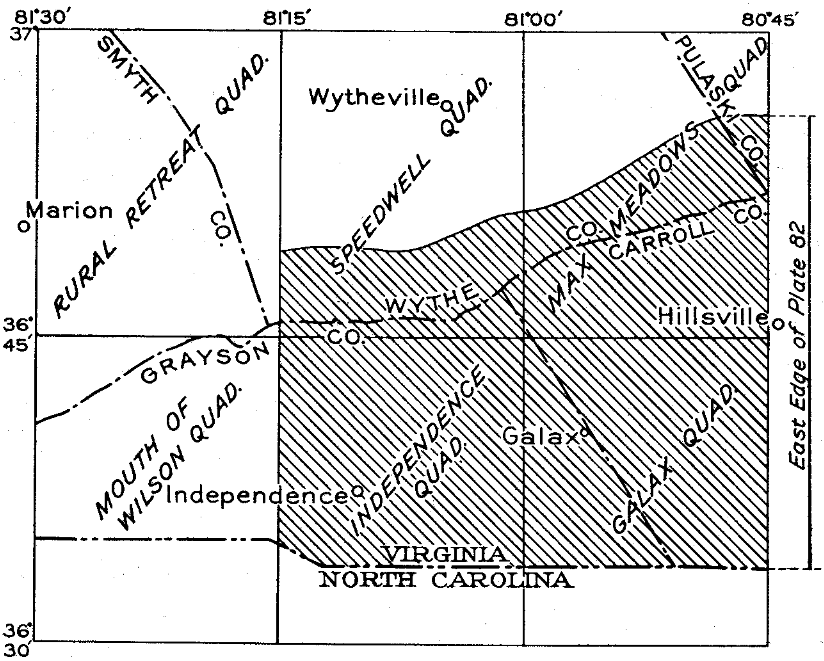

FIGURE 1.—Index map of area around Gossan Lead district, Virginia.

This district lies between meridans 80°45′ and 81°15′ west and extends from the North Carolina line, northward to parallel 36°50′ north in the western part of the district and to parallel 36°55′ north in the northeastern part. The greater part of the Gossan Lead district is in Carroll and Grayson Counties. The northern border is in the southern part of Wythe County, while the northeast portion lies in Pulaski County. The southern boundary along the North Carolina line is 27 miles in length. The length of the eastern side of the district is 24.5 miles, and of the western, 18 miles.

FIELD WORK

The writers of this report did their first geological work in the Gossan Lead district in 1928, during a reconnaissance for the geologic map of Virginia published by the Virginia Geological Survey in 1928. Anna J. Stose did this work for the Virginia Geological Survey and George W. Stose for the United States Geological Survey. They visited the area again in 1930 during a field reconnaissance for the southern Appalachian part of the geologic map of the United States, published by the United States Geological Survey in 1933. In 1932 Anna J. Stose began a detailed study of the area described in this report and continued field work during parts of the summer field seasons from 1932 to 1939. The work of Goerge W. Stose on the Paleozoic rocks on the northwestern border of the area was done during the field seasons from 1933 to 1939. The authors also have made a field reconnaissance of the area northeast of the Max Meadows and Galax quadrangles in Carroll and Floyd Counties, and have in large part completed geological mapping in the area west of the Speedwell and Independence quadrangles in Grayson, Wythe, Washington and Smyth Counties, Virginia, between the Great Valley and the North Carolina and Tennessee State lines.

In connection with the work in Virginia, they have made a field reconnaissance of the adjoining area in North Carolina, and in 1939 they made a geological map for the National Park Service of the Blue Ridge Parkway and vicinity from Adney Gap, Virginia, south of Roanoke, to Asheville, North Carolina.

While their field work was in progress on the Gossan Lead Area the writers published the following papers:

A preliminary paper by Jonas[4] described the Gossan Lead Area in part. Another paper by Stose[5] and Jonas[5] deals with the region around Austinville.

In other reports[6] they described the older and younger pre-Cambrian

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[4] Jonas, A. I., Hypersthene Granodiorite in Virginia: Geol. Soc. America Bull., vol. 46, no. 1, pp. 47-60, 1935.

[5] Stose, G. W., and Jonas, A. I., A southeastern limestone facies of Lower Cambrian dolomite in Wythe and Carroll counties, Virginia: Virginia Geol. Survey Bull. 51-A, pp. 1-30, 1938.

[6] Jonas, A. I., Pre-Cambrian rocks and their late-Paleozoic deformation in the Blue Ridge and Blue Ridge plateau, Virginia (abstract): Geol. Soc. America Bull. vol. 49, no. 12, pt. 2, p. 1961, 1938.

Jonas, A. I., and Stose, G. W., Age relation of the pre-Cambrian rocks in the Catoctin Mountain-Blue Ridge and Mount Rogers Anticlinoria in Virginia: Amer. Jour. Sci., vol. 237, no. 8, pp. 575-593, 1939.

Stose, G. W., Late pre-Cambrian volcanic rocks and Lower Cambrian sediments in the Blue Ridge province of Virginia and Maryland (abstract): Geol. Soc. America Bull., vol. 49, no. 12, pt. 2, pp. 1961-1962, 1938.

rocks of the Blue Ridge of Virginia.

PREVIOUS GEOLOGICAL WORK OF OTHERS

The Gossan Lead district was a producer of secondary copper from 1850 to 1858, of iron ore after 1880, and of sulphides from about 1850 to the present time. Most of the early geological work in this part of Virginia was done in connection with the development of these mineral deposits. During the copper mining of the 1850's, the area was visited by Curry.[7] In the later article, he discussed the general geology of the region and described a number of the mines that were being operated, or had been operated, at the time of his visit.

The geology and mineral resources of Wythe, Grayson and Carroll Counties were described by Boyd[8] in 1881. He gave special emphasis to the mineral wealth, including the brown iron ores and the lead and zinc deposits in the Great Valley in Wythe County and the pyrrhotite lodes that extend across Carroll and Grayson counties. He called the Gossan Lead the "Great Northern Lode" and described its extent from the Betty Baker Mine (Pl. 61) southwestward across Carroll County into northeastern Grayson County. A geological map showing the main ore zones accompanies Boyd's book. Watson[9] in 1905 and 1907 described the lead and zinc mines of the Austinville area and the history of lead mining in that area after 1750.

The iron mines, which were formerly operated in the vicinity of Cripple Creek and Foster Falls in Wythe County, were described by Holden.[10] Watson, T. L.[11] described the Copper mines opened along the Gossan Lead, and gave a list of papers that described the character

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[7] Curry, R. O., A geological visit to Floyd-Carroll-Grayson County plateau of the Blue Ridge, Virginia: Knoxville, Tenn., Beckell Haws and Co., 1859. 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.

[8] Boyd, C. R., Resources of southwest Virginia: 3rd ed., pp. 47-90, 268-311, New York, John Wiley and Sons, 1881.

[9] Watson, T. L., Lead and zinc deposits of Virginia: Dept. Agr. and Immigration, Geol. Survey of Virginia, Geol. Ser. Bull. 1, 156 pp. 1905; Mineral resources of Virginia, Virginia-Jamestown Exposition Commission, Lynchburg, Virginia, pp. 520-541, 544-548, 1907.

[10] Holden, R. J., Iron *in* Watson, T. L., Mineral resources of Virginia; Virginia-Jamestown Exposition Commission, Lynchburg, Virginia, pp. 451-459, 1907.

[11] Watson, T. L., Idem., pp. 208-209, 511-519, 1907.

and utilization of the ore, Weed[12] reviewed the earlier reports and the status of mining in 1911.

Ross[13] studied the ores of the Gossan Lead in connection with his regional investigation of related ore bodies. In the earlier report, he gave a brief description of the pyrrhotite veins at Iron Ridge. In the later report, he discussed all the copper-bearing pyrrhotite veins in southwestern Virginia, the criteria for the determination of mineral sequence, and the genetic history of the veins, and gave detailed descriptions of the veins.

A full account of the lead and zinc deposits of the Austinville area and the geology of the Great Valley in the area north of the Gossan Lead district has been prepared by Currier.[14] Brown [15] described ore zoning at the Bertha Mineral Company Mines at Austinville.

ACKNOWLEDGEMENTS

The writers are indebted to Dr. Jewell J. Glass, of the U. S. Geological Survey, for determining the character of the feldspars in some of the pre-Cambrian rocks and of many of the minerals of the ore deposits. They also wish to express appreciation for the help of the late E. B. Crabill of Galax in locating some of the mineral deposits in areas in which he was interested. Much of the historical information given in this report was supplied by Dr. J. K. Caldwell of Galax, whose family settled at the site of that town after the War between the States. Appreciation is expressed also to the many other residents of the region for their interest and helpfulness in the field investigation. The writers are indebted also to former state geologists, Dr. Arthur Bevan, and Mr. William M. McGill and to Dr. A. A. Pegau, Mineralogist and Petrographer, who critically read and revised the manuscript.

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[12] Weed, W. H., Copper deposits of the Appalachian States: U. S. Geol. Survey Bull. 455, pp. 115-127, 1911.

[13] Ross, C. S., Copper deposits in the eastern United States: Copper resources of the world, 16th Internat. Geol. Cong., pp. 151-166, 1935. Origin of the copper deposits of the Ducktown type in the southern Appalachian region: U. S. Geol., Survey Prof. Paper 179, 165 pp. 44 Plates, 1935.

[14] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull 43, 122 pp., 1935.

[15] Brown, W. H., Quantitative study of ore zoning, Austinville Mine, Wythe County, Virginia: Econ. Geology, vol. 30, no. 4, pp. 425-433, 1935.

GEOGRAPHY

EARLY HISTORY AND INDUSTRIES

This part of Virginia was settled before the Revolutionary War, when deer, bear, and other game roamed the dense forest, and hunting was the chief occupation. In 1775 patriots met at the old lead mines near the present Wythe-Carroll County line and prepared a "Declaration of Independence." Many of the early settlers came from the Piedmont region of North Carolina. Wythe County was separated from Montgomery County in 1790. Grayson County was formed from Wythe County in 1793, and the first County Court was held at Spring Valley in 1793 in a barn belonging to William Bourne. The county was named for William Grayson, a member of the Virginia Convention of 1778 that adopted the Federal Constitution. Carroll County was formed from Grayson County and a part of Patrick County in 1842. Oldtown, situated 2 miles west of Galax, was the County Seat of Grayson County from 1793 to 1842. The first clerk's office in the county is still standing in the town. Upon the formation of Carroll County, the County Seat of Grayson County was moved to Independence and the County Seat of Carroll County was moved to Hillsville, which lies just east of the area described in this report. The region, as a whole, is not thickly settled, and farming, grazing, and cutting of timber are the main industries outside of the towns. Galax and Fries are the main industrial centers. Independence contains a knitting mill and is an important center of the surrounding agricultural community as well as being the County Seat of Grayson County. Galax is now the largest town in the district. It lies partly in Carroll County and partly in Grayson County. The county line is nearly parallel to the Main Street. The first house in the town was built in 1903. The rapid growth of the population was in large part due to the extension to Galax of the Pulaski-Galax branch of the Norfolk and Western Railway in 1904. The town is at an altitude of 2,340 to 2,620 feet, in the valley of Chestnut Creek. It has spread to the hill slopes on the sides of the valley. The industrial district is along the railroad and Chestnut Creek, largely in Carroll County. The main industry of the town is the manufacture of furniture in four plants. Other industries include cotton and rayon knitting mills, a mirror factory, a condensed milk plant, lumber mills, two printing establishments, and brick kilns. Further details of the industries of Galax and vicinity are given in a report[16] on an industrial survey of Grayson County.

Fries, located in the eastern part of Grayson County on New River, is also served by the Norfolk and Western Railway. The Washington Mills textile plant is the main industry in the town. It derives most of its power, supplemented by steam, from the dam on New River southwest of the mill (Pl. 9A).

RAILROADS AND HIGHWAYS

The Pulaski-Galax Branch of the Norfolk and Western Railway is the only railroad in the district. It follows New River from Pulaski to Fries Junction, thence extends southward up Chestnut Creek to Galax. From Fries Junction a spur, 5 miles long, leads to Fries.

The Gossan Lead district is crossed by several paved roads, three of which are U. S. highways. The main east-west highway, U. S. Route 58, enters the eastern edge of the district just southwest of Hillsville and extends southwestward through Galax and Independence, and thence westward. This road in part follows one of the earliest stage roads, which was in existence before Hillsville was built.

One of the main north-south highways, U. S. Route 52, crosses U. S. Route 58-221 at Hillsville, and extends northwestward across the northeast part of the district. This road also follows a part of an old stage route, later called the Wytheville Turnpike. During the copper-mining period of the 1850's and the later iron-mining period, ore was hauled in wagons to the Great Valley over this road. The old Shot Tower, in which lead bullets were made during the Revolutionary War, still stands along this highway at Jackson Ferry. U. S. Route 21 crosses the entire district near the western border and passes through Independence.

The Blue Ridge Parkway crosses the southeastern part of the district, parallel to the summit of the Blue Ridge mountains. It crosses State Highway 97 at Drenn, and north of Low Gap it crosses State Highway 89 which leads from Galax into North Carolina. Other hard-surfaced State Highways radiate from Galax.

RELIEF

General character.—The Gossan Lead district is confined chiefly

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16 Humber, R. L., and others, Industrial Survey of Grayson County, Virginia; Blacksburg, Virginia. Engineering Extension Division, Virginia Polytechnic Institute, pp. 13-18, 1929.

to the Blue Ridge plateau which begins at the north of Bent Mountain, 15 miles southwest of Roanoke, and expands in width southwestward across Virginia into North Carolina. This plateau is bounded on the southeast by the Blue Ridge escarpment, 1,500 feet high. Its northwest boundary is marked by the less regular and more gentle northwest slopes of Iron Mountain.

A strip of the Great Valley at the north foot of Iron and Poplar Camp mountains, which form the northwest border of the plateau, is included in the area mapped and discussed in this report. A small part of the Piedmont lowland southeast of the Blue Ridge escarpment in the Galax quadrangle is also included in the Gossan Lead district (Pl. 1).

Blue Ridge plateau.—The Blue Ridge plateau, which is about 20 miles wide in this part of the State, has a general upland surface that ranges from 2,500 to 3,000 feet in altitude, and into which streams have trenched channels 300 to 500 feet deep. Although the plateau surface is not now a plain because of this dissection, the flat character of the original surface can be observed from the profile of the ridge tops. The greater dissection and the greatest lowering of the general surface level are in the vicinity of New River. A restoration of the plateau surface from the preserved remnants would have an altitude of about 3,000 feet.

The plateau is crossed, diagonally, by the winding course of New River, whose valley bottom has an altitude of 2,400 feet near the North Carolina line, where it enters the southwestern part of the district, and 1,950 feet at the north where the river leaves the plateau and flows northeastward across the Great Valley. New River flows in a valley with steep rugged, wooded sides, gouged by many tributary streams that flow in rocky ravines. The dissected plateau surface in the western part of the district has no systematic pattern of ridges and valleys, as the streams flow in various directions toward New River. In the eastern part of the plateau, a rude trellis system is developed by the larger streams, which flow northwesterly toward New River, and by their tributaries which trend generally northeast and southwest. This trellis system is reflected in the ridges and spurs.

The numerous knobs, ridges and mountain ranges which rise above the general surface of the plateau are considered generally from southeast to northwest.

The Blue Ridge rises in a series of peaks above the general surface (Pl. 6) along the southeast rim of the plateau. These peaks attain altitudes of 3,523 feet in Rich Mountain and 3,565 feet in Fisher Peak

(Pl. 6C.) The Blue Ridge in the Gossan Lead district is a part of a range of mountains which extends southwestward along the south edge of the Blue Ridge escarpment beyond the district. This escarpment rises from the Piedmont lowlands as a serrate wall 1,500 feet high (Pls. 6 and 7A-7B). The escarpment is deeply dissected by streams that flow between the peaks and promontories of the Blue Ridge in steep gorges (Pl. 7A).

North and northwest of the Blue Ridge, many more-or-less rounded knobs rise above the general surface of the plateau to a maximum altitude of 3,178 feet in Pike Knob.

Most of these knobs have steep upper slopes above the 2,900 to 3,000 foot level. A mountain range which rises above the plateau surface west of New River comprises Pine Mountain, Brierpatch Mountain, Point Lookout Mountain (4,554) (Pl. 2A-2B), and Buck Mountain (4,500) (Pl. 3A-3B). These mountains trend west and southwest and extend west of the Gossan Lead district for a distance of 25 miles where they culminate in Whitetop (Pl. 2C) 5,520 feet in altitude, and Mount Rogers, 5,720 feet, the two highest peaks in Virginia (Fig. 2).

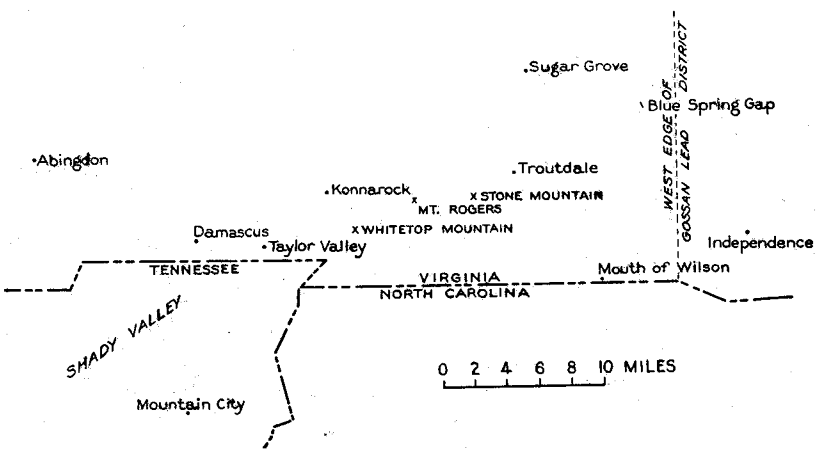

FIGURE 2.—Sketch map of area west of Gossan Lead district, Virginia.

The Point Lookout-Buck range forms a mountain mass that is a barrier to traffic, and except for U. S. Route 21 along Peach Bottom Creek, is crossed only by trails and a few wagon roads.

Poplar Camp Mountain and Iron Mountain are made up of a series of *en echelon* east-trending ridges that extend across the district at the northern border of the plateau. These ridges attain altitudes of

3,105 feet in Round Top (Pl. 5C), 3,400 feet in Chestnut Knob, and 4,035 feet in Comers Rock (Pl. 4A). These mountains at the northwestern margin of the plateau have a more regular trend than does the Blue Ridge escarpment (Pl. 5A), and a less precipitous descent to the Great Valley at the north.

Piedmont lowland.—The Piedmont province, of which only a small part is included in the southeast corner of the Gossan Lead district, is a relatively dissected lowland that has a general altitude of 1,500 feet near the Blue Ridge escarpment. It is trenched by streams to a depth of 200 or more feet. A few peaks rise above this surface in North Carolina (Pl. 7B). Skull Camp Mountain and other prominent hills lie southwest of Lambsburg. On a clear day, Sauertown Mountains in North Carolina, of which Pilot Knob is the southwest end, may be seen to the southeast.

Great Valley.—The Great Valley is the southeastern lowland part of the Appalachian Valley, or Valley and Ridge province. The part of the Great Valley shown on the geologic map (Pl. 1) and described in this report is a lowland about 2,000 to 2,300 feet in altitude. It is dissected by streams to a depth of about 150 to 200 feet. Linear ridges rise about 200 feet above the general surface. Farther north, beyond the area here described, Lick Mountain, Draper Mountain, and other ridges rise above the Valley floor as isolated mountain masses. The maximum altitude of Lick Mountain, south of Wytheville is 3,630 feet.

PHYSIOGRAPHY

On the basis of physiography, the district may be subdivided into these units: Schooley peneplain, Harrisburg peneplain, Piedmont peneplain and Younger River terraces.

Schooley peneplain.—The Schooley peneplain in the Gossan Lead district, is represented by the dissected remnants of the plateau surface at a general altitude of about 3,000 feet, The low hills that rise to 3,178 feet or less, such as Pike and Felt Knobs, have steep upper slopes above the 2,900 to 3,000 foot level, and are regarded as small residual hills on the peneplain. Dissection of the plateau is greatest in the vicinity of New River, and remnants of the peneplain are fewer. In the foothills of Buck, Point Lookout, and Brierpatch mountains, benches and flat-topped spurs at an altitude of about 3,000 feet apparently preserve remnants of the peneplain. Lundy Knob, Turkey Knob, high spurs on Stevens Knob, Tims Knob, and Poor Knob have about this same altitude, as do Farmer Mountain and most of the crest of Poplar Camp Mountain. It seems possible from this meager evidence that the Schooley peneplain had approximately an altitude of 3,000 feet in the Gossan Lead district. This surface was an old subaerial erosion surface because it is independent of the character or attitude of the underlying rocks. It is considered to be a peneplain that was formed when the land was reduced to a gentle lowland by prolonged erosion toward a base level. The drainage at that time probably was northwestward, following an antecedent course of New River, and probably emptied into the sea through the Mississippi River, just as New River today flows northwestward toward the Mississippi River, The peneplain sloped gently down this drainage valley. Its original altitude in this region is not determinable, but probably was much lower than it is now and has since been elevated to its present altitude.

Mountains composed of resistant rocks stood above this peneplain, and still exist as mountains. Poor Mountain, southwest of Roanoke, Buffalo Mountain southeast of Hillsville; and Buck, Point Lookout, and Brierpatch mountains and Fisher Peak, in the Gossan Lead district, are examples of such residual mountains.

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[17] Stose, G. W. et al., Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, pp. 5-11, 1919; Manganese deposits of western Virginia: Virginia Geol. Survey Bull. 23, pp. 16-24, 1922.

[18] Wright, F. J., The older Appalachians of the South: Denison Univ. Bull., Jour. of Sci. Labs., vol. 26, art. 2, pp 148-163, 1931.

The peneplain was first called the Upland[17] peneplain. It was later correlated by Wright[18] with the Schooley peneplain of New Jersey and Pennsylvania. In New Jersey and eastern Pennsylvania evidence[19] indicates that is passes beneath the Cretaceous deposits of the Coastal Plain and is there of late Jurassic-early Cretaceous age. Throughout Cretaceous and early Tertiary time, the land surface remained nearly stationery and its reduction by erosion to a peneplain continued into the early Tertiary. The Schooley peneplain in the Gossan Lead district, therefore, is probably early Tertiary in age.

Harrisburg peneplain.—In the Great Valley the higher ridge tops, that make up this peneplain adjacent to New River and North of Ivanhoe have a uniform altitude of 2,350 to 2,400 feet. To the southwest, adjacent to Cripple Creek in the Great Valley, similar ridge tops gradually rise upstream to 2,700 feet at the western edge of the Gossan Lead district. Within the Blue Ridge plateau area, the New River gorge is bordered by high flat terraces (Pl. 8) cut on the harder rocks, which rise upstream from 2,400 feet near Byllesby to 2,700 feet near the western edge of the district. Remnants of this terrace are well shown for 2 miles on either side of the river, beyond which the hilltops rise to higher levels and merge into the Schooley peneplain.

This lower plain was first recognized in the Great Valley and was named the Valley-floor[20] peneplain. Later it was correlated by Wright[21] with the Harrisburg peneplain of Pennsylvania and Maryland. It is recognized that this surface is only a partial peneplain cut locally on the softer rocks of the Great Valley, and is represented by a terrace cut on harder rocks bordering the larger streams in the plateau. It can be correlated with the Harrisburg peneplain of Pennsylvania only in a general way. It represents a period of widespread erosion when the land stood about 600 feet higher than it did during the Schooley epoch. The length of time during which the land stood at this level was not sufficient for a complete peneplain to be formed. The Harrisburg peneplain here described probably was formed in late Tertiary time by streams of a drainage system that flowed north and west into the Mississippi River, probably an antecedent of New River.

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[19] Stose, G. W., Age of the Schooley peneplain: Am. Jour. Sci., vol. 238, no. 7, pp. 461-476, 1940.

[20] Stose, G. W., et al., Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, pp. 6, 7, 34, 39-40, 1919.

[21] Wright, F. J., op. cit., pp. 164-206, 1931.

Piedmont peneplain.—The Piedmont lowland, in the southeast corner of the Gossan Lead district, is part of a wide dissected plain which has an altitude of 1,400 to 1,500 feet. Its drainage flows southeastward into the Atlantic Ocean, and the plain was formed near this base level. The Piedmont lowland, therefore, is much lower than the floor of the Great Valley, which is drained by New River northward into the Mississippi River and is very distant from sea level at the Gulf of Mexico. It is probable that the Piedmont peneplain in this district represents the Harrisburg peneplain in the Atlantic drainage area, and was formed in late Tertiary time.

Younger river terraces.—North of the Blue Ridge plateau a broad flat terrace, cut in the limestones of the Great Valley, borders both sides of New River at an altitude of about 2,200 feet. The terrace extends from Ivanhoe to the east border of the Gossan Lead district. South of the river the terrace is covered in large part with stream gravel and mountain wash, and rises to an altitude of 2,300 feet near Poplar Camp Mountain. A terrace, similarly covered with stream gravel, borders Cripple Creek from New River westward to the mouth of Dry Run, and its altitude rises gradually in that direction to 2,500 feet at Dry Run. This terrace is believed to have been cut in early Pleistocene time. It is best preserved where it is covered and protected from erosion by river gravel and wash from the mountains, such as in the area east of Ivanhoe.

Still younger gravel-covered terraces, at 2,000 to 2,100 foot altitude, border New River near Ivanhoe and eastward and were formed at a later stage in Pleistocene time.

DRAINAGE

General Characters.—The Gossan Lead district is drained by New River and its tributaries, but small streams belonging to the Yadkin River drainage have their headwaters in the southeastern part.

New River drainage.—New River flows across the district from southwest to northeast, and all the larger streams empty into it. It has its source in North and South Forks, which head in North Carolina at 4,000 feet altitude just north of the Blue Ridge crest and unite a mile south of the North Carolina line. The river enters Virginia just south of Mouth of Wilson and flows eastward with many bends, and lies mostly in Virginia except for two bends which swing southward into North Carolina. It is part of the Mississippi River drainage and is the only stream in the Appalachian region of Virginia that flows north and then west to the Mississippi rather than east or southeastward into the Atlantic Ocean.

New River enters the Gossan Lead district at an altitude of 2,400 feet, and flows in a steepsided valley cut 200 feet into the plateau surface. It has falls and rapids at many places where it crosses rocky ledges, and is dammed at several places for water power (Pl. 9A). Its valley is wider and its altitude lower in the limestone valley north of the mountain front. At Austinville it has an altitude of 1,940 feet.

The New River drainage in the Gossan Lead district comes from three water sheds. The tributaries in the western part of the district head on the south slopes of Iron Mountain and flow southwestward. Those in the southeastern part head on the northwest slope of the Blue Ridge and flow north and northeast. Those in the northern part head on the north side of Iron Mountain, flow eastward and enter New River in the Great Valley.

The largest streams heading on the south slopes of Iron Mountain are Elk and Peach Bottom creeks. Peach Bottom Creek flows southeastward through the gap between Point Lookout Mountain and Buck Mountain and empties into New River near the North Carolina Line. West of it are several smaller creeks, including Brush, Shoal, Saddle, and Bridle, all of which head south of the Buck Mountain divide and flow southward into New River. The headwaters of Saddle Creek have eroded a broad amphitheater-shaped valley in the south side of Buck Mountain, and the stream descends from an altitude of 4,060 feet at its head to 2,400 feet at its mouth in a distance of little more than 4 miles. Elk Creek rises in Iron Mountain in the northwestern part of the district where its upper forks flow through rocky gorges with many waterfalls. Near Elk Creek village and north of Point Lookout Mountain it occupies a wide valley, one-half to one mile wide. In its lower course it again flows through a rocky gorge from the point where it crosses the southeast spur of Brier Patch Mountain to its mouth, west of Riverside.

The main streams of the drainage group that heads in the Blue Ridge flow northwestward to New River. They include Little River and Meadow, Chestnut, Crooked, and Little Reed Island creeks. Little River which heads southwest of Sparta, North Carolina, flows for 4 miles across the southern part of this district, and empties into New River 2½ miles west of Baywood. Meadow Creek, a smaller stream that lies east of Little River, heads in the southern part of the district and joins New River at the bridge on U. S. Route 58. East of Meadow Creek are the two larger streams, Chestnut and Crooked creeks, whose watersheds are entirely in this district. East and West Forks of Chestnut Creek rise in the Blue Ridge northwest of Fisher Peak and unite just east of Tolivers School. Chestnut Creek flows in a sinuous course northward through Galax and flows northward through Iron Ridge and empties into New River south of Fries Junction.

Crooked Creek is formed by the Junction of three creeks, East Fork, Hurricane Fork, and Elkhorn Creek, which flow northwest from their sources in the Blue Ridge and unite north of Chisel Knob. Little Reed Island Creek, which lies east of Crooked Creek, heads east of this district and flows north near its eastern edge. At the north end of Dry Pond Mountain it joins Big Reed Island Creek and New River.

In the drainage group north of Iron Mountain the two larger streams, Cripple Creek and Brush Creek, head north of the mountains and flow eastward into New River. Cripple Creek, the longer of the two, is located along the northern edge of the district. Its larger tributaries from the south include Dry Run, Francis Mill Creek, and Cove Branch.

Yadkin River drainage.—In the southeast corner of the Gossan Lead district Fisher and Steward creeks flow southeastward from the Blue Ridge escarpment in Virginia into North Carolina and drain into Yadkin River, which, through the Pee Dee River, reaches the Atlantic Ocean near Georgetown, South Carolina. Fisher Creek heads on the south slope of the Blue Ridge northeast of Fisher Peak. The headwaters of North and South Forks of Stewart Creek west of Max have cut into the plateau surface for a distance of 3 miles back of the Blue Ridge escarpment. They form steep gorges in the Blue Ridge front and descend from an altitude of about 2,800 feet near Max to 1,700 feet at their junction in a distance of about 2 miles. South of this point Steward Creek flows southeastward across an alluvial fan to Lambsburg, which is on the Piedmont lowland. Other tributaries, Flat Creek and Bobbit Branch, head south of the Blue Ridge crest and have cut steep-sided gorges above the 1,600 foot level.

Water power.—There are numerous waterfalls in the district, some of which have been used to develop water power. Power is obtained from New River by impounding the water at several dams. A dam at Fries (Pl. 9A) is owned by the Washington Mills Textile Company whose plant is at Fries. Dams at Byllesby and at a point 2½ miles farther down river near Buck are owned by the Appalachian Power Company, whose transmission lines radiate from their power plant at Byllesby. The Honeycutt Milling Company of Woodlawn has a dam and power plant on Crooked Creek, 2 miles northwest of Woodlawn, operated by the Cranberry Manufacturing Power Company which distributes electric power to Woodlawn and vicinity. Hillsville obtains electric power and light from a small municipal dam and plant on Little Reed Island Creek, 3 miles northwest of the town. A dam farther up Little Reed Island Creek furnishes power for the Gardner grist mill. Numerous dams on smaller streams furnish power for small grist and saw mills. Power was formerly obtained from a large undershot wheel at the falls of Peach Bottom Creek, 1 mile northeast of Independence (Pl. 11B).

NATURAL ATTRACTIONS

The mountains in the Gossan Lead district have many scenic attractions which include peaks or knobs, ridges, ranges, waterfalls and flora. These attractions are especially appreciated by the tourist and traveler and therefore can be made a source of revenue to the state and community. Many grand distant views may be seen from the Blue Ridge Parkway, while others are visible from the main highways or mountain trails. A number of these scenes are shown in Plates 2-13 and 17.

Throughout the Gossan Lead district the Blue Ridge Parkway lies northwest of the Blue Ridge front from which a series of ridges and peaks extends to the southwest. Fisher Peak, which is connected with the Parkway by a road, commands a view of the Piedmont lowland. Plate 6C shows a view of the peak looking up from the lowland.

The Point Lookout-Buck Mountain range, about 1,500 feet above the general surface of the plateau (Pls. 2B and 3) is bisected by the narrow steep-sided valley of Peach Bottom Creek, whose floor, nearly, 2,000 feet below, is followed by U. S. Route 21. On the slopes of the mountains on both sides, there are many strikingly rounded bosses of granite. The smooth rounded cliffs of Striped Rock (Pl. 3C) and Little Striped Rock are conspicuous on the southwest face of Point Lookout Mountain. The highest point of Point Lookout Mountain, called the Pinnacle, forms a rocky crest at the southwest end of the mountain and is reached by a trail leading north from U. S. Route 21. Above Little Striped Rock this trail follows a spur formed by bare rock bosses or pavement (Pl. 2B) to the summit area around the Pinnacle. This area is carpeted by a dense growth of white clover. The north face of the Pinnacle is steep and densely forested.

Iron Mountain is probably the most scenic one of the mountain ranges as shown in Plates 4A, 4B, 4C, 5A, 5B and 5C. It comprises a series of *en echelon* east-trending ridges that extend from New River to beyond the western limits of the area. The wooded areas of Iron Mountain and the ridges to the north are a part of the Jefferson National Forest areas of Iron Mountain and the ridges to the north are a part of the Jefferson National Forest (Pl. 5C). U. S. Route 21 crosses this forest through Dry Run Gap (3,074 feet) and a forest road (Pl. 4B) ascends Iron Mountain from this gap to Comers Rock (Pl. 4A) where there is a lookout tower and a recreation camp.

Poplar Camp Mountain, which trends northeast from New River, is *en echelon* to Iron Mountain and about 3 miles north of it. Its highest peak is Round Top (3,105 feet). Farmer Mountain (Pl. 5C) and Cold Ridge, to the north, are included also in the Jefferson National Forest.

Some of the most picturesque scenic features in the district are to be found along stream courses. They include gorges, potholes, incised oxbows and waterfalls. A few of these scenes are shown in Plates 10, 11, 12 and 13C.

Potholes are best developed at Clito Mills in Elk Creek west of Riverside and in Pothole Park on Crooked Creek located one mile from its month. At Clito Mill, which is located in a rocky gorge, the stream forms waterfalls over rock ledges and large boulders (Pl. 12C). In the channel here are many potholes, one of which still contains the cobble that formed the hole. (Pl. 10A) In Pothole Park the rocks contain numerous potholes which are best seen at low water.

A series of incised oxbows in deep rocky gorges occur on Little Island Creek northwest and west of Sylvatus (Pl. 11A).

There are numerous waterfalls in the district which are purely scenic in interest. One of the most picturesque of these occurs on Jumping Creek, 2 miles south of Elk Creek Village and just west of U. S. Route 21 (Pl. 10B). South Branch of Elk Creek cascades over granite in a 25 foot fall at Lundy School, just west of the district (Pl. 12A). Chestnut Creek has attractive falls where it is obstructed by a diabase dike, and Poor Branch tumbles gracefully over ledges of an amygdaloidal basalt flow in the Unicoi formation near McGee School (Pl. 13C). "The Falls,"[22] from which Fallville is named, are on Falls Branch of Knob Fork, 1 mile west of Fallville (Pl. 12B). Another high falls occurs on North Branch of Knob Fork along the mountain road north of Fallville.

The flora of the Blue Ridge Plateau is quite distinctive and is characteristic of more northern latitudes. This type of flora grows on the higher mountains of the plateau because of the cool moist climate in high altitudes. In summer, dew is abundant and clouds envelop the summits much of the time, and during the winter the mountain tops are covered with snow. The forests and rocky ravines of the mountains abound in beautiful wild flowers and flowering shrubs. *Galax,* a low-growing evergreen herb with rounded, heart-shaped glossy leaves, grows abundantly in wooded places. Its white blossoms, which flower in June, are a beautiful sight, especially when it grows among lady ferns (Pl. 13A). In the fall the *Galax* leaves turn a bronzy red and are collected and sold to florists for wreaths and other decorations. The town of Galax takes its name from this plant. Maidenhair and lady ferns also grow in abundance with *Galax.* Pink lady slipper, wild lily of the valley, white *Clintonia,* and wood anemone are associated flowers in the forests. The graceful Indian physic, with its fine snowy petals, grows abundantly along the road sides. Flowering shrubs, which bloom from late May into July, include the pink azalea, flame azalea, laurel, reddish purple rhododendron, and pink rhododendron. They bloom in the order named, but their periods of flowering overlap, and the dates vary according to the altitude. Gardens of reddish purple bloom in late May and early June (Pl. 13B) are found on Fisher Peak and many places on Poplar Camp and Iron mountains. The pinkish white rhododendron is found

[22] A picture of these Falls, called Hale's Falls by him forms the frontispiece for C. R. Boyd's "Resources of South West Virginia," 321 pp., New York, John Wiley and Sons. 1881.

abundantly in the forests of the granitic area north of Independence and also along the Blue Ridge Parkway east of the district. With these shrubs grows the cucumber tree, with its large ornamental green leaves, large white magnolia-like flowers and red fruit in the fall. The sourwood is a low-growing tree charactedistic of the region. It bears gracefully drooping cream-colored flowers in spring, and fruit of the same color in the fall which contrast with the bright pinkish red of the leaves. Fiery-red sumac leaves also make bright masses of color in the fall and stand out in strong contrast to the dark-green of rhododendron and hemlock, pine, and spruce trees. On the higher mountain slopes, lady fern and bracken cover large areas and form a thick green carpet throughout spring and summer.

PETROGRAPHY, PETROLOGY AND STRATIGRAPHY

General Statement.—The Gossan Lead district contains sedimentary and igneous rocks which range in age from early pre-Cambrian to Middle Cambrian (Pl. 1). All of the rocks of the district are closely folded and are broken by thrust faults. The grade of metamorphism of the rocks varies greatly in different parts of the district.

Pre-Cambrian rocks are exposed in two belts: The Elk Creek anticline northwest of the Fries and Gossan Lead overthrusts in the northwestern part of the district in the Independence, Speedwell, and Galax quadrangles; and a wide belt southwest of the Gossan Lead overthrust, in the southeastern part of the district.

The pre-Cambrian injection complex is exposed in the Elk Creek anticline and along the border of the Fries overthrust near Sylvatus and southwest of Chestnut Creek. This complex series comprises the following formations, beginning with the oldest: Saddle gneiss, Cattron diorite, Striped Rock granite with syenite and white granite pegmatite facies, the Carsonville granite and an associated pink pegmatite, Comers granite gneiss, Grayson granodiorite gneiss, and a series of injection gneisses and hybrid rocks related to the Striped Rock and Carsonville granites.

The later pre-Cambrian rocks, called the Mount Rogers volcanic series, overlie the injection complex in the northern part of the Elk Creek anticline in the Speedwell and Independence quadrangles. This series is composed of tuffaceous sediments, arkose, basalt and rhyolite. Diabase and rhyolite dikes related to the flows of volcanic series, intrude the injection complex.

The Lynchburg gneiss also of late pre-Cambrian age underlies most of the southeastern part of the district. It is composed of muscovite-biotite gneiss, schist, quartzite, garnet-muscovite schist. The latter, in some zones, contains staurolite and in places micaceous marble layers. The gneiss contains intrusions of gabbro, peridotite, and pyroxenite, which have been metamorphosed into hornblende gneiss, actinolite schist, serpentine, and soapstone. The Lynchburg gneiss and its intrusives are strongly folded.

Lower Cambrian rocks include the Unicoi formation, the overlying Hampton shale and Erwin quartzite. They overlie the pre-Cambrian rocks of the Elk Creek anticline on its north flank and northeast plunging end, from Iron and Poplar Camp mountains and the foothills on the south side of the Great Valley. These rocks are closely folded and broken by thrust faults. Along their northwestern edge they have been thrust northwestward over the rocks of the Great Valley.

Much of the mineral wealth of the Gossan Lead district is derived from the mining of the mineral pyrrhotite at Iron Ridge, 4 miles north of Galax. The veins that contain this mineral together with pyrite penetrate the Lynchburg gneiss along foliation planes. These deposits extend southwestward across the southeastern part of the district in a series of *en echelon* bodies parallel to the strike of the country rock. Other minerals of the area include magnetite, spessartite, kyanite, rutile, ilmenite, and barite. These minerals occur in pre-Cambrian rocks, confined to zones of shearing.

Lead and zinc ores occur in the Lower Cambrian limestones of the Great Valley. They are mined at Austinville. Limonite deposits, which were formerly mined, occur also in the limestones of the Valley. The entire area was affected by folding and faulting during the late Paleozoic deformation and most of the ore-bearing solutions were introduced into the rocks during this orogeny.

INJECTION COMPLEX

SADDLE GNEISS

General description and distribution.—The oldest known rocks of the Gossan Lead district are a series of highly metamorphosed rocks of sedimentary origin that include biotite schist, biotite gneiss, and quartzite. These rocks have been named the Saddle gneiss, from Saddle Creek in the southwestern part of the district, where they are well exposed at the intersection of Saddle Creek and U. S. Route 58. The Saddle gneiss occurs in the Elk Creek anticline in a belt, about 1½ miles wide, that extends from Brush Creek, south of Independence, northeastward to Baxter Ferry on New River and in a wider belt north of Elk Creek Village. It is found also in narrow areas near U. S. Route 58 between Independence and Saddle Creek and west of Providence Church. The best exposures of this gneiss occur at several places along U. S. Route 58, on State Highway 95, and on U. S. Route 21 South of its junction with State Highway 95.

The Saddle gneiss is interlayered with Cattron diorite and permeated by white aplite and granite pegmatite to form an arteritic migmatite.[23]

[23] An injection gneiss formed by the permeation of the host rock by dilute solutions of the invading magma.

The extensive injection and alteration of the Saddle gneiss make it difficult to map well-defined areas of the gneiss, and even in the areas shown on the geologic map it contains much granitic material. Areas of Saddle gneiss with abundant granitic injection have been mapped separately. The Saddle gneiss occurs also in small unmapped xenoliths in the Striped Rock granite.

Character.—The Saddle gneiss comprises quartzite, biotite schist, gneiss and garnetiferous facies with and without sillimanite. The quartzite in places contains graphite. The individual layers of these rocks, nowhere more than a few feet thick, alternate with each other in every outcrop to such an extent that the different kinds of rock could not be mapped separately. The repetition of these layers is due to differences in original sedimentation and to close folding. Because of folding, the presence of intruded igneous bodies, and the occurrence of the Saddle gneiss in small discontinuous bodies, no stratigraphic sequence of the rocks of the formation could be determined. The Saddle gneiss is garnet and sillimanite-bearing in that portion adjacent to the southern border of the Striped Rock granite, in xenoliths included in that granite, and in an area east of Cattrons Mill.

The garnetiferous biotite gneiss is a medium-to fine-grained, banded rock composed of fine quartz grains, grayish-green feldspar and bronzy biotite flakes. A highly garnetiferous variety occurs 1 mile east of Cattrons Mill, at which place the gneiss is injected by white aplite. Contortion of the micas is a characteristic feature of the rock indicating that it has undergone deformation. The garnets occur as red skeletal grains, generally visible in a hand specimen. Sillimanite commonly appears as white needle-like fibers which lie parallel to the banding. The rock weathers to a brownish-black color due to the decomposition of minerals containing iron and manganese. Quartzite is abundant in the Saddle gneiss in several narrow zones which trend N. 45° E. and lie north of and along U. S. Route 58 from Baxter Ferry on New River southwestward to Independence. This quartzite is a dense, grayish-green rock containing small grains of red garnet. Graphite flakes have been found in the quartzite at several localities.

The Saddle gneiss contains the minerals quartz, oligoclase, biotite, garnet, chlorite, apatite, allanite, ilmenite, and titanite. Quartz and feldspar grains have cracks that are filled with smaller crushed feldspar and quartz grains. The quartz grains show strain shadows while the apatite grains are broken. Quartz and feldspar bands alternate with bands rich in biotite and garnet. Biotite occurs in blades that are folded and twisted (Pl. 14A). It is of a red-brown color and contains rutile needles (Pl. 14B). Its index of refraction, 1.650, is high for biotite. The mineral exhibits strong pleochroism, which ranges from a deep red-brown to a light yellow-brown. The index of refraction and the depth of color increase with the iron content.

Southwest of Independence, the biotite is of a lighter brown color and contains bands of fine-grained, dark-colored dust-like material parallel to the cleavage and across the cleavage. Some of the biotite blades contain veinlets of fine-grained epidote and inclusions of zircon that exhibit wide pleochroic halos. The garnet is the manganese variety, spessartite. It occurs as skeletal grains which include quartz. In some specimens it is very irregular in shape. The garnet is in part replaced by red-brown biotite which penetrates it as wide blades along fractures. Some of this biotite lacks the rutile network characteristic of most of the biotite in the Saddle gneiss. Both forms of biotite have altered in part to chlorite. The alteration of garnet to biotite is so extensive in places that the unaltered garnet appears as small residual grains in a network of felt-like biotite. Ilmenite is generally altered to leucoxene, but titanite is in fresh grains. In the area north of Elk Creek Village, the gneiss is a garnet-free biotite injection gneiss (Pl. 14A).

The quartzite of the Saddle gneiss that is interlayered with the biotite gneiss is found chiefly in the belt northwest of the Fries overthrust and south of the Striped Rock granite, and in the area north of Elk Creek Village. The quartzite contains strained or finely granulated quartz grains; plagioclase, sericitized and strung out in shreds; skeletal garnet; scanty red-brown biotite (Pl. 15A) and graphite.

Sillimanite has been found as bundles of short fibers in the Saddle gneiss near U. S. Route 58 west of Independence and in xenoliths in the Striped Rock granite west of Striped Rock. A sillimanite-bearing, biotite-garnet gneiss from a point 1 mile east of Cattrons Mill (Pl. 14C), is injected by pegmatite and contains myrmekite[24], plagioclase, garnet, red-brown biotite and rutile.

Origin.—The recrystallization, alteration and granitic injection of the Saddle gneiss make it difficult to determine the original material from which the gneiss was derived. The mineral content of the quartzite suggests the quartzite to have been derived from impure quartzose sediments. The variation in composition of the different bands of the

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24 Myrmekite is an intergrowth of plagioclase feldspar and vermicular quartz formed at the contact of plagioclase and potash feldspars.

gneiss further tend to confirm a sedimentary origin of these beds. They may have derived from shale containing calcareous layers as is attested by the presence of graphite in the gneiss.

CATTRON DIORITE

General description and distribution.—The Cattron diorite is intruded into and associated with the Saddle gneiss in many outcrops. The diorite is here named from Cattrons Mill on Elk Creek, where one of the larger outcrops occurs. The diorite is injected and replaced by white aplite and pink pegmatite, so that much of the rock is now an injection gneiss described under the heading "Injection gneisses." The areas mapped (Pl. 1) as Cattron diorite represent only those in which there is a preponderance of diorite.

Field relations indicated that the diorite may have intruded the Saddle gneiss as sills parallel to the foliation. Most of the later aplite injections appear to have followed the same planes of weakness. In the vicinity of the Fries overthrust and in the numerous shear zones in the Elk Creek anticline, secondary foliation was the only structure observed in the diorite.

The largest area of diorite mapped occurs north of Point Lookout Mountain in the valley of Elk Creek and northeastward along Farmers Branch, where it connects with an irregular area that extends northwest of Spring Valley and west of Fallville. Other exposures occur near Longs Gap, west and northeast of Big Ridge, and near Bennington Mill. Narrow linear bands are found northwest of the Fries overthrust.

Character.—The Cattron diorite is a fine-grained, grayish-green gneissic rock in which milky-gray feldspar and green hornblende are the only minerals discernible to the unaided eye. In thin section, the diorite is seen to have a granoblastic texture and in places a cataclastic texture. Hornblende, green to brown in color, often has residual cores of pyroxene. The feldspar is andesine, partially replaced by common epidote and in places by the variety clinozoisite. The original rock may have been either a gabbro or a diorite. In many instances biotite has replaced hornblende. The diorite contains injection of both white and pink aplite which is composed of microcline and quartz. This has resulted in two varieties of injection gneiss that have been mapped separately. In the injection gneiss the white aplitic bands range from the thinness of paper to a few inches in width. They are generally crenulated into complicated puckers that follow the foliation. In places the white aplite crosses the foliation in a zigzag pattern. Injection gneiss formed by the intrusion of white aplite in diorite, is exposed in the vicinity of Salem Church, Cattrons Mill, on the northwest side of Brierpatch Mountain, and east of Fallville (Pl. 20A). Pink aplite containing hornblende and epidote replaced the diorite to form a migmatite seen near Bennington Mill, south of Elk Creek Village, and southwest of Fallville and elsewhere.

The diorite north of Big Ridge at the western edge of the Gossan Lead district shows very little evidence of aplitic intrusion. The rock here has been sheared and much of the hornblende has been altered to chlorite (Pls. 15B-15C). Plate 16B shows a photomicrograph of a biotite-free hornblende diorite injected by white aplite. A thin section of Cattron diorite from 1½ miles west of Riverside on U. S. Route 58 (Pl. 16A) contains andesine and a perthitic microcline with myrmekite borders.

Where red-brown biotite is very abundant and spangles the rock, as in areas northeast of Spring Valley, it is difficult in the field to distinguish the diorite from the Saddle gneiss characterized by that variety of biotite. In thin section the biotite diorite is seen to contain more augite than hornblende. The andesine feldspar is but little altered, and the biotite is in clear, red-brown blades that appear to have formed later than the augite. The red-brown biotite in the Cattron diorite has a high refringence and birefringence, similar to the biotite in the Saddle gneiss.

The diorite also contains green biotite and hornblende in fine, green fibers, in part altered to chlorite and epidote. Quartz, feldspar, and apatite grains show cataclasis. The plagioclase feldspars are extensively sericitized. The green biotite appears to have formed during stress from the alteration of red-brown biotite.

Amphibolite facies.—Small outcrops of amphibolite which may be a facies of the Cattron diorite, occur southwest of Powdermill Creek, south of Longs Gap and elsewhere. It is not mapped separately. This rock is fine-grained to schistose and has the constituents of the type of Cattron diorite that contains green biotite and chlorite.

The injection gneisses and migmatities resulting from white and pink pegmatite injection in Cattron diorite are discussed later.

STRIPED ROCK GRANITE

General description and distribution.—The Striped Rock granite forms an elliptical area 8 miles long by 3 miles wide, on the southeast side of Point Lookout and Buck mountains. It is here named from Striped Rock (Pl. 3C), a smooth-faced cliff of granite 300 feet high, on a spur of Point Lookout Mountain (Pl. 2B). Striped Rock in turn takes its name from the dark ribbon-like streaks produced on its surface by limonite staining from the water which trickles over the rock cliff. It is visible from U. S. Route 21 which crosses the granite belt between Independence and Longs Gap. The main area of granite extends from a point near Pilgrims Rest Church southwestward to Saddle Creek. Its greatest width is northwest of Independence. It is bordered on the northern and northeastern sides by the Carsonville granite. On the southeastern side, white aplite, related to the Striped Rock granite, has injected the Saddle gneiss in a narrow border zone between the granite and the gneiss. Smaller masses of Striped Rock granite and injection gneiss occur between the main body and Longs Gap, and west of Quaker Church on the south flank of Brierpatch Mountain.

A syenite facies of the Striped Rock granite forms a narrow body within the southern part of the main granite area where it parallels the strike of the main granitic mass. The syenite is bordered in places by narrow bands of Saddle gneiss which separate the syenite from the Striped Rock granite. There are small inclusions and shreds of Saddle gneiss and Cattron diorite in the Striped Rock granite.

White aplite and pegmatite, related to the granite, have a wide distribution throughout the older pre-Cambrian rocks of the Elk Creek anticline.

The Striped Rock granite weathers to rounded, bare bosses and cliffs. It is well exposed in the gorge of Peach Bottom Creek north of Independence, on the bordering mountain slopes, and in cuts along U. S. Route 21 which follows the creek and crosses the divide between Point Lookout and Buck mountains. It occupies the southern spurs of these mountains and may be seen in the gorges of the streams that head in the mountains and flow south. The "Mole" (Pl. 17A) is a long bare spur of granite that extends south from Striped Rock to U. S. Route 21. A smaller striped cliff, called "Little Striped Rock," occurs east of Striped Rock. North of "Little Striped Rock" is Flat Rock, a small granite dome on the spur of Point Lookout Mountain west of Roaring Branch. The Striped Rock granite forms the crest of Pine Mountain, the eastern spur of Point Lookout Mountain. Two miles east of Indepenendence the granite is well exposed at the falls of Peach Bottom Creek (Pl. 11B). It occupies the southeastern crest and the lower slopes of Buck Mountain north of U. S. Route 58.

Character.—The Striped Rock granite is a medium-grained, light-gray, granular rock containing dark-green biotite in small clots. In places it contains white to flesh-pink microcline phenocrysts. A fine-grained, biotite granite facies occurs locally. White aplite dikes intrude both the coarse-and-fine grained facies.

The medium-grained granite contains 50 to 60 per cent microcline and as much as 20 per cent albite-obigoclase. Microcline may be untwinned, or may show Carlsbad twinning and the characteristic gridiron structure. It is intergrown with crystals of twinned plagioclase. Some of the microcline is perthite in which thread-like striae of plagioclase are intercalated with the potash feldspar. In some cases (Pl. 18A) the microcline is intergrown with plagioclase, in which the twinning lamellae are uniformly oriented so as to suggest an antiperthite rather than a perthite. There is also a development in the plagioclase of chessboard structure.[25] The potash feldspars are veined with clear plagioclase. These features suggest that the high soda feldspar replaced potash feldspar in the granite. The plagioclase crystals are in large part sericitized, and in many specimens the twinned lamellae are bent. Quartz constitutes from 20 to 45 per cent of the rock, and seems to replace the feldspars in places; locally it crosses them in veinlets. It is strained and has cataclastic borders. Mafic minerals, which average about 2 per cent of the rock, include a dark-green biotite as blades and epidote as grains, some of which have cores of allanite. Fluorite is present.

The Striped Rock granite is an alkaline granite in which microcline is intergrown with albite-oligoclase. The tendency of albite-oligoclase to develop chessboard structure and the presence of clear veinlets of albite-oligoclase and quartz, as well as the fact that some of the quartz appears to replace the feldspars, suggest that the rock has been replaced by late soda-rich solutions.

In the smaller masses and on the borders of the main body, where the rock is finer-grained, biotite in finely divided particles is disseminated through it. At some localities it is a white aplite containing scattered masses of green biotite. These finer-grained facies inject and cross cut biotite augen gneiss, the coarser-grained facies of the Striped Rock granite, and the Saddle gneiss.

The fine-grained granite has the same constituents as the coarse-grained facies. Both contain fluorite. The white aplite contains 70 per

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[25] Gilluly, James; Replacement origin of the albite granite near Sparta, Oregon: U. S. Geol. Survey Prof. Paper 175-C, pp. 68, 73, Pl. 22A, 1933.

cent microcline and 25 per cent quartz, and small amounts of sericitized plagioclase and green to brown biotite that has partially replaced skeletal garnet (Pl. 18B). Garnets occur in the aplite where it has intruded the Saddle gneiss. Aplite which has intruded the Cattron diorite is not usually garnetiferous. The Striped Rock granite in the area northwest of Quaker Church, 1 mile northwest of Lundy Knob, is porphyritic, banded with mica, and contains inclusions of biotite gneiss. Porphyritic biotite granite gneiss, which occurs northwest of the main area of the Striped Rock granite along the Point Lookout-Buck Mountain divide was formed by advance solutions of the granite that invaded the older rocks. The porphyritic granite gneiss was later intruded by Striped Rock granite of the equigranular texture and injected and cross cut by fine-grained biotite granite and white aplite with garnet-biotite knots. Figure 3 illustrates these relations. The

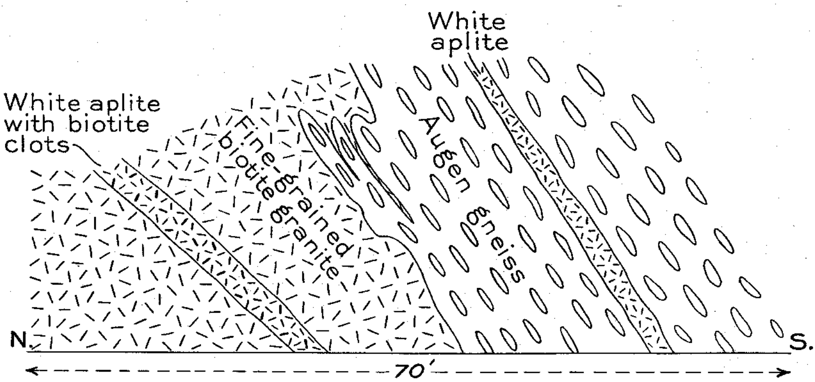

FIGURE 3.—Sketch showing order of intrusions, Striped Rock granite.

porphyritic biotite granite in places northwest of the Striped Rock granite resembles the Beaverdam Creek augen gneiss which is discussed later.

Xenolithic inclusions.—In some places the inclusions in the granite are sharply defined, as seen in the outcrops near Peach Bottom Church, where the granite contains small xenoliths of fine-grained, black, biotite gneiss intersected by thin veinlets of white aplite. These fine-grained xenoliths have a hornfels texture and are composed of fine grains of feldspar and quartz and short blades of biotite and grains of epidote. They appear to have been recrystallized by the magma without the addition of much material. In exposures in the quarry on the northwestern side of the "Mole" (Pl. 17B), the Striped Rock granite shows irregularly shaped inclusions of biotite gneiss (Pl. 19A) which have white microcline metacrysts, bordered by myrmekite. Other constituents are strained quartz, zoisite, epidote, and biotite in crumpled stringers. In an outcrop on U. S. Route 21, half a mile west of the "Mole," fine-and-coarse grained biotite granite has injected and engulfed large and small xenoliths of gneiss and has altered them to a garnet-sillimanite biotite gneiss. (Fig. 4)

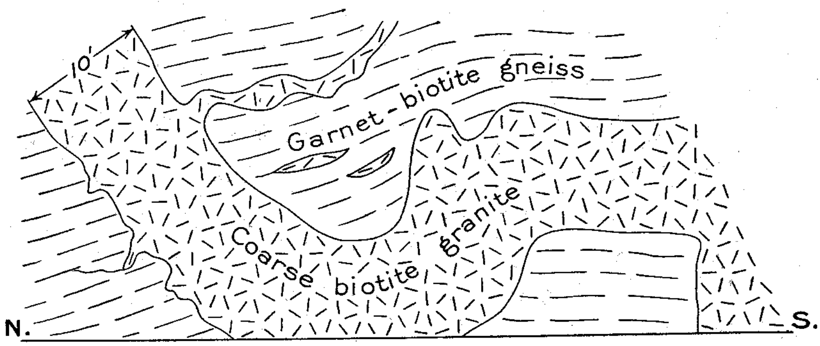

FIGURE 4.—Sketch showing xenoliths of Saddle gneiss injected by Striped Rock granite.

On the spur of Point Lookout Mountain north of "Little Striped Rock," the flat-lying bosses of Striped Rock granite are exposed at altitudes of 3,500 to 4,350 feet (Pl. 2B) and show many included masses. The xenoliths in that area are composed of a dark-gray porphyritic rock with white euhedral feldspar phenocrysts. The xenoliths have an irregular oval shape and have been embayed by the granite. Xenoliths average 2 inches in their longest dimensions, but some are 5 inches long and 3 inches wide (Fig. 5). Since they weather more readily than the granite, they mottle the weathered surface of the granite in dark irregular pits. Similar xenoliths occur in the Striped Rock granite on the south slopes of Buck Mountain.

This section of the xenoliths shows a groundmass composed of fine-grained hornblende, biotite, and labradorite with euhedral feldspar phenocrysts which have sharp crystal outlines. The feldspars contain minute inclusions, are polysynthetically twinned, and have the optical properties of a calcic labradorite. The composition and texture of the xenoliths suggest that they may be an andesite flow whose groundmass was crystallized during the intrusion of the Striped Rock granite.

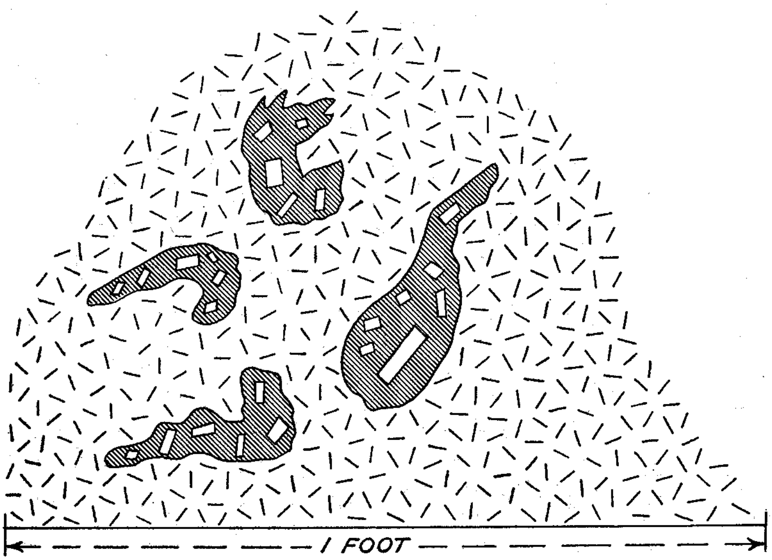

FIGURE 5.—Sketch of porphyry xenoliths in Striped Rock granite.

Syenite facies.—The syenite facies occupies an oval area, 4 miles long and half a mile wide, that extends from a point a short distance northeast of Flat Rock School southwestward to U. S. Route 21. Flat Rock Church near the school (Pl. 18C) is built on a circular boss or pavement of the syenite, which measures about 300 feet across the top.

The syenite is a dark-colored coarse-grained rock with a somewhat gneissic structure. It is composed of white to pink feldspar, green biotite, and hornblende (Pl. 20A). Microcline and albite-oligoclase, in about equal amounts, form 85 per cent of the rock, quartz 5 per cent, and mafic minerals 10 per cent. The microcline is perthitic and is granulated along cracks which are filled by quartz and calcite veinlets. Albite-oligoclase also occurs in fresh twinned crystals (Pl. 20A) and has in part replaced microcline, as in the granite. Green chloritized biotite is derived from hornblende and shows folding. Epidote grains are intergrown with the biotite. In the vicinity of Peach Bottom Church the hornblende is blue and is of the soda-bearing variety hastingsite. Accessory minerals include apatite, titanite, and zircon. A porphyritic biotite granite on the northern border of the syenite at Peach Bottom Church consists of gray microcline-perthite intergrown with crystals of albite-oligoclase and oligoclase-andesine, 50 per cent, and quartz, 35 per cent. The more calcic plagioclase is greatly altered and forms 5 per cent of the rock.

The biotite is red-brown, with rutile network, and the blades are crumpled and associated with epidote, hornblende, apatite, chlorite, ilmenite, and magnetite. The rutile-bearing biotite is of the variety characteristic of the Saddle gneiss and some facies of the Cattron diorite rather than of the green variety that is persent in the Striped Rock granite. The feldspar of the syenite is more calcic than that of the Striped Rock granite.

White pegmatite facies.—White pegmatite, related to the Striped Rock granite, is found in the older pre-Cambrian rocks of the Elk Creek anticline on the southern border of the Striped Rock granite, in the Saddle gneiss and the Cattron diorite on the northwestern side of the granite, near Cattron's Mill and in the granite mass itself, the pegmatite consists almost entirely of soda-microcline, or microperthite, and a small amount of quartz. The feldspar is white to gray, and, where the pegmatite has been deformed, the feldspar is veined by a fine network of albite-oligoclase veinlets. The pegmatite shows a notable absence of muscovite and tourmaline, characteristic of the pegmatites of Paleozoic age in adjoining regions. A fine-grained aplitic phase cuts across the coarser grained pegmatite. In some places, where it has intruded the Saddle gneiss, the pegmatite contains red-brown biotite. The white pegmatite has penetrated the Cattron diorite in a reticulated network in many localities (Pl. 19B). It has permeated both the diorite and Saddle gneiss as thin layers resulting in a banded rock or injection gneiss characterized by close plications. The larger areas of injection gneiss are shown separately on the map (Pl. 1.) as a phase of the host rock. Such injection gneisses have been called "lit-par-lit," "leaf" injection, by Sederholm[26] and others. They are called also arterities or arteritic migmatites, because of the analogy between molten magma of the earth and its passage through small openings in the rocks, and the blood of the body which passes from the heart into the circulating system of the body.

BEAVERDAM CREEK AUGEN GNEISS

General description and distribution.—The Saddle gneiss in this district has not only been injected by white aplite but also has been permeated by granitic solutions related to the Striped Rock granite

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[26] Sederholm, J. J., Gneisfragan och andra uber gaspörmal Geol. Fören.; Stock. Forh., Bd. 30, p. 165, 1908. On migmatites; Bull. Comm. Geol. Finlande no. 58, pp. 92 and 127, 1923; Part II, no. 77, p. 17, 1926.

which recrystallized it into a granite gneiss with microcline metacrysts. A biotite-augen gneiss so derived is here called the Beaverdam Creek augen gneiss from its occurrence on Beaverdam Creek southeast of Independence. It has wide distribution in a belt that extends from Baxter Ferry on New River southwestward to Penitentiary Ford on the same river. Smaller areas are found west of Independence and between Hollow Rock Hollow and Longs Gap and near Quaker Church. In the belt southwest of Baxter Ferry, the biotite augen gneiss is well exposed on U. S. Route 58, on U. S. Route 21 along Beaverdam and Peach Bottom creeks, and in the adjacent stream cuts. There are all graduations from the Saddle gneiss with and without granitic injection to dark-colored, biotite augen gneiss with blue quartz and light-colored granite gneiss with biotite only on the parting planes.

Character.—The Beaverdam Creek augen gneiss is a dark-gray rock banded by red-brown biotite, with coarse gray microcline metacrysts, which are deformed into augen, and blue quartz grains. The biotite is in small bent flakes that wrap around the feldspar and quartz grains. In thin section the texture is crystalloblastic and cataclastic (Pl. 20B). The coarse metacrysts are microcline, veined with quartz and calcite. The quartz is strained. The folded biotite flakes enclose fine epidote grains. The biotite and coarse epidote grains band the rock, and in places the banding bends around lenticular microcline metacrysts. Saussuritized plagioclase with clear albite rims (Pl. 20B) and myrmekite are generally present. Garnet, where it occurs in the gneiss, is in part altered to biotite. Accessory minerals are titanite and apatite.

The Beaverdam Creek augen gneiss owes it microcline metacrysts

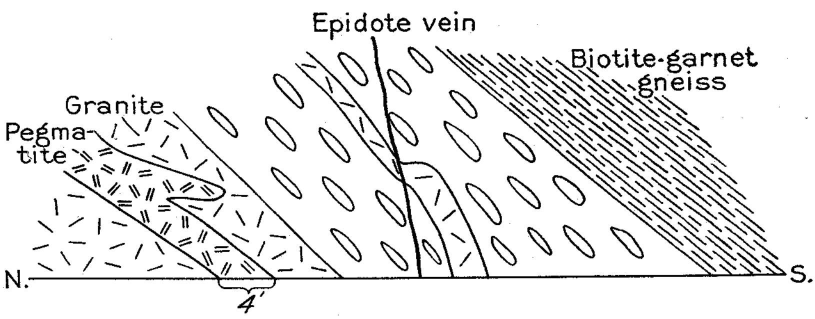

FIGURE 6.—Sketch showing order of intrusion of granite, pegmatite, and epidote vein, Beaverdam Creek augen gneiss.

to the Striped Rock granitic magma whose advance solutions permeated the Saddle gneiss. Later soda-bearing solutions formed clear albite rims about the sericitized plagioclase and developed myrmekite on the borders of the microcline. White granitic pegmatite later intruded the Beaverdam Creek augen gneiss. The relations of the granite and pegmatite in the Beaverdam Creek augen gneiss are shown in Figure 6.

CARSONVILLE GRANITE

General description and distribution.—A narrow belt of fine-grained pink felsitic granite forms the northern border of the Striped Rock granite. It is here called the Carsonville granite from the village of that name located 2 miles north of Baxter Ferry on New River. This granite is inter-banded with a porphyritic biotite granite which has pink microcline phenocrysts, and which is mapped as a part of the Carsonville granite, (Pl. 1). Where the Carsonville granite occurs within areas of the Comers granite gneiss and Grayson granodiorite gneiss it is not mapped separately. The Carsonville granite is exposed on the road near Carsonville, near Mountain View School to the west, on Rock Creek, on Roaring Branch, on a tributary to Saddle Creek, and near the head of little Peach Bottom Creek. On Rock Creek and Little Peach Bottom Creek it contains xenoliths of the Saddle gneiss.

Character.—The Carsonville granite is for the most part a fine grained rock that consists of pink microcline, clear twinned albite-oligoclase, myrmekite, and quartz together with thin partings of biotite and of epidote and chlorite developed from hornblende. The porphyritic facies contain pink microcline phenocrysts. In both the fine-grained and porphyritic facies the microcline is perthitic.

The mafic minerals in the Carsonville granite are less abundant than in the Striped Rock granite. Its microcline is pink rather than white, and it contains a more calcic plagioclase than does the Striped Rock granite.

Pink pegmatite facies.—Pink pegmatite related to the Carsonville granite, occurs widely in the pre-Cambrian rocks of the Elk Creek anticline. The pegmatite is coarse grained and consists largely of pink microcline with small amounts of quartz, hornblende, chlorite, and epidote. In places it has a graphic texture. The pink pegmatite has a fine-grained aplitic phase. The pink color of the microcline results from fine dust-like inclusions of hematite. The pegmatite facies of the Striped Rock granite contains soda-microcline or microperthite, rather than microcline, and does not contain hornblende and chlorite, characteristic of the pink pegmatite. The Carsonville granite and its pink pegmatite facies of this report, are similar in composition to the Air Point granite[27] which intrudes diorite and granodiorite in the western part of the Blue Ridge region in northern Virginia.

Pink pegmatite has metasomatically replaced Cattron diorite in wide zones of alteration in the northwestern part of the Elk Creek anticline. The larger areas of this hybrid rock are mapped separately (Pl. 1). The best exposures are on Jumping Creek (Pl. 10B), Flat Branch, and Farmers Branch, near Hines Church, and east of Fallville (Pls. 20C, 21A, 22A).

Pink pegmatite has penetrated the diorite in wrinkled bands which swell out into irregular bodies that include diorite xenoliths. The diorite contains pink microcline phenocrysts, in part connected with the pegmatite veins. The contacts of the pegmatite with the diorite are gradational. Such a hybrid rock illustrates a stage in the formation of a granodiorite by metasomatic replacement of the diorite by alkaline solutions.

Thin sections (Pl. 22B) of the replaced diorite from State Highway 95, east of Fallville (Pl. 22A), show pink sericitized microcline, saussuritized plagioclase, party replaced by potash feldspar, and myrmekite developed at the contact of the two feldspars. Quartz grains are few. The mafic minerals are green hornblende, green biotite, chlorite, epidote and ilmenite, with borders of titanite, apatite and in some places pyrite. Biotite has replaced plagioclase. The plagioclase has become more sodic and the released lime has gone into epidote. Potash feldspar has replaced the plagioclase feldspar in the diorite. Numerous epidote veins are present in the altered diorite.

These changes become more extensive as the amount of introduced felsic material increases, and, in the areas near Bennington Mill, Flat Branch, and northeast of Longs Gap, pink pegmatite has injected and replaced the diorite to form banded migmatites that grade from a diorite into granodiorite or a pink granitic rock streaked by hornblendic bands. Outcrop areas of pegmatite composed of pink microcline, with scanty quartz-bearing bands and containing large hornblende crystals and veins of prochlorite and epidote, are extensive. The pegmatite contains inclusions of undigested or partially granitized diorite. There

[27] Jonas, A. I., Hypersthene granodiorite in Virginia: Geol. Soc. America Bull, vol. 46, no. 1, pp. 49, 54-56, 1935.

are no sharp boundaries between the various types of injected and replaced diorite and the resultant rocks are mixed in all degrees of intimacy.

Unakite facies.—Unakite occurs as thin layers where the pink pegmatite facies of the Carsonville granite intrudes the Cattron diorite and in rocks discussed later as the Comers granite gneiss and Grayson granodiorite gneiss. Unakite is exposed near State Highway 95 southwest of Spring Valley, on that highway northwest of Fallville, on U. S. Route 21 south of Elk Creek village, and in the vicinity of Big Ridge. It is composed of pink microcline, epidote, and blue or clear gray quartz and varies in the grain size of the feldspar and the epidote content. This rock was named by Bradley[28] from occurrences in North Carolina and Tennessee and has been described in Virginia[29] where it occurs in association with hypersthene granodiorite or hypersthene syenite and pink pegmatite. Phalen considers that unakite is formed by hydrothermal alteration of syenite. Watson and Cline stated that unakite was formed as a differentiation of the syenite and that the epidote is in part of hydrothermal origin. In the region west of Montebello, Nelson County, Virginia, the formation of unakite[30] was described as a hydrothermal replacement of hypersthene granodiorite (syenite) by hot solutions from the Air Point granite pegmatite. The replacing solutions entered the granodiorite along fracture zones and in places thoroughly penetrated the granodiorite and produced all gradations from dark-green granodiorite to pink and green unakite.

RELATIVE AGE OF THE STRIPED ROCK GRANITE AND CARSONVILLE GRANITE

The Carsonville granite intrudes the Striped Rock granite along its northern and western borders. The pink pegmatite facies of the former intrudes the Striped Rock granite and the aplitic and augen gneiss facies of the Striped Rock granite at many places; hence the Carsonville granite is the younger. One of the best outcrops showing the

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28 Bradley, F. H., On unakite, an epidotic rock from the Unaka Range on the borders of Tennessee and North Carolina: Am. Jour. Sci., 3rd ser., vol. 7, pp. 519-520, 1874.

29 Phalen, W. C., A new occurrence of unakite, Smithsonian Misc. Coll. vol. 45, pp. 306-310, 1914.

Watson, T. L., and Cline, J. H., Hypersthene syenite and related rocks in the Blue Ridge region, Virginia: Geol. Soc. Amer. Bull. vol. 27, p. 222, 1916.

30 Jonas, A. I., Hypersthene granodiorite in Virginia: Geol. Soc. Amer. Bull. vol. 46, pp. 50-55, Pl. 4, 1935.

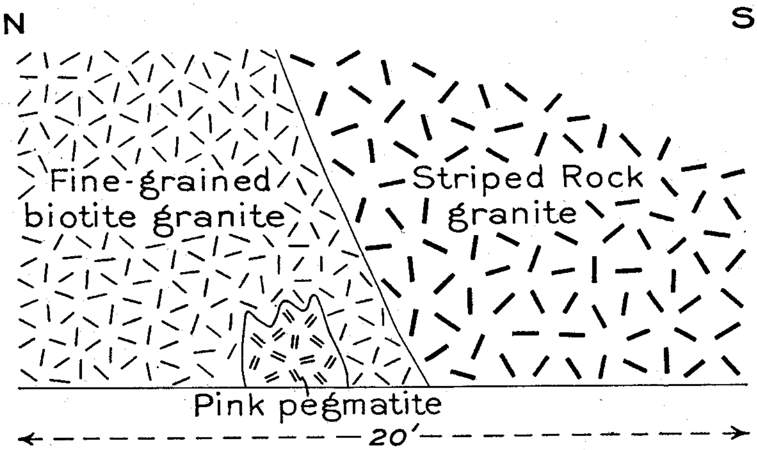

FIGURE 7.—Sketch of pink pegmatite in Striped Rock granite.

relations of the pink and white pegmatites is illustrated in Figure 7, which is a sketch of an outcrop 2 miles south of Longs Gap of U. S. Route 21. Here the equigranular Striped Rock granite is cut by a finer grained white aplitic facies and later by the pink pegmatite facies of the Carsonville granite. Epidote veins are later than the pink pegmatite. In an exposure on State Highway 94, one-fourth mile east of the mouth of Farmers Branch, Cattron diorite is injected by white aplite and this injection gneiss in turn is cut across by a pink pegmatite (Fig. 8). Here

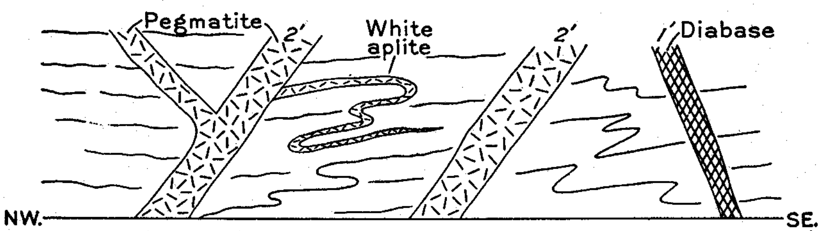

FIGURE 8.—Sketch of Cattron diorite injected by white aplite and later pink pegmatite.

also it is evident the pink pegmatite was intruded later than the Striped Rock granite and related white aplite.

COMERS GRANITE GNEISS

General description and distribution.—The Comers granite gneiss occurs in a wide area in the northwestern part of the Elk Creek anticline, northwest of Point Lookout Mountain, it is here named from Comers Rock village in the northwestern part of the Independence quadrangle. It is well exposed on Elk Creek and its tributaries, south and southeast of Elk Creek village (Pl. 12A), and on Turkey Fork east of Tims Knob. Its massive character is shown in the gorge of Powdermill Creek. The area mapped as Comers granite gneiss (Pl. 1) includes also bodies of pink pegmatite, unakite, Cattron diorite, and injection gneisses too small to be mapped separately.

Character.—The Comers granite gneiss is an equigranular to porphyritic rock which consists of pink microcline and quartz in a greenish-gray matrix composed of chlorite and epidote. In thin section (Pl. 22C) the porphyritic variety is seen to contain 50 per cent flesh-pink microcline, much fractured and veined with calcite and quartz, 15 to 20 per cent albite-oligoclase, and 25 to 30 per cent quartz. The mafic minerals form only 5 per cent of the rock. The albite-oligoclase grains are fractured and sericitized. Myrmekitic intergrowths of quartz and plagioclase border the microcline, which in places includes grains of plagioclase. Quartz usually has a blue color due to fine needle-like inclusions. Chlorite and epidote, in part derived from biotite and in part from hornblende, were observed in most of the thin sections studied. The accessory minerals are apatite and ilmenite.

The Comers granite gneiss contains less mafic minerals than the Carsonville granite, but the two rocks are otherwise similar in mineral content. The Comers granite gneiss is injected with pink pegmatite related to the Carsonville granite. It has a cataclastic texture and gneissic structure. It may be a composite rock formed by a partial replacement of older rocks by the Carsonville granite.

GRAYSON GRANODIORITE GNEISS

General description and distribution.—The Grayson granodiorite gneiss is a porphyritic gneiss of granodiorite composition, which is widely distributed in the Elk Creek anticline. In a paper on the hypersthene granodiorite or hypersthene syenite of northern Virginia the junior author[31] briefly described the Grayson granodiorite gneiss as the Grayson granite gneiss following her usage on the Geologic map of Virginia, published by the Virginia Geological Survey in 1928. Because of its

[31] Jonas, A. I., Op. Cit.: Geol. Soc. America Bull. vol. 46, no. 1, pp. 47-60, 1935.

mineral constitution the gneiss is a granodiorite. The character and extent of the Grayson and its relations to other rocks in southwest Virginia and to the rocks of the northern Blue Ridge of Virginia, were discussed also in the paper just referred to.

This gneiss forms the crest of Point Lookout Mountain, the southeastern spurs of Brierpatch Mountain, and the crest of Buck Mountain (Pl. 3A). It weathers to rounded bosses and spheroidol masses that cover the surface underlain by this rock (Pl. 16C). It is well exposed on State Highway 95 where the road follows Knob Fork, and in the gorge of Elk Creek from its mouth northwestward to Chestnut Flat. At Clito Mill, half a mile north of the point where the Elk Creek highway crosses Elk Creek, the falls in the creek are of the Grayson granodiorite gneiss. Below the falls spheroidal masses of the rock 10 feet in diameter nearly fill the valley bottom.

Character.—The Grayson granodiorite gneiss is a coarse grained porphyritic rock with phenocrysts of pink and red microcline, (Pls. 23A, 23B) in a dark-colored, gneissic matrix of dull-green feldspar, quartz, bronzy biotite, hornblende, and epidote. The rock is much veined with epidote. Quartz grains are of a white to deep blue color. In hand specimens microcline phenocrysts, that range from half an inch to 2 inches in their longest dimension, form euhedral tabular crystals that possess terminal faces (Pl. 23A). In areas where the rock has been deformed, microcline occurs as augen.

In thin section the pink feldspar phenocrysts are seen to be microcline with a prominent grid structure, show Carlsbad twinning, and in part have a perthitic character (Pl. 24A). In some specimens microcline constitutes as much as 80 per cent of the rock. The coarse microcline phenocrysts are irregularly disposed in a groundmass composed of plagioclase, hornblende, biotite, and quartz, with accessory titanite that has an ilmenite core, epidote, and apatite. Plagioclase grains are almost entirely replaced by saussurite and sericite and can be indentified as andesine in only a few of the thin sections which were studied. The plagioclase is bordered by a crush zone that may have been produced in part by chemical granulation due to solution during the introduction of the microcline. Myrmekite, composed of quartz and albite, occurs at the contact of the plagioclase with potash feldspar. The albite is sericitized, showing that the alteration is later than the formation of myrmekite. Microcline contains irregularly shaped inclusions of andesine and mafic minerals. Quartz is in wavy areas and generally is strained (Pl. 24A). The plagioclase (andesine) has clear albite veinlets which extend into the potash feldspar. The mafic minerals are green hornblende and red-brown biotite which has a network of rutile needles. The hornblende has been altered to biotite and epidote. and these in turn commonly are altered to chlorite and calcite. The rock has been deformed since crystallization, as is indicated by the granulation of quartz, feldspars, and apatite and the folding of the biotite and chlorite flakes (Pl. 24A).

The average mineral composition of the gneiss is that of a granodiorite, but the field relations and texture do not indicate that the rock was formed by the intrusion of a granodiorite magma. The granodiorite gneiss is interbanded with fine-grained granite and also is injected by pegmatite and aplite (Fig. 9). In places it shows an equigranular facies

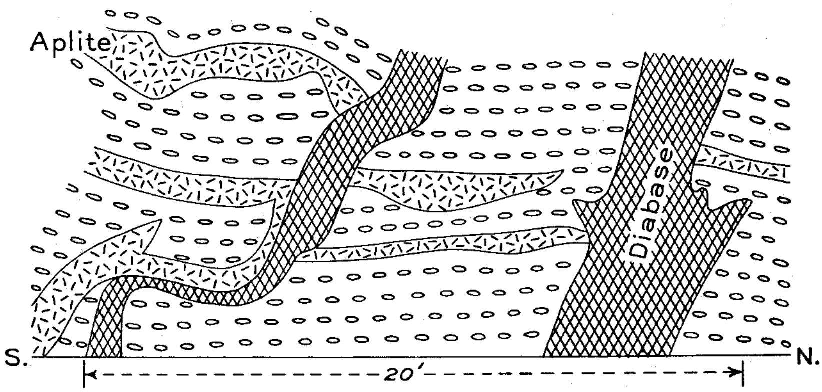

FIGURE 9.—Sketch showing Grayson granodiorite gneiss injected by aplite and diabase of Mt. Rogers Volcanic series.

which resembles the rock formed by replacement of the Cattron diorite by pink pegmatite and aplite. It also contains unakite which is believed to have been formed by hydrothermal replacement.

It is evident that the large microcline crystals did not form as early crystallizing phenocrysts since they replace and include minerals of the groundmass and are less deformed than the groundmass and the larger plagioclase grains of the gneiss.

It seems probable that the coarse pink microcline crystals are metacrysts, which replaced a diorite, and that the potash-rich solutions which formed the microcline also sericitized the plagioclase of the diorite, and later the albite of the myrmekite. The epidotization of the rock, and its alteration to unakite, occurred as a result of these replacement reactions. Because of the character of the microcline and the association of granite and pegmatite with granodiorite gneiss, it is concluded that the replacing solution are related to granite and that it is a granodiorite formed by metasomatic replacement.

The occurrence of porphyritic granite, granodiorite, and augen gneiss, formed by metasomatic replacement, has been described from many other places. Agar considers that the Danbury granodiorite gneiss[32] has such an origin. Buddington[33] regards most of the Hermon porphyritic granites in the Adirondacks as a product of metasomatic replacement of older rocks.

SHOAL GNEISS

General description and distribution.—The area mapped as Shoal gneiss is located in the extreme southwestern part of the district. It extends from Beaverdam Creek, south of Independence, southwestward to the edge of the map, south of New River. The area lies largely south of U. S. Route 58.

Deformation of the Shoal gneiss and associated rocks has resulted in the cataclasis (crushing) of quartz and feldspar, the shredding out of micas, and the recrystallization of feldspar and the mafic minerals to muscovite, green biotite and chlorite. These metamorphic effects are variable in degree in the different belts. The character of the resultant rock depends on that of the original rock affected. They include Saddle gneiss, Cattron diorite, injection gneisses, Grayson granodiorite gneiss and Beaverdam Creek augen gneiss types which are not separately mapped (Pl. 1).

Character.—The Shoal gneiss in the belt south of U. S. Route 58 and south of Shoal Creek and New River, between the mouths of Saddle and Bridle creeks, is a fine-grained, banded gneiss containing quartz and feldspar porphyroclasts. Along the partings occur sericite with a silvery sheen. Sericite schist is interlayered with the porphyroclastic gneiss. Such rocks are well exposed on Beaverdam and Peach Bottom creeks, on U. S. Route 21 south of Independence, and in stream and road cuts to the west. On the uplands they weather to a micaceous clay soil containing sericitic fragments. In some thin sections of the Shoal gneiss the feldspars appear as lens-shaped bodies with inclusions of blue quartz.

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[32] Agar, W. M., Notes on the Danbury granodiorite gneiss of Connecticut: Am. Jour. Sci., 5th. Ser., vol. 25, pp. 4-5, 1933.

[33] Buddington, A. F., Adirondacks igneous rocks and their metamorphism: Geol. Soc. America, Memoir 7, pp. 160-171, 1939.

Microcline when present is drawn out and broken. The plagioclase is sericitized and penetrated by veinlets of chlorite, quartz, and epidote. In other thin sections the feldspars are clear and without inclusions. The lenses of felsic material are wrapped about by schistose layers of sericite, green biotite, and epidote. The accessory minerals which are apatite, titanite, and allanite, show effects of crushing. Biotite is shredded and smeared out.

In places along Beaverdam and Brush creeks, near Penitentiary Hill and northward, and in Privett Knob, the Shoal gneiss is a dark-colored biotite mylonite schist in which the biotite along the foliation planes is shiny, and the surfaces are grooved in the direction of the movement. In thin section this biotite is of a green color and occurs in fine shreds that wrap around lenses of crushed rock composed of quartz and feldspar.

The predominant type of Shoal gneiss between New River and U. S. Route 58 and west of Saddle Creek is a greenist-gray schist with blue quartz grains and coarse flesh-colored microcline. A polished specimen and photomicrograph of this rock are shown in Plates 24C and 24B. In Plate 24B the border of the microcline crystal is formed by a zone of fine-grained quartz. The cataclastic matrix of the rock exhibits a schistose structure oriented at right angles to the border zone of the microcline. It seems probable therefore that the border zone represents a crush zone along which the rock was replaced by microcline rather than a zone of later cataclasis. Myrmekite, which embays the microcline, belongs to this period of replacement and has not been destroyed by the later regional cataclastic deformation. A similar augen gneiss, which occurs near Mouth of Wilson, is illustrated in Plate 25A. It resembles the "flaser gneiss" figured by Buddington[34], who described the quartz of the "flaser Gneiss" as neomineralized in large leaves, each leaf of which has a uniform extinction under crossed nicols.

The schist and augen gneiss facies of the Shoal gneiss in the region south of Bridle Creek contains blue quartz. Under the microscope quartz is strained and granulated, microcline porphyroclasts contain inclusions of plagioclase, veins of chlorite, quartz, epidote, and calcite. The foliation layers consist of hornblende, chlorite, muscovite, and epidote. Apatite is crushed and drawn out along the foliation. Some of the plagioclase has inclusions of quartz.

Small areas of amphibolite which may represent metamorphosed Cattron diorite, and are so designated on the geologic map, are exposed

[34] Op. Cit., Geol. Soc. Amer. Memoir 7, Pl. 13, fig. 1, p. 290, 1939.

in the Shoal gneiss 1½ to 2 miles southwest of Independence on Brush and Beaverdam creeks. The southern band of amphibolite extends southwestward to a point three-fourths mile northeast of Bethany Church. A narrow band occurs half a mile north of Cox Chapel south of New River. The amphibolite is a fine-grained green schistose rock cut by quartz and epidote veins and made up of hornblende, chlorite, and lenses of altered plagioclase. In places it grades into actinolite schist veined with asbestos.

Origin: The Shoal gneiss, as shown by the thin sections described above, was formed by the mylonitization (crushing) and neomineralization (later crystallization) of biotite and feldspathic rocks, probably the Saddle gneiss, injection gneiss, and Beaverdam Creek augen gneiss. The green biotite, epidote, chlorite, and sericite were formed by the shearing out and alteration of an original red-brown biotite. This mineral change is retrogressive in that the red-brown biotite is of higher metamorphic rank than the green chloritized biotite present in the Shoal gneiss. A part of the Shoal gneiss may include igneous or metamorphosed sedimentary rocks of early pre-Cambrian age which do not occur in the Elk Creek Anticline north of the Shoal gneiss. The deformation and retrogressive changes may be early pre-Cambrian in age and thus are not related to the late Paleozoic deformation that mylonitized the rocks on the sole of the Fries thrust discussed later.

THE ORIGIN OF THE INJECTION COMPLEX

The oldest rocks of the injection complex in this district are composed of meta-sedimentary and meta-igneous rocks intruded and reconstituted by two periods of granite intrusions, the Striped Rock and the Carsonville granite.

The meta-sedimentary rocks described as the Saddle gneiss are biotite-garnet-sillimanite-microcline gneiss, garnetiferous quartzite and a graphite-bearing facies. The Saddle gneiss was altered from siliceous shale and the presence of graphite suggests that the shale series may have included dolomitic beds.

The hornblende-biotite-andesite gneiss, called the Cattron diorite in this report, and the associated amphibolite which are interlayered with the Saddle gneiss have been assumed, in this report, to be of igneous origin. The Cattron diorite and amphibolite show no evidence of intrusive relations to the Saddle gneiss. Therefore it is impossible to determine whether they should be classed as igneous rocks or reconstituted dolomitic layers in the gneiss.

The texture of the porphyritic andesite which occurs as xenoliths in the Striped Rock granite on the south side of Point Lookout and Buck mountains proves that the andesite is a volcanic rock present in the oldest rocks of the district. The Grenville Series of the Adirondacks and Canada is a metamorphosed sedimentary series which closely resembles the old series in the Elk Creek anticline. It can be demonstrated that the hornblende-andesine-amphibolite and other mafic types of the Grenville Series have been derived from dolomitic beds in the silliceous shale series.

In the Elk Creek anticline no residual body of limestone has been found, but marble occurs to the west in a narrow belt that crosses Little Wilson Creek 1 mile southwest of Grant. White pegmatite containing hornblende intrudes the marble. Black hornblende prisms, some 3 inches long and half an inch across, are present in this marble, which is made up of coarse-grained pink and white calcite and scales of brown phlogopite. The rock is streaked by bands of fine, green chlorite scales. The marble contains rounded nodular masses of amphibolite composed of quartz, hornblende, and calcite formed by the thermal alteration of the limestone. No garnets or lime silicate minerals common to thermally altered rocks were noted. It is possible therefore, that the hornblende diorite, which occurs northwest of the marble area, may have been derived from the recrystallization and replacement of the adjoining marble, and the Cattron diorite and amphibolite in the Gossan Lead district may have a similar origin.

The Striped Rock granite appears to be a concordant injection that was intruded into the older rocks of the Elk Creek Anticline parallel to the regional structure during a period of folding. The granitic material entered along foliation planes that offered slight resistance, in both the sedimentary rocks and the diorite, to form a composite rock (migmatite).

Advance solutions of the magma of the Striped Rock granite replaced parts of the invaded rock to form a porphyritic gneiss containing microcline metacrysts. Granite pegmatite material then permeated the older rock to form an injection gneiss which had been closely folded in places, as in a zone on the south side of the Striped Rock granite in the area west of Independence, north of Elk Creek village, and in the vicinity of Spring Valley. Xenoliths were preserved where the temperature of the magma was too low to assimilate the blocks. That there was considerable assimilation of the country rock is shown by the occurrence of hybrid rocks (migmatites). The blocks of country rock were elongated by flowage parallel to the main body of the Striped Rock granite the form of which is bluntly lenticular. In the Striped Rock granite and related pegmatite there is evidence of the action of soda and silica bearing solutions of late emanations which acted to some extent on the crystallized rocks to produce replacement. The Striped Rock granite was intruded during a period of folding and the metamorphism was both contact and regional. The minerals formed in the gneisses indicate that the metamorphism was of a high grade. At some later date in early pre-Cambrian time the Carsonville granite and pegmatite permeated this older series by metasomatic replacement and formed migmatities of variable composition. At some localities pink aplite with sharp boundaries cut across the older foliation (Pl. 21B) but for the most part the pink pegmatitic material penetrated the older rocks along earlier structures.

AGE OF THE INJECTION COMPLEX

The intrusive rocks of the injection complex do not penetrate the two younger overlying series of rocks, namely the Mount Rogers volcanic series and the Unicoi formation. The rocks of the injection complex were folded and metamorphosed during the intrusion of the Striped Rock granite. The overlying volcanic series and Lower Cambrian rocks are but little metamorphosed and their structural trends are discordant to the primary structures of the Striped Rock and Carsonville granites. Dike rocks of the Mount Rogers volcanic series cut across the trends of the injection complex (Fig. 3). The injection complex is much older than the Lower Cambrian rocks and the Mount Rogers volcanic series. For these reasons the age of the complex is assigned to the early pre-Cambrian.

GRANITE MYLONITE

General discription and distribution.—The Fries overthrust is bordered on the southeast by a zone of mylonite, about a mile wide, that extends for a distance of 20 miles from Crooked Creek southwestward to the State line. This zone contains both granite mylonite and quartzose mylonite (Pl. 1) formed by cataclastic deformation and recrystallization of rocks of the injection complex on the sole of the overthrust. The best exposures are along New River northeast of Fries, along State Highway 94 west of Fries, and in the cliff 200 feet in height on the south side of the river south of the dam at Fries. Good exposures are also found at a point where New River cuts across the strike of the mylonite east of the mouth of Elk Creek. At this point New River flows through a gorge with cliffs 100 to 200 feet high, and outcrops are easily accessible only where the river is followed by a road or the railroad. Granite mylonite is found also on John and Brush Creeks.

Northeast of Stoneman Hill, from Chestnut Creek to Shorts Creek, the zone of granite mylonite is greatly narrowed. Between Crooked Creek and Shorts Creek the mylonites in the Fries block have been overridden by the Lynchburg gneiss. The mylonite and the augen gneiss are well exposed on Little Reed Island Creek and its tributary, Rock Creek.

Character.—The granite mylonite is a slaty-looking schistose rock with small pink porphyroclasts of feldspar visible on planes that cross the foliation. The layered surfaces are grooved along the plane of movement, and in places, as on Johns Creek, the layered mylonites are closely folded. In the outcrops on State Highway 94 north of Fries, the granitic layers of injection gneiss have been squeezed into discontinuous lenses which are enclosed in schistose mylonite layers (Pl. 25B) that have a 20° dip to the southeast. In some facies of the granite mylonite the feldspar porphyroclasts occur as small white grains in a gray thin-layered schistose matrix.

Thin sections near the sole of the Fries overthrust reveal that feldspar grains have been granulated on the borders of granite mylonite, and have assumed lenticular shapes (Pl. 26B). The cataclastic borders of these augen are composed of microperthite, while the feldspars themselves probably represent fragments of larger feldspar grains. The minerals in the crush zones are enclosed in a matrix of fine felty fibers of sericite, chlorite, and fine grains of epidote and quartz. In the more slaty bands the phenocrysts have been entirley ground out, and the feldspar remnants are discernible only with high magnifications. In the zone of the Fries overthrust, mylonite formed from diorite, occurs in places with the granite mylonite. Mylonites produced from diorite may be recognized by the abundance of epidote which was derived from original plagioclase. Other minerals include biotite, chlorite, titanite with ilmenite cores, apatite, and zircon.

On the south border of the Fries overthrust, near Sylvatus, there was found a layered, grayish-green mylonite schist which resembles the mylonite schist that occurs southwest of Fries. East of Round Knob School occurs a green crinkled muscovite mylonite schist which contains residual pink feldspar in small grains. Similar mylonite schists occur on the north border of the granite mylonite area. The central part of the granitic area, north of Sylvatus, is formed by a pink and green augen gneiss exhibiting a prominently layered structure formed by green hornblende, twisted biotite, and epidote grains. The microcline here is deformed and the quartz is strained. This rock appears to be the Grayson granodiorite gneiss that has been considerably deformed but has not reached the stage of a mylonite which crops out south of it along the Fries overthrust.

QUARTZITE MYLONITE

General description and distribution.—From the vicinity of Pleasant Grove School northeastward to Stoneman Hill, quartzite mylonite forms narrow bands within the granite mylonite (Pl. 1). Quartzite mylonite is well exposed in a headland on the south side of New River south of the junction of State Highway 94 with U. S. Route 58, and on both of those roads near their junction (Pl. 26A). Quartzite mylonite is a grayish-white, compact, thinly banded, straight-layered rock. It consists principally of quartz which occurs in grains too fine to be recognized in the hand specimen. Such a thinly banded dense rock is considered to be an ultramylonite. In places this quartzite mylonite is interlayered with lenticular bands of a sericitic mylonite schist.

Character.—Thin sections of the quartzite mylonite (Pl. 26C) show that it is made up principally of a brecciated quartz and to a less extent of feldspar grains in layers of sericite. Remnants of apatite, titanite, and zircon were seen in some sections. The original composition of this mylonite appears to have been that of a quartzose arkose. Northeast of the mouth of Elk Creek the Fries overthrust has overridden an arkosic quartizite of the Unicoi formation and it is here suggested that the quartzite mylonite in the Fries block to the south may be slices of the Unicoi formation involved in the overthrust movement.

OTHER MYLONITES

General description and distribution.—The pre-Cambrian rocks northwest of Point Lookout Mountain have been mylonitized in several zones of movement. These zones are discontinuous and vary in width from 50 to 100 feet. Only the largest are shown on the geologic map (Pl. 1). A shear zone at Longs Gap, northwest of Independence exposes granite mylonites. East of the gap mylonite in this zone is a layered flinty gray rock with narrow bands and eyes of clear pink feldspar which occur in a fine-grained groundmass composed of shattered fragments of the original feldspars cemented by secondary quartz. In some places the shear planes are covered by thin films of fluorite.

In several localities near Kingdom Hollow, on the northeast spur of Point Lookout Mountain, the Grayson granodiorite gneiss has been converted to a dark-green mylonite schist with residual masses or eyes of pink feldspar. The epidotized plagioclase has been smeared out into green lenses. Half a mile north of Elk Creek village a mylonite occurs in a zone 3 miles long. The mylonitized rock is a quartzose phase of the Saddle gneiss which has been crushed to a white, quartzose mylonite with sericite partings. In places it contains grains of blue quartz and slaty layers of sericite.

Where the sills and dikes of younger pre-Cambrian rhyolite porphyry are mylonitized, as at Rudy School south of Tims Knob, and south of Longs Gap, the rock becomes a quartz-sericite schist. Mylonitized pre-Cambrian diabases occur as fine-grained, chlorite-hornblende schists.

MOUNT ROGERS VOLCANIC SERIES

General statement.—The early pre-Cambrian injection complex in the Elk Creek anticline is overlain unconformably by a volcanic series of younger pre-Cambrian age. This volcanic series is named the Mount Rogers series from its occurrence on Mount Rogers (5,720 feet), the highest peak in Virginia, located on the Smythe-Grayson counties line 16½ miles west of the western boundary of the Gossan Lead district.

The Mount Rogers series in the Gossan Lead district comprises, in descending order, rhyolite, the Flat Ridge formation including the Cornett basalt member at the base, and the Cinnamon Ridge member near the base. The formations are named from localities west of the Gossan Lead district. The Flat Ridge formation is named from the village of Flat Ridge which is located in Grayson County 5 miles west of the district mapped. The Cinnamon Ridge member receives its name from Cinnamon Ridge, 1 mile west of the district, and the Cornett basalt member is named from Cornett Store, (erroneously named Cornell Store on mouth of Wilson quadrangle), 3 miles southwest of Cinnamon Ridge (Pl. 60).

General description and distribution.—The Mount Rogers series occurs in small areas in the western part of the Gossan Lead district where it is made up largely of sediments, tuffs, and rhyolite. The location of these formations and members is somewhat generalized on the geologic map (Pl. 1). Their location is shown in some detail on Plate 60, as well as their relations to the relatively larger areas of these formations in the region west of the district.

Small areas of these rocks are exposed northwest of Elk Creek village, in the vicinity of Comers Rock village, and southwest of Bennington Mill. Diabase and rhyolite, which are genetically related to the rocks of this series, occur as dikes throughout the northern part of the Elk Creek anticline from Comers Rock village eastward to Liberty Church and are particularly numerous in the vicinity of Stevens Knob.

A section of the Mount Rogers series, which occurs in the north central part of Grayson County, is as follows:

GEOLOGIC SECTION 1.—ON COMERS ROCK BRANCH, NORTH OF COMERS ROCK VILLAGE, GRAYSON COUNTY, VIRGINIA

	Thickness Feet
Rhyolite porphyry with many coarse red feldspar phenocrysts, in part flow banded	500±
Flat Ridge Formation	
Crumbly arkose, and coarse pebbly arkose	100
Red shaly tuff and coarse feldspathic spotted tuff and coarse grained feldspar-quartz tuff with pinite and with thin rhyolite flows	200±
	800±
Injection Complex	

Half a mile to the west of Comers Rock branch the Cinnamon Ridge member is present near the base of the section. In the section on Wolfpen Branch, northwest of Comers Rock village, the volcanic series is much thinner and is overlain by the basal Cambrian Unicoi formation.

FLAT RIDGE FORMATION

General description and distribution.—The Flat Ridge formation, is composed of volcanic agglomerate and conglomerate, arkose, tuffaceous slate, and basalt. In the vicinity of Comers Rock village it caps low hills and ridges and overlies older pre-Cambrian rocks, chiefly the Comers granite gneiss. The formation is exposed at several places on the roads east and north of Comers Rock village, along the headwaters of Comers Rock and Wolfpen branches and their tributaries. The Cornett basalt member, generally occurs at the base of the formation. Volcanic agglomerate, flow breccia, and thin basalt flows, that lie above the base, form the Cinnamon Ridge member.

South of the Trent Cove normal fault quartzose sediments overlie the Flat Ridge formation and in part replace it. These sediments cap several high hills between Vaughan and Comers Rock branches and southwest of Bennington Mills. West of Comers Rock Branch, the Cinnamon Ridge member of the Flat Ridge formation makes a more-or-less continuous ridge that extends from the Comers Rock-Blue Spring Gap road (Pl. 60) westward beyond the Gossan Lead district where it caps Cinnamon Ridge also.

The Cornett basalt member is not always present at the base of the formation in the Gossan Lead district. Its distribution is shown in Plate 60. The basalt, generally present north of the Trent Cove normal fault, is absent or very thin in most places south of that fault. On the Comers Rock-Blue Spring Gap road, northwest of Comers Rock village, a narrow band of the Cornett basalt, at the base of the Flat Ridge formation, trends north from the Trent Cove normal fault to the foot of Iron Mountain, and then trends eastward, and has been traced along the slope of the mountain for 2 miles (Pl. 60). The overlying beds of the Flat Ridge formation thin out at Wolfpen Branch, and for about half a mile eastward the basalt is overlain by rhyolite, which in turn thins out east of Wolfpen Branch. East of the rhyolite, the Cornett basalt member is overlain by the quartzose sediments.

The Cornett basalt member forms a high hill southwest of Union Church on the Comers Rock-Elk Creek road. A thin layer of this basalt and purple tuff occurs in places along the border of the outlying areas of quartzose sediments southwest of Bennington Mill and also southeast of Comers Rock School. East of Comers Rock village, in the vicinity of Round Mountain, these sediments overlie Cornett basalt.

Character.—The main part of the Flat Ridge formation in this district is composed of purplish-red feldspathic tuff, purplish-red shale, and purple arkose. In places the tuffaceous layers are conglomeratic; at some localities thin layers of this tuff have been replaced by apple-green pinite; in other places the tuff is a buff sericitic slate. The purplish-red shale sometimes has flattened green amygdules (Pl. 27A). The formation contains also thin, current-bedded arkosic layers that are made up of grains of glassy quartz and pink feldspar. These arkosic beds are exposed on the road just east of Comers Rock village. Purple-banded quartzite, with layers of red jasper and interbedded purplish-red shale, occurs in many places. Massive beds of arkose without apparent bedding overlie the granite at the base of the formation. A conglomerate, which is composed of granite boulders as much as 10 inches in diameter, and of smaller fragments of rhyolite and quartz in a dark-colored arkosic matrix, forms the base of the formation just west of Cinnamon Ridge. Because of the variable character of the formation, no general section could be given. On the hill 1 mile north of Union Church the formation was estimated to be 150 feet thick. On Comers Rock Branch, north of Comers Rock village, the thickness of the purple and red-spotted tuffaceous shale (Pl. 27A) underlying the rhyolite flows, representing the Flat Ridge formation, was estimated to be 250 feet.

The agglomerate and tuff of the Flat Ridge formation have been silicified and replaced by chalcedonic quartz. Silicification by red jasper has been accompanied by the hydrothermal alteration of potash feldspar to pinite, which is an apple-green crypto-crystalline form of sericite. The pinite occurs in lenticles that have been sheared and drawn out.

Cornett basalt member.—The Cornett basalt member is a green amygdaloidal basalt flow, or series of flows, whose vesicles are filled by quartz and epidote. In some places a few feet of a green quartzite occur at the base. West of Cornett Store, the member contains beds of purple and green tuffaceous slate.

Cinnamon Ridge member.—The Cinnamon Ridge member, which occurs west of the Comers Rock-Blue Spring Gap road and northwest of Comers Rock village, lies above the base of the Flat Ridge formation. (Pl. 60). It consists of a blue dense basalt, with veins of epidote and red jasper, a green amygdaloidal basalt with epidote-filled vesicles, and a tuff. These are underlain by an agglomerate and a flow breccia containing angular blocks of purplish-blue, flow-banded, vesicular basalt, of red rhyolite, of red jasper, and of granite, in an epidotic groundmass.

These rocks cap Cinnamon Ridge, where the section is approximately as follows:

GEOLOGIC SECTION 2.—ON CINNAMON RIDGE, MOUTH OF WILSON QUADRANGLE, GRAYSON COUNTY, VIRGINIA

	Thickness Feet
Flat Ridge formation	
Cinnamon Ridge member (190±)	
3. Purplish-red rhyolite tuff with bands of red slate, blue andesitic flow with amygdules filled with chlorite and white chalcedony, and coarse tuff with white feldspar fragments; contains much red jasper near base	140±

2. Tough dark purplish-blue and green dense basalt and fine-grained green basalt, in part amygdaloidal, interbedded with agglomerate and flow breccia composed of blocks of purple rhyolite basalt, epidote, jasper, and granite.......................... 50±

Lower part of Flat Ridge formation

1. Purple and green tuff with flattened green blebs and pink feldspar fragments...................................... 100±

Granite of the Injection complex

A similar section of these rocks is exposed on a south spur of Iron Mountain east of the headwaters of Elk Creek. Gently dipping beds of basalt and associated flow breccia and agglomerate of the Cinnamon Ridge member cap this spur. The agglomerate is underlain by 3 to 10 feet of purple tuff. The underlying Comers granite gneiss is exposed on the east side of the spur and on the top of the spur, where the tuff locally is absent. Eastward the Cinnamon Ridge member forms a distinct ridge. The agglomerate is of a bluish purple color and weathers to rough irregular blocks. It is composed of angular fragments of a dense, purplish-blue rhyolite, of granite and of flattened blebs of pinite, in a groundmass of jasper and fine-grained rhyolite. Some of the finer grained layers contain glassy quartz grains. The volcanic flows are green, blue, and red colored. They contain abundant amygdules filled with white quartz, white chalcedony, and pinite. In the red flows the fillings are in concentric bands, which are composed of a narrow border of dark-red jasper with white, quartz-filled centers. The purple flow contains dark green chalcedony fillings. The fine-grained flows are banded with jasper.

The presence of a considerable thickness of agglomerate and volcanic breccia and associated thin flows, which cap the two spurs of Iron Mountain, as just described, may indicate a near-by vent as the source of some of the volcanic rocks of the Mount Rogers series. If so, the angular blocks of granite contained in the agglomerate may have been torn from the walls of the volcanic vent during the explosion.

QUARTZOSE SEDIMENTS

General description and distribution.—From Wolfpen Branch eastward where the volcanic series is thin, quartzose sediments replace most of the Flat Ridge formation. These sediments have not been named. They cap hills northeast of Union Church, southeast of Comers Rock village and southwest of Bennington Mill. To the east they form Round Mountain and several spurs and narrow ridges that extend southwest to the Elk Creek-Comers Rock road. In places they overlie the Cornett basalt and thin beds of tuff, elsewhere they rest directly on granites of the injection complex.

Character.—The quartzose sediments are made up of green to gray arkose, quartzite, and white conglomerate. The coarser conglomerates have rounded pebbles of quartz that measure one inch in diameter. The formation locally contains beds of a bluish-black, granular sandstone which, near the Trent Cove normal fault. is silicified to a quartzite.

West of the Gossan Lead district the Flat Ridge formation thickens greatly. The arkose above the purple tuffaceous beds and red shale attains a thickness of several hundred feet. It contains beds of conglomerate with rounded white quartz pebbles, some of which are 6 to 8 inches in length. The purple tuffaceous beds in the lower part of the volcanic series contain tuffaceous and arkosic layers (Pls. 28A-28B) and some beds that are rhythmically banded with buff layers (Pl. 29A). From Troutdale, westward, red conglomerate near the base of the volcanic series contains round and subangular cobbles and boulders of granite that measure as much as 10 inches in diameter. (Pls. 30 and 31A). Beds of coarse volcanic breccia also are present (Pl. 28C).

RHYOLITE

General description and distribution.—The rhyolite, which underlies large areas west of the Gossan Lead district, is exposed only in the northwestern part of the district. It overlies the Flat Ridge formation. The largest area of rhyolite lies south of the Trent Cove normal fault and northwest of Comers Rock village. It is best exposed just east of the Blue Spring Gap road in Comers Rock Branch (Pl. 60), where it accounts for the falls and rapids in the gorge of the stream. Fresh rock is exposed in a quarry along the branch, where its thickness is estimated to be 500 feet. The rhyolite is well exposed also in a small ravine west of the Blue Spring Gap road and in the headwaters of Elk Creek, just west of the Gossan Lead district.

Another rather large area of rhyolite occurs on the Blue Spring Gap road in the Rural Retreat quadrangle which extends eastward across Wolfpen Branch. It is only 40 feet thick at the stream and ends abruptly east of the stream. Other small outcrops of rhyolite are shown on Plate 1. The former extent of the rhyolite is shown in Figure 10.

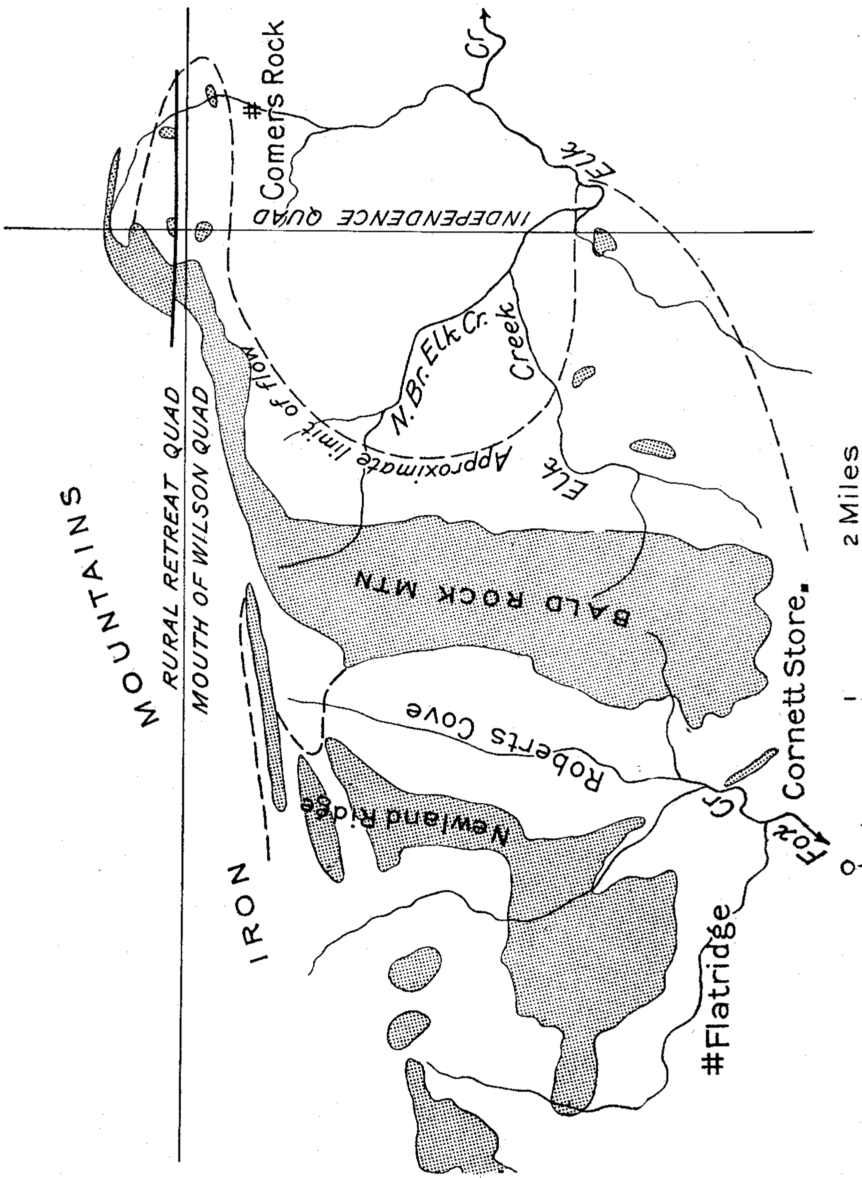

FIGURE 10.—Sketch map showing former extent of rhyolite.

Character.—Rhyolite, in this district, is a purplish-red, fine-grained rock, with and without phenocrysts of euhedral pink feldspar and anhedral quartz. The rock shows flow-banding in many places. The rhyolite near the base of the flow, is of a bluish-purple color and microcrystalline texture. Adjacent to the normal faults it contains veins of jasper, chalcedonic quartz, epidote, and asbestos. The rock is much jointed, and the joint surfaces are highly slickensided. A flow-banded, vesicular red facies, with vesicles filled by chalcedonic quartz and epidote, forms the flows in the area south of the Trent Cove normal fault, which extends from the Comers Rock-Blue Spring Gap road westward to Elk Creek. These red vesicular flows, interbedded with red tuffaceous slate, grade westward and eastward into a red porphyritic facies. North of the Trent Cove normal fault the rhyolite is a reddish-purple porphyritic facies and in part a fine-grained blue facies.

As seen under the microscope the porphyritic facies consists of euhedral phenocrysts of potash feldspar set in a cryptocrystalline groundmass of quartz and orthoclase stained red by hematite. The quartz grains are angular. The feldspar phenocrysts are dusted with hematite. The rock is cut by hematite veinlets and thin veins of quartz, calcite, and epidote.

Rhyolite flows, similar in character to those which occur in the Gossan Lead district, extend southwest of the district to the vicinity of Troutdale. West of that town in the larger area of the volcanic series that forms Stone Mountain, Mount Rogers, and Whitetop Mountain, there is a thick series of rhyolite flows of varying character. The youngest, which forms Mount Rogers, is a purple-red porphyry that resembles the flows in the area from Troutdale northeastward. Some of the older flows near Mount Rogers are in part spherulitic (Pl. 27B) and other flows contain lithophysae (Pl. 27C). The spherulitic facies is a mottled, red and white rock in which the red color is due to hematite. Thin section (Pl. 31B) of polished specimen figured in Pl. 27B shows the spherulities to be composed of a crystalline aggregate of quartz and feldspar in a fine groundmass strained with hematite and to contain anhedral phenocrysts of quartz and feldspar.

RELATION OF THE MT. ROGERS VOLCANIC SERIES TO THE INJECTION COMPLEX AND THE LOWER CAMBRIAN

The Flat Ridge formation, which lies at the base of the Mount Rogers volcanic series in the Gossan Lead district and in the areas to the west, overlies the Comers granite gneiss, injection gneisses, and the

Saddle gneiss. These formations are part of the injection complex of earlier pre-Cambrian age. Contacts of the basal volcanic beds with the underlying granitic rocks may be seen on the Comers Rock-Blue Spring Gap road northwest of Comers Rock village, where the volcanic rocks dip gently north or west away from the granite, and in the hills southeast of that village. One and one-half miles southwest of Bennington Mill, on a road along Elk Creek, the volcanic rocks are gently folded and the granite beneath them is exposed in gentle anticlines.

The conglomerate in places at the base of the volcanic series contains pebbles and large boulders of the granitic rocks. West of Cinnamon Ridge these boulders measure 10 inches or more in diameter. The volcanic breccia and agglomerate of the Cinnamon Ridge member contain angular fragments of granite. At a similar horizon, west of Troutdale, a red conglomerate contains round pebbles and large boulders of granitic rocks (Pls. 30 and 31A) and fragments of the Cattron diorite. It is evident that the rocks of the injection complex were part of the bedrock whose erosion contributed fragments to the conglomerates and volcanic breccias.

The variable thickness and varied character of the basal beds of the volcanic series and their irregular distribution, and also small outcrops of granite that project through the Cornett basalt member on Elk Creek north of Cornett Store, west of the Gossan Lead district, suggest that the pre-volcanic surface was irregular.

The base of the series on the west slope of Bald Rock Mountain, near the head of Roberts Cove, has an altitude of about 3,380 feet for a distance of 2 miles. On the east side of the mountain, the base of the volcanic series is about 100 to 200 feet lower, showing a general eastward slope of the floor. It is concluded from the character of the erosional pattern and the gentle dips of the beds, that the volcanic series was deposited on a generally even floor of granitic rocks in which there were local irregularities, and that the volcanic rocks have since been only gently folded.

The volcanic series is not metamorphosed. It contains beds of soft argillaceous shale and arkosic quartzite (Pls. 28A-28B, 29A) which are in places cemented by silica but the bedding structures are little disturbed. The rhyolite shows textures common to recent lava flows, although its groundmass is now crystalline and contains no glass. The rocks of the injection complex have been highly metamorphosed. It is concluded that the volcanic series is much younger than the injection complex on which it was deposited after a period of extensive erosion.

On the north edge of the volcanic series, north of Comers Rock village and also west of the Gossan Lead district, the volcanic series dips gently north and is overlain by the lower Cambrian Unicoi formation. That this is an unconformable contact is indicated by the following evidence: 1. There is marked discordance in the general strike of the lower Cambrian formations and the underlying volcanic rocks. 2. Eastward the Cambrian beds transgress the volcanic series and in the Gossan Lead district they progressively overlap the rhyolite, and the underlying Flat Ridge formation. 3. They rest on older pre-Cambrian granitic rocks. 4. In the eastern part of the Elk Creek anticline where the volcanic series is absent, except for related diabase and rhyolite dikes, some of the rhyolite in the vicinity of Stevens Knob and northwestward, however, is amygdaloidal and has flow-banding, indicating surface or near-surface conditions. It seems reasonable to infer that the large and numerous dikes in this vicinity, which do not penetrate the nearby Cambrian rocks, were feeders of surface flows that were formerly present and were removed by erosion in pre-Cambrian time before the Lower Cambrian was deposited. The Mount Rogers series, therefore, is pre-Cambrian in age.

DIKES

General statement.—Dikes of diabase and rhyolite cut the older pre-Cambrian rocks throughout the Elk Creek anticline. They are most numerous in the north-eastern part of the anticline. Their general strike is N. 15° E. In places they curve slightly and branch. Several rhyolite dikes converge and unite in Stevens Knob, a prominent conical peak 2 miles east of Spring Valley (Pl. 32A). The thicker dikes near Stevens Knob and east of Fallville are resistant enough to form small hills and ridges. These dikes cut across the structure of the older pre-Cambrian rocks.

DIABASE DIKES

General description and distribution.—Numerous diabase dikes occur throughout the northern and northeastern parts of the Elk Creek anticline, northwest of Fries. From Brierpatch Mountain eastward they are associated with, and are parallel to, rhyolite dikes. The diabase dikes have a general N. 10°—30° E. strike. They vary in width from a few inches to a known maximum of 260 feet with an average width between 10 and 30 feet. The diabase in the larger dikes is a dark-colored, fine-grained rock. The rock in some dikes has a schistose structure. The coarser grained dikes occur east of Fallville and southward to Chestnut Flat. The widest dike in the district forms a north-south ridge half a mile east of Fallville. It crops out on State highway 95 along Knob Fork, and extends southward into Brierpatch Mountain where its width is greatly reduced. Many of the diabase dikes, less than 10 feet thick, occur within a few feet of each other as a parallel and branching series. Numerous dike zones are exposed on State Highway 95 west of Eureka School, near Turkey Knob, and farther west. These dike zones have been mapped on Plate 1 as single dikes. A branching network of diabase dikes is well exposed 2 miles north of Spring Valley on the road that leads to Mountain View School. Here, the main diabase intrusion, which is a dike 8 feet wide, dips 40° SE, and cuts across the foliation of the country rock. Two sills of this net-work follow the trend of the country rock, and dip 40° N.

Thicker diabase dikes, in the western part of the Gossan Lead district, occur near Bennington Mill and southwest of Fellowship Church. A dike, exposed in a road cut at Bennington Mill, is 20 feet wide and forms a prominent ridge to the north. Three-fourths of a mile north of Bennington Mill this dike connects with a small body of the Cornett basalt member of the Flat Ridge formation. Just south of Bennington Mill it seems to connect with another mass of the same basalt and appears to be a feeder dike. The diabase at Bennington Mill is of a dark-green color and a fine-grained texture, but to the north, where the dike is wider, and the rock contains white feldspar phenocrysts 1 mm. in length in a fine-grained, dark-colored groundmass. The diabase dike that connects with the Cornett basalt member west of Bennington Mill furnishes evidence that this and similar diabase dikes in the Gossan Lead district are genetically related to the basalts in the Mount Rogers volcanic series. The Cornett basalt member is not known to occur in the eastern part of the Elk Creek anticline. A diabasic mass that occurs on the west side of Stevens Knob, resembles a flow basalt. It may be a small remnant of a basalt flow related to the Cornett basalt member.

The diabase dikes in the Elk Creek anticline (Pl. 29B) have sharp contacts with the earlier pre-Cambrain rocks which they cut. Many of the dikes have been chilled, and are therefore finer grained at the contacts. The dikes have vertical to 70°-80° SE. dips. They cut across the structures of the older injection complex. In places deformation later than the intrusion of the diabase has produced a schistosity common to both the diabase and the intruded rocks. Figure 11 is a sketched cross section of a composite dike exposed on State Highway 95, half a mile

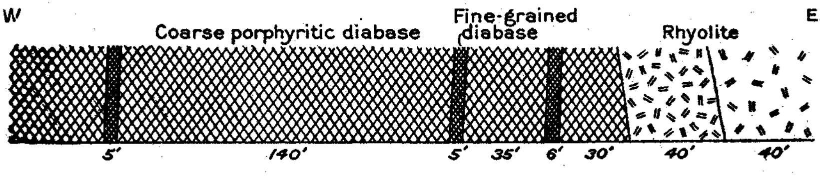

FIGURE 11.—Sketch showing composite dike of diabase and rhyolite.

east of Fallville. On the east side, the diabase is in contact with a porphyritic rhyolite. This diabase dike is coarse-grained throughout (Pl. 32B). It is intruded by three dikes of fine-grained diabase whose chilled borders show that they were formed later than the main intrusion.

Character.—The diabase throughout the Gossan Lead district ranges in color and grain size from a green colored rock with white feldspar crystals 5mm. in length to a fine-grained, greenish-gray rock in which the feldspar grains appear as shimmering white specks. The diabase in the very thin dikes exhibits a schistose structure.

In thin section the coarse-grained diabase shows an ophitic texture in which labradorite, in well-defined laths and tabular crystals is enveloped by large crystals of augite (Pl. 32C). The feldspar is greatly saussuritized and the augite is altered to pale-green hornblende, felty chlorite, biotite, epidote, and iron oxides. Titanite and ilemnite are abundant as minor constituents. The fine-grained diabase shows the same texture and constituents. The schistose diabase is now a recrystallized hornblende schist.

RHYOLITE DIKES

General description and distribution.—Many rhyolite dikes occur east of Fallville, more especially east of Spring Valley in the vicinity of Stevens Knob, where they are parallel and closely spaced (Pl. 1). Throughout this area the rhyolite dikes are closely associated with diabase dikes. The belt of closely spaced dikes is over 4 miles wide and is traceable southward for a distance of 4 to 6 miles. The dikes in this belt trend S. 20°—30° W. Rhyolite dikes thicken and converge in Stevens Knob (Pl. 32A) and in a hill one mile northwest of it. Another group of dikes, which have a S. 40° W. trend, occurs southwest of Elk Creek village and extends as far as Longs Gap. The rhyolite in many of these dikes has a fine-grained texture and a schistose structure. The rocks in the dikes just west of Longs Gap have a porphyritic fabric. The rhyolite dikes throughout the district pinch and swell and have an average width of 20 feet. The rhyolite occurs in single dikes and in a series of thin dikes. Such a series exposed on State Highway 95, 1 mile east of Eureka School, is shown in Figure 12. The

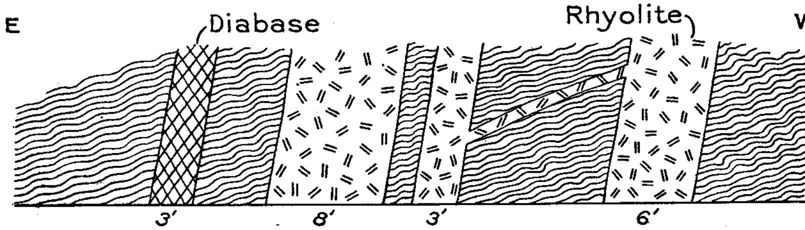

FIGURE 12.—Sketch section of lower part of Unicoi formation.

rhyolite in the wider dikes forms small knobs and linear ridges and crops out in many road cuts. This rock is jointed and weathers to angular blocks, the smooth weathered surfaces of which are of a light-gray to buff color.

A large mass of a coarse-grained, porphyritic rhyolite, which is relatively finer grained on its borders, occurs in a hill 1 mile northwest of Stevens Knob. The width of the outcrop measured in an east-west direction, is about 700 feet and the length, from north to south, measured 1,000 feet. Two parallel dikes which extend south from Stevens Knob form prominent spurs. The westerly dike is at least 200 feet wide. The size and shape of the outcrop of this large body of the coarse-grained, porphyritic rhyolite and the thick dikes that branch from it suggest that it may be a stock.

A dike swarm centers in Stevens Knob (Pl. 32A) whose shape and altitudes are determined by the resistant rhyolite intrusions. A dike that extends into the Knob from the north forms a rocky crag, the top which has an altitude of 3,155 feet, 300 to 400 feet higher than the adjacent plateau surface. Three rhyolite dikes diverge southward from the crest of the knob to form prominent spurs. The middle dike is the widest, and, near the crest of the knob, measures 40 feet in width. Two of the dikes extend across State Highway 95, where they are exposed in a road cut.

The widest rhyolite dike in the Gossan Lead district lies along the eastern border of a wide diabase dike, half a mile east of Fallville, as shown in Figure 11. A green to gray, porphyritic rhyolite, with round, green inclusions, is intruded along the east wall of the diabase. which has a trend of N. 20° E. It then cuts across the diabase with a trend of N. 30° W. and ends in a small hill. The rhyolite intrusion appears to be later than the diabase intrusion because the diabase is coarse-grained even at the contact, whereas the rhyolite shows evidence of chilling. In the eastern part of the district where there are numerous closely spaced dikes, similar parallel relations were observed.

Character.—The rhyolite in the dikes is of a fine-grained texture and of a light-pink, purplish gray, to grayish green color. In the fine-grained porphyritic varieties, euhedral pinkish gray feldspar phenocrysts average 1 mm. or less in length, while the glassy quartz grains are smaller. The pink rhyolite variety dominates over the other varieties. The mafic minerals appear as green specks in hand specimens. In the pink variety, both the groundmass and the phenocrysts are of a pink color.

The fine-grained, light-gray to pink variety shows, in thin section, a cryptocrystalline groundmass of quartz and feldspar with micrographic intergrowths of the same minerals. The phenocrysts are orthoclase dusted with hematite which accounts for the pink color. Quartz is present as phenocrysts and is embayed by magmatic corrosion. Fine biotite blades, in part altered to chlorite and epidote, ilmenite, and titanite occur sparingly. The dense, grayish-green variety has the same microtexture as the gray and pink varieties. It contains microphenocrysts of a euhedral feldspar which is clouded by small grains of sericite, hematite, and albite, the latter in part replaced by calcite. The mafic minerals include epidote, chlorite, biotite and titanite. In the porphyritic rhyolite from the dike a mile northwest of Stevens Knob, the feldspar phenocrysts show a range in length from 3mm. to 7mm. Some of the rhyolite from this locality shows flow-banding.

In thin sections the pink and gray, coarsely porphyritic rhyolites are seen to be composed of radially arranged spherulites and branching quartz and feldspar intergrowths. (Pl. 31C). Most of the phenocrysts are of a euhedral orthoclase and a twinned albite. Quartz phenocrysts are embayed by the groundmass. The pink rhyolite is dusted by hematite, the gray rhyolite by black iron oxides. The mafic constituents include epidote in small grains, chlorite, as flakes and biotite as radiating clusters. Irregular grains of titanite, dulled by alteration, are present.

The rhyolite of Stevens Knob is a pink to purplish gray rock that contains pink feldspar phenocrysts 1 mm. in length. Locally it contains clusters of pink orthoclase 6 mm. in diameter. On the southwestern spur of the knob, float fragments of spherulitic rhyolite were found, but none was seen in place. This spherulitic rhyolite is pinkish gray in color, shows flow-banding, and has rounded, irregularly oval spherulites, 3 mm. in diameter, which contain concentric bands white, pink, and green in color. Many of the centers are euhedral pink feldspar crystals. Such a rock texture is characteristic of rhyolite flows, but may be found in a dike rock if the magma contained sufficient volatile constituents. In thin section, the spherulities are seen to consist of a cryptocrystalline growth of quartz, feldspar, and an alteration of thin bands of sericite and iron oxides which produces the white, green, and red bands observed in hand specimens. Some spherulites have a radial structure. The centers of the spherulities consist of euhedral crystals of orthoclase and masses of chlorite, sericite, and iron oxides.

The eastern half of the porphyritic rhyolite dike east of Fallville (Fig. 11) is light gray to pink in color and contains pink euhedral feldspar throughout while the western half is a dark grayish green rock with relatively smaller pink feldspar phenocrysts. The rhyolite has numerous, round, dark-green, fine-grained inclusions, with clearcut outlines, which range from small specks to a maximum of 6 inches in diameter. In thin section the rock exhibits cryptocrystalline and micrographic textures, with euhedral orthoclase phenocrysts dusted with hematite, flakes of chlorite and biotite, and lesser amounts of albite, chlorite, and muscovite (Pl. 33A). The dark color of the western part of the dike is due to the larger amount of chlorite, sericite, epidote, and altered titanite. The twinned plagioclase is in part replaced by chlorite, biotite, and calcite. The dark round or oval inclusions have a clearcut outline. They have a finer crystallization and a greater percent of mafic minerals than the rhyolite. If the inclusions are segregations in the rhyolite, the fine crystallinity may be due to the fact that the minerals that crystallized early tended to form small crystals. The proximity of a rhyolite dike, containing dark-colored inclusions, to a diabase dike suggests that the inclusions may be xenoliths of diabase rather than segregations.

AGE RELATIONS OF THE DIKES

The diabase and rhyolite dikes cut across the structure of the rocks of the injection complex and show chilled contacts. The rhyolite dikes were generally intruded parallel to the diabase dikes although in some places they cut across the diabase (Fig. 12). Since none of the dikes have cut the Unicoi formation but end abruply at its base, they appear to be pre-Cambrian in age. Diabase dikes which in places appear to connect with flows of the Cornett basalt member of the Flat Ridge formation, may be feeder dikes for these flows. The rhyolite dike swarm, in and near Stevens Knob, is so large that it seems likely that this mass might be directly connected with a body of the magma which welled up along tension cracks. The crest of Stevens Knob and the hill 1 mile to the northwest, where there is a broad area of a coarse rhyolite porphyry, may be small stocks from which the dike swarms diverge. As has been stated, the volcanic series is separated from the Lower Cambrian by an erosional uncomformity and any flow that came to the surface at these places would have been eroded before Cambrian time. Because these dikes are younger than the pre-Cambrian injection complex which they intrude and older than Lower Cambrian rocks and because the diabase dikes connect with flows of the volcanic series, they are syngenetically related to the Mount Rogers volcanic series of later pre-Cambrian age.

LYNCHBURG GNEISS

General description and distribution.—The Lynchburg gneiss underlies the southeastern portion of the Gossan Lead district (Pl. 1). Its northwestern boundary, which parallels the Gossan Lead overthrust, extends, from a point south of Sylvatus, southwestward through Fries and River Hill Church to the North Carolina State line, near U. S. Route 21. The Lynchburg gneiss is essentially a quartz mica gneiss and schist. It contains intrusions of altered gabbro, serpentine and soapstone. The ore veins of the Gossan Lead occur in the northwestern part of the belt of Lynchburg gneiss.

The Lynchburg gneiss, named from exposures at Lynchburg[35] Virginia, is stratigraphically continuous from this type locality southwestward to Gossan Lead district, and thence extends southwestward into North Carolina. The largest part of the Lynchburg gneiss underlies the Blue Ridge plateau and forms the higher ridges, locally called The Knobs, which rise above the plateau surface, and southeast and south of Galax reach a maximum altitude of 3,180 feet. The Lynchburg gneiss forms the Blue Ridge escarpment and the dissected mountains of the Blue Ridge front, as Fisher Peak, Rich Mountain, and Sams Knob. It underlies also the Piedmont lowland southeast of the escarpment.

The best exposures of the Lynchburg gneiss in this district are

[35] Jonas, A. I., Geologic reconnaissance in the Piedmont of Virginia: Geol. Soc. America Bull., vol. 38, no. 4, p. 845, 1927.

found along Chestnut Creek and in cuts of the Norfolk and Western Railway that follows Chestnut Creek north of Galax. It is well exposed at many places in the gorges of Crooked and Little Reed Island creeks. New River, which cuts across the northwestern part of the belt of Lynchburg gneiss in a series of sweeping curves that extend from Fries southwestward to U. S. Route 21 at the North Carolina Line, and its tributary Little River, afford many good exposures. Along U. S. Route 52, which follows Short Creek northwestward from the divide at Mount Tabor School, and State Highway 89, south of Galax, are good exposures of the formation. The gneiss crops out in the gorges along the Blue Ridge escarpment and along the Blue Ridge Parkway which crosses the southeastern part of the belt of gneiss.

The Lynchburg gneiss weathers to a micaceous clay soil which makes good farm land where the surface is not too steep and stony.

The distribution of the Lynchburg gneiss, its topographic expression, and the variation of its lithologic types and microtexture are closely related to the structure of the gneiss. The gneiss is strongly folded and the regional structure has a N. 45° E. strike. South of Galax, east of Poplar and Walker knobs and southeast of Woodlawn, where the Lynchburg gneiss has major folds with pitching axes, the gneiss has a curving strike. Its trends are reflected in the topography because of the presence of beds of differential hardness. The gneiss forms ridges which are separated by valleys that are underlain by less-resistant mafic rocks that are intruded into the gneiss.

Character.—The Lynchburg gneiss is a medium to fine-grained biotite-muscovite gneiss and schist, containing garnet. Facies of the Lynchburg include; a spangled muscovite-garnet schist with quartzose layers, which occurs in places in the southeastern part of the district; a pebbly biotite quartzite and fine-grained quartzite interlayered with muscovite and ferruginous schist, lying in a belt that crosses the district northeast of Galax; and a ferruginous schist and quartzite that occurs along the Gossan Lead overthrust. In places south and southeast of Galax, a biotite-bearing marble and a calcareous biotite gneiss are infolded in the Lynchburg gneiss.

The typical Lynchburg gneiss, which forms the larger part of the formation, is a medium-to fine-grained, gray gneiss composed of quartz, feldspar, biotite, and a small amount of muscovite. The gneiss is interlayered with schist. A variety of Lynchburg gneiss, spangled with biotite, extends from the eastern border of the Gossan Lead district, near Dalton Hill School, to Galax and southwestward through Baywood to the North Carolina line. It is characteristic also of the area southeast of U. S. Route 58 as far as Hanks Knob and Crooked Creek School. Where the folds in the Lynchburg gneiss are sheared out, the rock has "straight layers" composed chiefly of quartz and feldspar, with thin micaceous partings, and contains quartzose lenses drawn out parallel to the foliation. These lenses may be in part remnants of quartz veins which were injected parallel to the bedding and have been sheared out into lenses. The City quarry, south of Galax, is in such a "straight-layered" quartzose gneiss, which has a monoclinal dip of 30° S.E. It breaks readily into slabs, parallel to the layering.

In thin section the gneiss is seen to be a recrystallized intergrowth of quartz, microcline, plagioclase, and calcite. Brown biotite and colorless muscovite, in fine to coarse flakes, coat the foliation planes (Pl. 33B). Zircon and apatite are the chief accessory minerals. The schistose layers have the same constituents, although the percentage of quartz and feldspar is less.

FACIES OF THE LYNCHBURG GNEISS

Staurolite schist facies.—A narrow belt of mica schist containing staurolite, garnet, and biotite occurs in the Lynchburg gneiss just north of Galax. It extends from a point 2 miles northeast of Galax southwestward for 6 miles (Pl. 1). The schist is composed of frosty muscovite blades wrapped around small masses of granulated quartz. Garnet occurs as small red grains which, in many places, are closely packed. Bronze-colored biotite and staurolite are present as large porphyroblastic blades and crystals. The schist weathers readily, and in many outcrops is stained with hydrous iron oxides derived from the weathering of pyrite in the rock. In an outcrop in Galax on U. S. Route 58, east of Chestnut Creek, both biotite and staurolite have random orientation with respect to the plane of the foliation and the direction of lineation of the schist. The foliation strikes N. 45° E., and dips 25° SE.. It cuts across the bedding, which strikes N. 45° E. and dips 60° N.E. In Plate 34, the staurolite crystal lies in the plane of the foliation but is elongated at right angles to the direction of the lineation.

The prismatic crystals of staurolite in this belt range in length from three-fourths inch to 4 inches. Some measure 1½ inches across. The crystals shown on Plate 34 were collected on a hill south of West Galax and north of U. S. Route 58, where they strew the surface. Cruciform penetration-twins, with a twinning angle of 60°, are abundant, but no right-angle twins were found. Many of the crystals were broken and the sharp angles had worn off.

The staurolite crystals in the mica schist are coated usually with a thin film of sericite. In some crystals, staurolite, which forms the core, is surrounded by a rim of sericite. Some of the crystals are made up of muscovite blades, quartz grains, and small residual grains of staurolite. It seems evident that staurolite has been replaced by sericite in variable amounts. The change of staurolite to sericite was not produced by weathering, but by hydrothermal alteration.

Muscovite-garnet schist facies.—A muscovite-garnet schist facies of the Lynchburg gneiss occurs in zones in a belt 7 miles wide southeast of Pipers Gap (Pl. 1). This belt crosses the southeastern part of the Blue Ridge plateau, the Blue Ridge escarpment, and the Piedmont lowland. The schist is greenish gray and contains muscovite, chlorite, quartz, and garnet, the latter commonly in large crystals. The muscovite-garnet schist is infolded with biotite-muscovite schist and gneiss, which in places also has garnet and chlorite. On Rich Mountain and Fisher Peak the schist contains coarse magnetite crystals. The largest belt of muscovite-garnet schist which has a width of 1¼ miles is located south east of Low Gap. It extends from the North Carolina line, where it forms Norvale Crags, (Pl. 7A), northeastward across the Gossan Lead district. The Blue Ridge Parkway crosses this belt of schist near Blue Ridge School, 2 miles northeast of Low Gap, and follows it westward to a point 1 mile west of Max. Other infolds of muscovite-chlorite-garnet schist are parallel to the strike of this wide belt.

Thin sections of the muscovite-chlorite-garnet schist (Pl. 33C), reveal thin layers of quartz and plagioclase between the micaceous layers. Felty blades of muscovite and chlorite lie parallel to the foliation and bend around fine plagioclase grains. The schist also contains coarse chlorite fibers with closely spaced parallel thin rods of ilmenite. In the fine crinkled folds the ilmenite rods are bent. Porphyroblasts of clinochlore, which encloses large ilmenite grains and well-formed muscovite blades, lie across the foliation. The biotite is in part altered to green chlorite. In some specimens the coarse plagioclase contains a stream-line of inclusions of other minerals which make up the rock, namely muscovite, chlorite, and iron oxides. Skeletal garnets, without well-defined crystal form, are elongated parallel to the cleavage. These garnets are partially altered to chlorite along cracks and on their borders. In other places the garnets are present as euhedral and unaltered crystals.

The more quartzose beds that are infolded with the muscovite-garnet schist are finely crystalline and contain quartz, plagioclase (albite), brown biotite, altered in part to chlorite, garnet, iron oxides, ilmenite, and abundant fine grains of epidote. Ilmenite occurs as bent rods. Muscovite blades occur as porphyroblasts. Apatite and titanite are the accessory minerals. Garnet, where present, is in skeletal grains with quartz inclusions.

Biotite quartzite facies.—Another facies of the Lynchburg gneiss occurs in the area lying northwest of a line extending from Gardner Mills southwestward through Galax, Baywood, and Cox Ford on New River. It contains the Gossan Lead ore body. Besides quartzose biotite gneiss and schist this facies contains quartzite and dark-colored shiny biotite schist. The quartzite occurs in thin beds, infolded with schist, in a belt that extends southwestward from the mouth of Daniel Branch across Chestnut Creek, and in another belt that extends southwestward from the eastern edge of the district, south of Sylvatus, through Richardson, Corinth, Pinegrove School on New River, and Longview Church. The quartzite is well exposed on Daniel Branch, on Crooked Creek northwest of Woodlawn, on Cranberry and Mill creeks, on Chestnut Creek north of Hickory Flat, and along New River, The shiny biotite schist occurs in certain zones as far southeast as Colston Church and Galax. In this facies the folding is close, and most of the folds are sheared out into foliation layers.

Near the pyrrhotite mine at Iron Ridge, quartzite is infolded with sparkling biotite-muscovite-quartz gneiss and schist. The quartzose mica schist that forms the footwall at the mine is spangled with a bronze-colored biotite. It contains small crystals of pink garnet of the manganese-bearing variety, spessartite. The hanging wall is formed by mica schist, and the ore veins follow the foliation of these rocks, which dips 40°—60° SE. During the shearing out of the folds, much of the mica in the schist was shredded out and now appears as a shiny film on the foliation planes.

Coarse-grained biotite quartzite, containing quartz and feldspar grains, is found on Daniel Branch near its mouth and to the southeast on Crooked Creek, north of Hebron, and near Richardson. In places the quartzite contains grains of blue quartz and a milky feldspar as crystals 3 mm. in diameter. In a thin section of a specimen from near Hebron (Pl. 37C), the feldspars were seen to be perthite and microcline penetrated by calcite veins. Brown biotite and muscovite formed the foliation partings. Magnetite, titanite, and apatite were generally present in accessory amounts.

Thin sections of mica schist from the vicinity of Iron Ridge (Pl. 36A) show it to consist of biotite, muscovite, chlorite, quartz, fine plagioclase grains and skeletal garnet with inclusions of quartz and iron oxides. The garnet has an alteration rim of chlorite which has penetrated along cracks. Biotite is in part altered to chlorite and clinochlore. The euhedral pink garnets and coarse biotite that occur in these rocks appear to have been formed at the time of the introduction of the ore solutions, since the gangue minerals of the ores include biotite, and garnet.

Ferruginous mica schist and quartzite facies.—The facies composed of ferruginous mica schist and quartzite occurs in a belt that extends from a point northeast of Woodlawn southwestward across Crooked Creek to Cliffview north of Galax; in an area that extends from Oldtown southwestward across New River; and also in a belt northwest of the Gossan Lead which extends from the northeast end of the district southwestward to Peach Bottom Creek. These rocks are well exposed along Glade, Crooked and Mill creeks, and on New River west of the bridge on U. S. Route 58. The ferruginous schist in the belt southwest of Woodlawn is shown on the geologic map (Pl. 1). The other areas of schist are not sufficiently well defined to be mapped. The more schistose and ferruginous layers alternate with quartzite layers (Pl. 35). Both schist and quartzite contain garnet grains and a bronze-colored biotite as coarse blades. The rocks are closely folded and show transposition cleavage in the schistose layers. In the ferruginous mica schist (Pl. 36B) the fine black dust-like particles are parallel to the closely crinkled foliation. Biotite blades that grew during the folding are parallel to the foliation and include black dust-like grains of magnetite and abundant small grains of garnet. Quartzite lenses, with scanty biotite blades, are elongated parallel to the foliation. Porphyroblasts of plagioclase in elongated crystals with frayed outline, that have replaced the rock parallel to the foliation, contain a stream-line of fine magnetite inclusions. Some of the biotite blades have a border of pale-green chlorite. Fine flakes of sericite and needle-like prisms of ilmenite and tourmaline lie diagonal to the foliation. Irregular masses of pyrite have penetrated the rock along the foliation.

The original rock of the ferruginous schist appears to have been an argillaceous quartzose sediment. The magnetite particles are believed to have been formed by the grinding out of an earlier-formed mineral, such as biotite, during the deformation and before the crystallization of the biotite and plagioclase that now include the stream lines of dust-like particles. The magnetite is not, however, of later hydrothermal origin, like the pyrite lenses that have replaced the rock along the foliation layers.

Facies along the Gossan Lead overthrust.—Mica schist and quartzite, occur along the northwest border of the Lynchburg gneiss in a belt that has a width of 1 to 2 miles and a length of about 30 miles. This belt lies adjacent to and south of the Gossan Lead overthrust fault and extends across the district from a point south of Sylvatus southwestward to the North Carolina line near New River (Pl. 1). It passes south of Round Knob, north of Oak Grove, southeast of Fries, and southwestward across the bends of New River north of Boyer Ferry and Peach Bottom School. Exposures of the rocks in this belt occur on Little Reed Island Creek north of Richardson, on U. S. Route 52 north of Mt. Tabor School, and in cuts along Crooked Creek, Chestnut Creek, and New River southwest of Fries.

The mica schist in this belt is fine grained, shiny, and blue black, with sparkling muscovite layers between fine-grained quartzose layers. It is closely crinkled, has prominent cleavage which is closely spaced, and breaks into slaty cleavage pieces. In beds of differential hardness, the foliation layer wraps around the harder beds, and the rock has a lumpy surface with grooving in the direction of the shearing movement. The quartzite is in straight-layers and contains lenticles of quartz and quartz veins formed during the shearing of the folds. The micas on the foliation planes are shredded out and form shiny films.

As seen in thin sections of mica schist (Pl. 36C), the dark bands are formed by mica which bends around lenses of quartz that is finely cataclastic, has irregular sutures, and has undulatory extinction in the unreduced grains. Muscovite is present as fine fibers, banded with magnetite dust. Fine grains of quartz and associated epidote form wavy lenticles around grains of plagioclase that also include magnetite. In some thin sections chlorite and brown biotite are seen to occur with muscovite. These micaceous minerals follow the folds but are not bent around the arches (Pl. 37A). Pink garnet occurs in a bluish-black phyllite, which breaks into lumpy lenticles and is especially abundant in the schist southwest of Riverside The garnet is in small grains, closely crowded and commonly fractured. The ferruginous mica layers wrap around the garnets (Pl. 37B). The schist contains black dust-like bands included in the biotite, like those in the ferruginous schist described from the Woodlawn belt.

In the quartzite beds that are associated with the mica schist, the quartz and feldspar grains are cataclastic, that is broken. Secondary calcite is usually present. Apatite and titanite are the accessory constituents. Black, ferruginous quartzite, spangled by coarse biotite blades, occurs near Redman Branch, north of Baywood. Bronze-colored biotite porphyroblasts are present in the ferruginous garnetiferous schist and in the mica schist to the southwest of Redman Branch. The mica schist is interlayered with mica gneiss southwest of Todd Ford on New River. The foliation surfaces of the schist here show shiny biotite and muscovite separating lenticles of quartz and feldspar.

Limestone beds in the gneiss.—Crystalline limestone is infolded in the Lynchburg gneiss in an area which lies 4 miles southwest of Galax, and in two smaller areas northeast of Lambsburg (Pl. 1.) The limestone area southwest of Galax, extends from a point near Mountvale Church in a S. 30° W. direction for three-fourths of a mile. It is exposed along the road from Mountvale Church to Meadow Creek and in the hill just south of the creek. The limestone is closely folded, strikes S. 25° W. and dips southeast. Southwest of the road leading east from Dalhart, the limestone crops out in the valley of a south-flowing stream. It was quarried in this belt on the Blevin farm, one-fourth mile north of the North Carolina line. On the upland between the outcrops on Meadow Creek and those near the State line, the limestone could not be traced because of surface weathering.

A blue micaceous crystalline limestone, similar to that which occurs southwest of Galax, crops out on the Blue Ridge School road just northeast of the intersection of that road with the Lambsburg road. The limestone is closely folded and strikes N. 35° E. The axial planes of the folds dips 30° SE. Another outcrop of limestone, with parallel strike, was observed 1 mile to the southeast in Bobbit Hollow, at an elevation of 1,800 feet near the foot of the Blue Ridge escarpment. The limestone southwest of Blue Ridge School and in Bobbit Hollow is infolded with the Lynchburg gneiss.

The limestone from the Meadow Creek area is a bluish-gray, crystalline, highly biotitic rock with veins and masses of coarsely crystalline white calcite and associated quartz grains. This limestone grades laterally into a calcareous biotite gneiss. The fresh rock resembles the fresh bluish

Lynchburg gneiss, but its calcareous character is very evident in weathered outcrops where solution of the calcite has produced a rough pitted surface and has left the less soluble quartz grains and biotite flakes in relief. In thin section the rock is seen to be composed chiefly of coarse calcite grains and to a lesser extent of quartz and feldspar. Epidote and apatite occur in accessory amounts. Biotite is present as clear brown blades. The limestone north of Lambsburg is fine-grained and contains also muscovite and pyrite.

METAMORPHISM

The Lynchburg gneiss is a medium-to coarse-grained crystalloblastic gneiss and schist composed of muscovite, biotite, quartz, feldspar, and garnet. The present composition and texture of the Lynchburg gneiss indicates the gneiss to have been derived from the metamorphism of ferruginous, argillaceous, and quartzose sedimentary rocks which crystallized during regional deformation. The mineral assemblage of the gneiss is characteristic of metamorphic rocks that were deformed in the chlorite zone and the upper part of the biotite zone of metamorphism. This metamorphism accompanied the folding of the Lynchburg gneiss. The contained porphyroblasts of muscovite, biotite, garnet, and staurolite which are not oriented with the foliation and contain inclusions of earlier-formed minerals of the gneiss, evidently were formed later than the main folding and crystallization of the Lynchburg gneiss.

The muscovite-garnet schist facies of the Lynchburg gneiss which occurs Southeast of Pipers Gap Post Office, northeast of Galax and in the vicinity of Iron Ridge appears to have been derived from the biotite-muscovite schist of the typical Lynchburg gneiss by retrogressive changes. In the muscovite-garnet schist facies biotite has altered to chlorite and ilmenite and to clinochlor. Garnet also altered to chlorite and staurolite to muscovite. These mineral changes from minerals of higher rank metamorphism to those of lower rank took place after the main folding of the Lynchburg gneiss during a period of deformation which sheared out the folds and developed a schistosity along which the ore veins of the district penetrated the Lynchburg gneiss. As well be shown later this deformation and the Gossan Lead overthrust are regarded to be late Paleozoic in age. The main folding of the Lynchburg gneiss may have occurred early in late Paleozoic orogeny or may have occurred during Ordovician orogeny.

THICKNESS

The Lynchburg gneiss contains schist and gneiss of different compositions, crystallinity, and degrees of metamorphism. The rocks are closely folded. The prominent structural feature is a folded layering made up of closely packed folds. Many of the closures have been sheared out and the limbs torn apart by slipping movements. The layered structure may be bedding layers but, because the beds have undergone a complete transposition and inversion, the present superposition of layers is in no sense a stratigraphic succession. No estimate of the thickness, therefore, can be made and no vertical succession of the formation can be determined.

AGE AND CORRELATION

Since the Lynchburg gneiss, in the Gossan Lead district, occurs in an overthrust position on older pre-Cambrian and Lower Cambrian rocks, its age can not be determined from relations in this district. It is stratigraphically continuous to the northeast with the Lynchburg gneiss of the type area at Lynchburg, Virginia, where the gneiss contains mafic and ultra-mafic intrusive rocks similar to those in this district.

From the vicinity of the type locality of the Lynchburg gneiss northeastward, the Rockfish conglomerate[36] lies at the base of the formation and contains pebbles and bolders of grantic rocks derived from the underlying Lovingston granite and other rocks of the injection complex. It is evidence, therefore, that the Lynchburg gneiss was deposited on the injection complex of early pre-Cambrian age and is later in age than the complex.

From the vicinity of Charlottesville, Virginia northeastward the Lynchburg gneiss is less metamorphased than at the type locality and is made up of arkosic quartzite and graphitic slate. In the vicinity of Warrenton these sediments were named the Fauquier formation by Furcron.[37]

From a point a few miles northeast of Lynchburg, in northern Virginia, the Catoctin basalt overlies the Lynchburg gneiss. In northern Virginia the sediments of the Lynchburg thin greatly. There they comprise a series of conglomerate, arkose, marble and volcanic tuffs which lie at the base of the Catoctin basalt.

In an earlier paper the writers[38] stated that the series of tuffaceous

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[36] Nelson, W. A., Informal Communication; Jour. Wash. Acad. Sci. Vol. 22, pp. 456-457, 1932.

[37] Furcron, A. S., Geology and Mineral resources of the Warrenton quadrangle, Virginia: Virginia Geol. Survey Bull. 54, pp. 37-41, 1939.

[38] Jonas, A. I., and Stose, G. W., Age relations of pre-Cambrian rocks in the Catoctin Mountain-Blue Ridge and Mount Rogers anticlinoria in Virginia: Am. Jour. Sci. vol. 237, No. 8, pp. 575-593, Fig. 1, 1939.

and sedimentary rocks which overlie the injection complex and underlie the Catoctin basalt on the west limb of the Catoctin Mountain-Blue Ridge anticlinorium extend around the north end of the Middletown anticline in Maryland and continue southwestward into Virginia on the east limb of the anticlinorium where they pass into rocks equivalent to the Lynchburg gneiss. These relations are shown in Figure 1 of the paper quoted above. The writers, therefore, correlate the tuffaceous and sedimentary rocks which underlie the Catoctin basalt on the west limb of the anticlinorium with the Lynchburg gneiss and equivalent rocks.

In describing the rocks of the Elk Creek anticline it is shown in this report that the Mount Rogers volcanic series, which is on the west limb of the anticline, is younger than the injection complex and older than the Lower Cambrian, and is therefore of late pre-Cambrian age. The Lynchburg gneiss, which is also of late pre-Cambrian age, is therefore of the same general age as the Mount Rogers volcanic series.

HORNBLENDE GNEISS, SERPENTINE AND SOAPSTONE

General description and distribution.—A series of rocks which includes hornblende gneiss, serpentine, and soapstone occurs in the southeastern part of the district where they are intrusive in the Lynchburg gneiss. These rocks are derived from the metamorphism of gabbro, peridotite and pyroxenite. In places they contain remnants of original olivine and pyroxene. The general term mafic rocks will be used in referring to them.

The mafic rocks occur in the southeast part of the Gossan Lead district, where they form parallel bands in the Lynchburg gneiss. Northwest of a line that passes through Baywood, Galax, and Woodlawn, the strike of the mafic rocks follows the general regional trend, N. 45° E. In the area southeast of that line the strike of the mafic rocks curves because of the major folds in these rocks pitch steeply. The mafic rocks southeast of the line through Baywood, Galax, and Woodlawn are grouped in four belts which will be discussed separately.

In the first belt, which lies south and southeast of Galax, several parallel bands of mafic rocks, separated by layers of Lynchburg gneiss, form a steeply pitching fold. From a point near Little River, at the North Carolina line, the mafic rocks are hornblende gneiss, with the exception of a small body of serpentine exposed on Meadow Creek one half mile north of Edwards Hill. The thickest layer in this belt passes north of McCamant Hill and Cody Knob. This and parallel layers trend eastward to Hanks Knob, where it curves sharply to the southwest, following the arch of the Hanks Knob pitching fold. There hornblende gneiss is well exposed at the arch and is closely folded, and the minor folds pitch 50° SW. Other layers of mafic rocks follow the trend of this thick layer around the end of the fold. At the arch of the fold near Hanks Knob, hornblende gneiss passes southwestward into a serpentine rock, soapstone. These rocks, with thin layers of hornblende gneiss, comprise the mafic rocks on the southeast limb of the fold. They extend for a distance of 8 miles from Hanks Knob to Edmonds at the North Carolina line. Southwest of Hanks Knob, serpentine is well exposed at Blue Ridge Mill, on Piney and Chestnut creeks, and northeast of Edmonds where it forms a lowland, one mile in width, called the Glades. One mile north of Low Gap the lowland is crossed by State Highway 89.

The second belt of mafic rocks lies northeast of the first belt and southeast of Walker and Poplar knobs. The mafic rocks in this belt are hornblende gneiss, which occur in two parallel layers north and south of a wide area of Lynchburg gneiss. In the southern part of this belt, two parallel layers of hornblende gneiss extend from Poplar Knob S. 70° E. to Higgins Crossroads, where the strike changes to east and then to N. 70° E. to the eastern edge of the district. The two parallel layers in the northern part of this belt trend parallel with those on the south side but in places are not continuous and appear to be cut out by shearing. The southern one of these two layers has been traced only for a distance of one mile east of Elkhorn Creek. The layers of hornblende gneiss in this belt are cut off at the northwest by two parallel northeast-trending shear zones marked by vein quartz. These shear zones pass through Poplar and Walker knobs respectively.

In the third belt, which lies southeast and south of the first and second belts, a schistose hornblende gneiss occurs in several discontinuous bands. They trend in general N. 45° E. to a line which passes southeast from Crooked Creek School to Drenn, and then curve to a N. 70° E. direction and pass eastward out of the district. Where hornblende gneiss is well exposed on the road from Drenn to Lambsburg, one mile northwest of Lambsburg.

In the fourth belt, several layers of hornblende gneiss extend from the North Carolina line, south of Crab Orchard School, northeastward, and pass north of Willie, Hampton, and Ward knobs in a N. 45° E. direction to Crooked Creek. There the strike curves eastward and in general trends east to the eastern edge of the district. Near Crooked Creek, two of the thicker layers of hornblende gneiss in this belt diverge, and the more northerly layer passes north of Pike Knob, where field observations show that it merges into soapstone at the eastern edge of the district. The southerly layer passes south of Pike Knob along the north face of Edwards Knob. The thickest layer of hornblende gneiss extends from Woodland eastward to the edge of the district.

In the first, second, and fourth of these belts, the mafic rocks occur on the slopes of ridges, at divides, and in stream valleys, and the more resistant Lynchburg gneiss, which lies between the layers of mafic rocks, forms the intervening ridges.

The mafic rocks northwest of the line through Baywood, Galax, and Woodlawn form a series of thin layers which trend in a general N. 45° E. direction.

Southwest of Oldtown, hornblende gneiss in this belt has a considerable local variation in trend. In the region southwest of New River and U. S. Route 58, the areas of hornblende gneiss in this belt are discontinuous.

In the belt northwest of the Gossan Lead ore body, thin continuous layers of hornblende gneiss and soapstone are present in the Lynchburg gneiss and are more numerous in the area from Crooked Creek northeastward to the edge of the district. The most continuous layers of hornblende gneiss enter the district 2 miles southeast of Sylvatus and extend for 8 miles southwestward with a curving strike to the vicinity of Corinth, where small areas of soapstone are associated with the hornblende gneiss. Two miles northeast of Richardson, at the eastern border of the district, the hornblende gneiss appears to grade into a soapstone and a garnetiferous dark-green chlorite schist.

Hornblende gneiss.—In the Gossan Lead district the hornblende gneiss is more widely distributed than either the serpentine or the soapstone. The gneiss is a fine-to medium-grained, dark-green, rock composed of sparkling green hornblende with a subordinate amount of chlorite, epidote, plagioclase feldspar, and quartz. In places it contains large crystals of hornblende or actinolite.

Plate 38B shows a thin section of fine-grained hornblende gneiss from Meadow Creek, near the mouth of Beaver Creek. The dominant constituent is a bluish-green hornblende which is present in prisms with a pronounced orientation of the longest axis of the prism parallel to the foliation. Small grains of quartz, andesine, and epidote occur as interstitial material. Plate 52B shows the layered and folded character of the hornblende schist from an area 2 miles northwest of Lambsburg. There it is cut by epidote and quartz veins containing calcite and clusters of bluish-green actinolite fibers.

The coarse-grained facies of hornblende gneiss, characterized by large crystals of hornblende or actinolite, occurs on Crooked Creek one mile west of Woodlawn, down that creek near the mouth of Daniel Branch, and south and west of Oldtown where the gneiss crosses New River near the bridge on U. S. Route 58. East of the bridge, where this facies is well exposed in a small quarry, it is made up almost entirely of dark-green hornblende crystals. In the hornblende gneiss near the mouth of Daniel Branch and southwest of Oldtown, a dark-green hornblende occurs in aggregates of radiating sheaves, which form dark-green blotches in a fine-grained white matrix composed of quartz and feldspar. Just south of Oldtown, an actinolite-quartz gneiss is associated with a coarse-grained hornblende gneiss. The actinolite in the gneiss occurs in aggregates of radiating blades. The hornblende gneiss is garnetiferous in places along Crooked Creek, south of Cliffview, just northeast of Galax, near Eona east of Woodlawn, and southwest of Oldtown.

As seen in thin sections (Pl. 38A), coarse-grained hornblende gneiss from near the mouth of Daniel Branch contains pale bluish-green hornblende blades with ragged outlines, largely in aggregates and clusters. The hornblende includes grains of quartz and is intergrown with chlorite and small grains of titanite altered to leucoxene. The groundmass is formed of interlocking grains of quartz, andesine, epidote, and zoisite.

Actinolite gneiss from west of Oldtown (Pl. 38C), has a fine-grained groundmass of quartz, epidote, and clinozoisite. Pale-green actinolite fibers are in sheaf-like arrangement.

Serpentine and soapstone.—Serpentine is a dense, dark-green rock which, in many places, contains sparkling white flakes of talc. Serpentine near Blue Ridge Mill has asbestos fibers which lie on slip planes and are elongated in the direction of the slip. The serpentine in The Glades has concentrations of white talc and grades into soapstone which has been quarried in places. Soapstone is a light grayish-green or dull-white rock composed almost entirely of talc blades, with a small amount of pale-green chlorite. Soapstone exposed southwest of Hanks Knob contains radiating fibers of actinolite. Chlorite schist in many places forms the border facies of serpentine at the contact with Lynchburg gneiss. Southeast of Piney Creek, on the southeast limb of the fold that passes through Hanks Knob, chlorite schist contains actinolite fibers which radiate from centers containing cubic pyrite crystals. Magnetite is a common mineral in serpentine, soapstone, and chlorite schist, and when these rocks are weathered they have large holes partially filled by hydrous iron oxides derived from the magnetite.

A section across the serpentine area in the northeastern part of The Glades, east of the mouth of Piney Creek, shows the following sequence from northwest to southeast; actinolite schist bands in mica schist of the Lynchburg gneiss, chlorite schist, a wide belt of dark-green serpentine, soapstone with sparkling flakes of white talc, soapstone containing magnetite, and garnetiferous mica schist of the Lynchburg gneiss with hornblende gneiss layers.

Many thin sections of serpentine from the belt between Hanks Knob and Edmonds show residual grains of olivine which is altered to serpentine (antigorite) along cracks and parting planes. Magnetite present in the rock was released in this alteration.

Tremolite is present in long bladed prisms lying parallel to the foliation of the rock. Coarse fibers of talc and crysotile are in part parallel to and in part lie across the foliation. Plate 39A shows a serpentine of the type just described. Serpentine from near Blue Ridge Mill (Pl. 39B) is made up largely of a fine felty mass of serpentine. Scanty fibers of talc and tremolite are present with the serpentine. No remnants of olivine occur in it.

One mile southwest of Baywood there is a small outcrop of dark-green serpentine with radiating clusters and veins of tremolite. In thin section (Pl. 39C) the rock is composed of large crystals of colorless enstatite, which has altered to long blades of tremolite stained black by magnetite, to long chrysotile fibers, and to blades of talc. It contains epidote grains. The more altered part of the rock (Pl. 39C) is composed almost entirely of a felty mass of antigorite, with wide blades of chrysotile. It contains some tremolite blades, magnetite and calcite.

Origin and metamorphism.—The hornblende gneiss has a pronounced foliation and a crystalloblastic texture. The hornblende prisms lie in the plane of the foliation and are elongated in the direction of the lineation. Recrystallization has obliterated the original textures and minerals. The mineral content indicates that the hornblende gneiss represents an original gabbro, in which the original pyroxene has changed to hornblende and chlorite and the original calcic plagioclase to sodic plagioclase, quartz, and epidote. The hornblende gneiss, therefore, was intruded into the sedimentary rocks of the Lynchburg gneiss as gabbro dikes and sills. Serpentine was derived from the alteration of peridotite and pyroxenite. Soapstone was formed by alteration of serpentine to talc. The original peridotite and pyroxenite may have graded into the original gabbro. The mafic rocks appear to have been concordant intrusions into the Lynchburg gneiss, for no crosscutting relations have been observed.

The writers found no evidence that any of the hornblende gneiss in the Gossan Lead district was derived from intercallated basalt flows, although, in North Carolina, metabasalt flows are present in the Lynchburg gneiss over a wide area.

At one locality in the district, in a cut of the Norfolk and Western Railway along Chestnut Creek, half a mile east of Iron Ridge, there is a nearly vertical dike of metadiabase 15 feet wide which strikes N. 50° W. The dike cuts the Lynchburg gneiss which strikes N. 20° E. The age of the metadiabase and the relations of the metadiabase to the hornblende gneiss and serpentine were not determined.

The alteration of gabbro, peridotite, and pyroxenite took place during regional folding and metamorphism, for the secondary fibrous minerals in these rocks have an orientation in the direction of the regional trends.

CAMBRIAN SYSTEM

General Statement.—The Cambrian system comprises a series of quartzose rocks at the base and a series of carbonate rocks above. The quartzose rocks are exposed in the mountains along the northwestern border of Grayson County and in adjoining parts of Smyth and Wythe counties. The carbonate rocks are found chiefly in the Great Valley northwest of these mountains. In the vicinity of Austinville, Wythe County, the carbonate rocks occur in a broad embayment back of the mountain front and also in narrow synclinal valleys within the mountains. The series of quartzose rocks are Lower Cambrian. The carbonate rocks are of Lower and Middle Cambrian age.

LOWER CAMBRIAN QUARTZOSE ROCKS

General statement.—The quartzose rocks include, in ascending order, the Unicoi formation, the Hampton shale, and the Erwin quartzite. In this area the Unicoi formation, at the base of the Cambrian system, is composed of arkosic quartzites, shale, and beds of conglomerate. A medial series of shale, argillite, arkosic quartzite, and basalt flows separates two ridge-making members which comprise a lower arkosic quartzite and an upper, more massive quartzite.

The Hampton shale overlies the Unicoi formation. It is a dark-gray shale, or argillite, with thin quartzose beds that form valleys or low ridges. The Hampton shale is overlain by the Erwin quartzite, which is composed of hard white quartzite with beds of banded argillaceous quartzite. It forms ridges and mountains, and is the uppermost formation of the Lower Cambrian quartzose series. The Erwin underlies lower Cambrian dolomite.

The Unicoi formation was named from Unicoi County, Tennessee, where it is well exposed in the gorge cut by Nolichucky River through the Unaka Mountains. The Hampton shale was named from Hampton, Carter County, Tennessee, and the Erwin quartzite from a village of that name in Unicoi County. The writers have traced all of these formations northeastward from Tennessee into the Gossan Lead district.

UNICOI FORMATION

General description and distribution.—The Unicoi formation forms the main belt of east-trending ridges and knobs of Iron Mountain, which extends from the western border of the Gossan Lead district eastward to New River, and which lies north of the pre-Cambrian rocks (Pl. 1). Just west of New River the Unicoi formation curves south and then southwest around the pre-Cambrian rocks at the northeast plunging end of the Elk Creek anticline and is terminated by the Fries overthrust near the mouth of Elk Creek (Pl. 1). Northeast of New River the formation extends across the Gossan Lead district in a narrow belt, broken by faults, on the southeast side of Popular Camp Mountain.

The northern boundary of the area of Unicoi in the western part of the Gossan Lead district is the Byllesby overthrust (Pl. 1). The formation is enclosed in two synclines. The section of the formation in the southern syncline is more complete than in the northern one. The upper quartzite beds in the southern syncline cap the ridges that culminate in Perkins Knob and High Knob. East of Falls Branch the lower arkosic quartzite forms the southern ridge of Iron Mountain, which extends to the divide that is crossed by State Highway 94 in western Carroll County, 3 miles north of Fries. Northeast of Fries Junction the Unicoi does not form linear ridges or knobs because there the rocks have been weakened and broken by faulting.

From Comers Rock lookout eastward to the Grayson-Carroll county line the crest of the northern ridge of Iron Mountain is formed by the upper quartzite of the Unicoi exposed in anticlines in the Hampton shale. The two highest peaks are Comers Rock (4,102 feet) and Jones Knob (3,835).

South of Iron Mountain there are small outliers of the coarse arkosic conglomerate and green shale of the lower member of the Unicoi in synclines in the pre-Cambrian rocks (Pl. 1). The largest outlier caps a high hill northwest of State Highway 95 at the divide between the drainage of Knob Fork and Turkey Fork of Elk Creek. The contact of the Unicoi with the underlying pre-Cambrian granite is exposed on the highway. A small downfaulted outlier of Unicoi occurs east of Stevens Knob and south of Liberty Church, where the formation overlies Comers granite gneiss. The beds exposed in a road cut west of Liberty Church are shown in Figure 13.

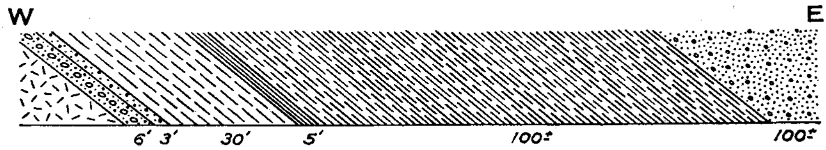

FIGURE 13.—Sketch section of lower part of Unicoi formation.

Character and thickness.—The best exposures of the Unicoi formation occur along stream gorges that have been cut across the structure, in road cuts, and at the crests of ridges. The best outcrop, and also the most complete section, of the formation is shown on U. S. Route 21 along the headwaters of Turkey Fork south of Dry Run Gap, where the road crosses Iron Mountain at right angles to the strike of the formation.

Completion of the construction of the U. S. Route 21 in 1938 made available for the first time the measured section given below. Upon the basis of this section, supplemented by data obtained from other places, the three-fold division of the Unicoi was recognized and mapped, and its structure was deciphered by tracing recognizable beds. The Unicoi is broken by thrust faults, and sections in one fault block may differ materially from those in an adjacent block because the rocks now near together were deposited at some distance apart.

The Unicoi formation in the Gossan Lead district is generally divisible into three mappable units, as follows:

GEOLOGIC SECTION 3.—ALONG IRON MOUNTAIN IN GRAYSON AND WYTHE COUNTIES, VIRGINIA

	Thickness Feet
Unicoi formation	
Upper member	
Banded light-colored and white hard quartzite with hard arkosic quartzites	600±

Middle member	
Thick amygdaloidal basalt flows with banded green argillite, probably tuffaceous, and a thick, coarse, pebble bed in arkosic quartzite	400±
Lower member	
Arkosic quartzite with coarse grains and pebbles of white quartz and pink feldspar, some beds of which are very massive and ridge makers, and shaly arkose and argillite with interbedded conglomerate at the base	700±
	1,700±

The 3 members, shown in the above section, have been mapped throughtout the Gossan Lead district (Pl. 1), and individual units with the members also have been mapped in places. The hard, ridge-making beds in the lower member have been shown on the map by a single line, except at the northeast plunging end of the Elk Creek anticline where, because of low dips, they are mapped as a wider band. The middle member generally has been mapped as a unit, but in the belt between the Byllesby and Falls overthrusts, the basalts and the thick arkose between them are shown separately. The upper, ridge-making quartzite of the upper member is mapped separately in the Fries Junction syncline.

A composite section of the Unicoi formation in the Fries junction syncline south of the Falls overthrust exposed on U. S. Route 21 south of Dry Run, is given below. This section is interpreted by the writers as a tightly compressed syncline, called the Fries Junction syncline, broken on its north side by the Falls overthrust which cuts off the north limb of the syncline. A sketch of the section, as interpreted, is given in Figure 14.

GEOLOGIC SECTION 4.—SECTION OF THE UNICOI FORMATION ALONG U. S. ROUTE 21, SOUTH OF DRY RUN GAP, GRAYSON COUNTY, VIRGINIA

	Thickness Feet
Unicoi formation	
Upper member (570 feet):	
17. Thick-bedded pebbly quartzite; dark-colored quartzite and black, compact quartzose argillite; coarse, pebbly quartzite with conglomerate beds of angular fragments of black argillite (Pl. 40; Fig. 15)	40±

16. Thick-bedded, white and green, hard, vitreous quartzite	70±
15. Green graywacke with shaly arkose at base	30±
14. Green quartzite with large pink feldspar grains and small pebbles of quartz and feldspar	60±
13. Thick-bedded, current-bedded, dark-colored quartzite laminated with white, hard, vitreous quartzite	60±
12. Thin-bedded, finely laminated green quartzite	45±
11. Thick-bedded, hard vitreous, white and green quartzite and fine-grained, green quartzite, dark banded at top	105±
10. Hard, fine-grained, compact, greenish arkosic quartzite, or quartzose argillite, containing small pink feldspar grains	110±
9. Coarse, pebbly, dark-green quartzite with pebbles of pink feldspar and white quartz, and current-bedded quartzite; manganiferous at base (Fig. 16)	50±
Middle member (430 feet):	
8. Amygdaloidal basalt, including an interbedded two-foot bed of arkose	138±
7. Compact, dark-gray to green arkose with many scattered pebbles and coarse grains of pink feldspar	40±
6. Pebble bed, densely packed, rounded pebbles up to 3 inches in diameter of quartz, black argillite, jasper, and granite. (Pl. 41, Fig. 17)	20±
5. Interbedded purple and green argillite and thin, green, laminated quartzite and a bed of small pebbles	52±
4. Amygdaloidal basalt	116±
3. Green argillite with scattered pebbles of feldspar	64±
Lower member (678 feet):	
2. Massive-bedded, light-gray, pebbly arkose and hard, dark-colored feldspathic quartzite and arkose; a ridge maker	530±
1. Green argillite with thin rust-colored quartzite beds and thin arkose at base	148±
	1,678±

Pre-Cambrian injection gneiss

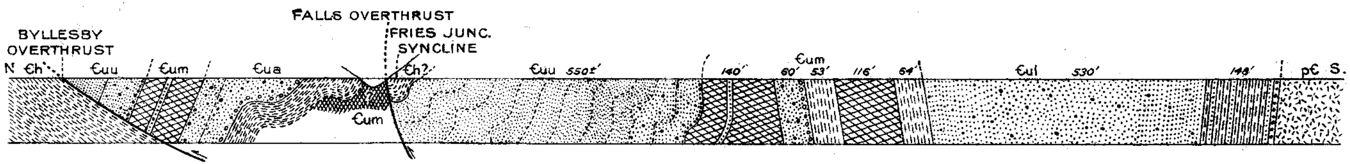

FIGURE 14.—Sketch section along U. S. Route 21, Speedwell Road. €h, Hampton shale; €uu, Unicoi formation with upper quartzites; €um, Unicoi formation with basalt flows and black argillite; €ua, Unicoi formation with medial arkose; €ul, Unicoi formation with lower arkose, conglomerate, and quartzite; p€, pre-Cambrian.

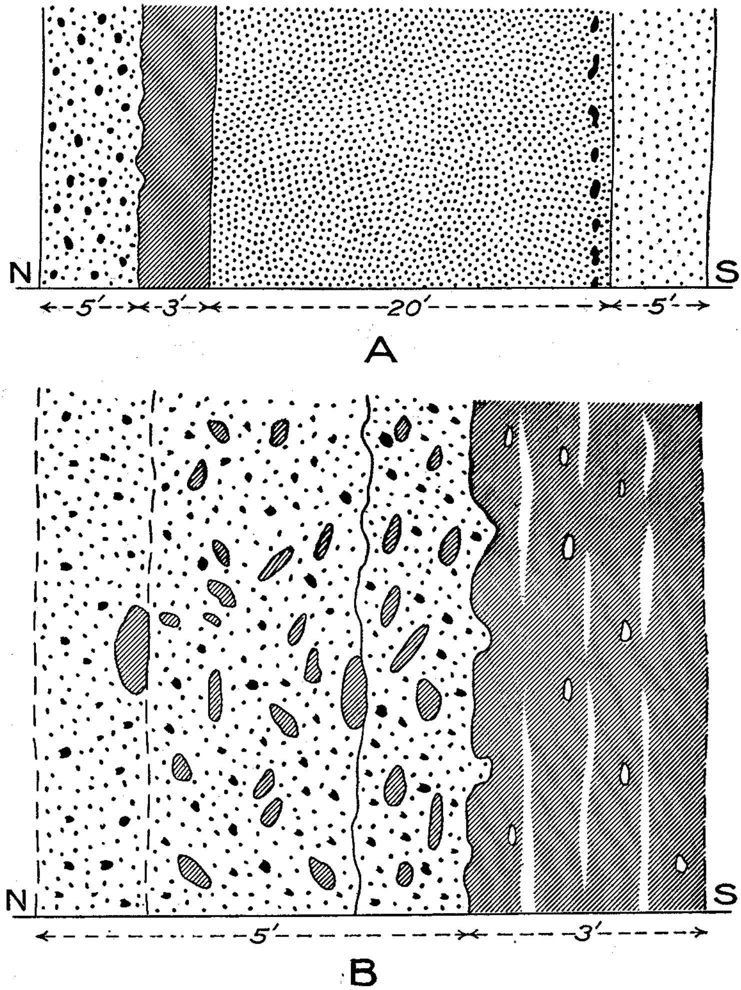

FIGURE 15.—Sketches showing black pebble conglomerate in Unicoi formation.

The formation is repeated on U. S. Route 21, north of the Falls overthrust. There, green argillite, arkosic beds with the coarse pebble bed at the base, and the upper basalt with a medial arkose layer composing the middle member, are overlain by arkose and quartzite of the upper member. The basal bed of the upper member is a manganiferous, porous pebbly arkose similar to the equivalent bed in the Fries Junction syncline to the south (Fig. 16). These beds dip north into another syncline.

Part of the Unicoi formation is exposed on the road that ascends a small branch of Knob Fork from Fallville to the top of Iron Mountain and eastward to Mountain View School, but the section is complicated

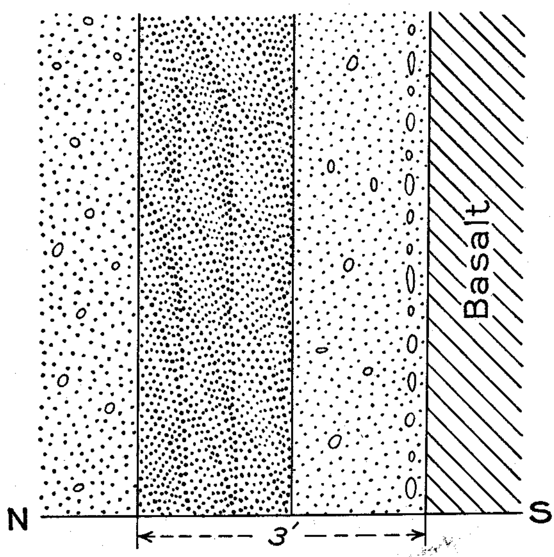

FIGURE 16.—Sketch showing current-bedded quartzite and manganiferous beds in Unicoi formation.

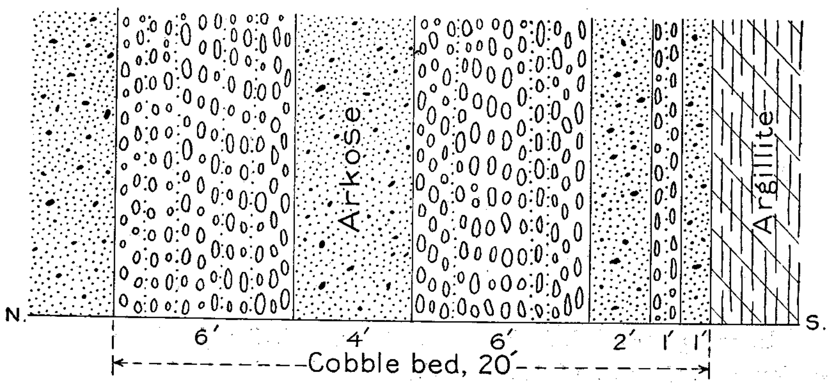

FIGURE 17.—Sketch showing coarse pebble beds in Unicoi formation.

by a normal cross fault, as well as by the Falls overthrust. South of the overthrust, about 270 feet of hard, pebbly arkose and white vitreous quartzite of the upper member overlie the arkose and basalt of the middle member. All beds dip 80° N., into the Fries Junction syncline. North of the Falls overthrust and west of the cross fault, about 30 feet of dark-colored and white-banded argillite and interbedded arkose, overlain by about 200 feet of thick-bedded vitreous arkose containing quartz pebbles in the lower 20 feet, is followed by thick amygdaloidal basalt, above which are buff argillite and micaceous fine-grained arkose containing coarse pebble beds, all of which belong to the middle member. A sketch of the geology north of Fallville, as here interpreted, is given in Figure 18.

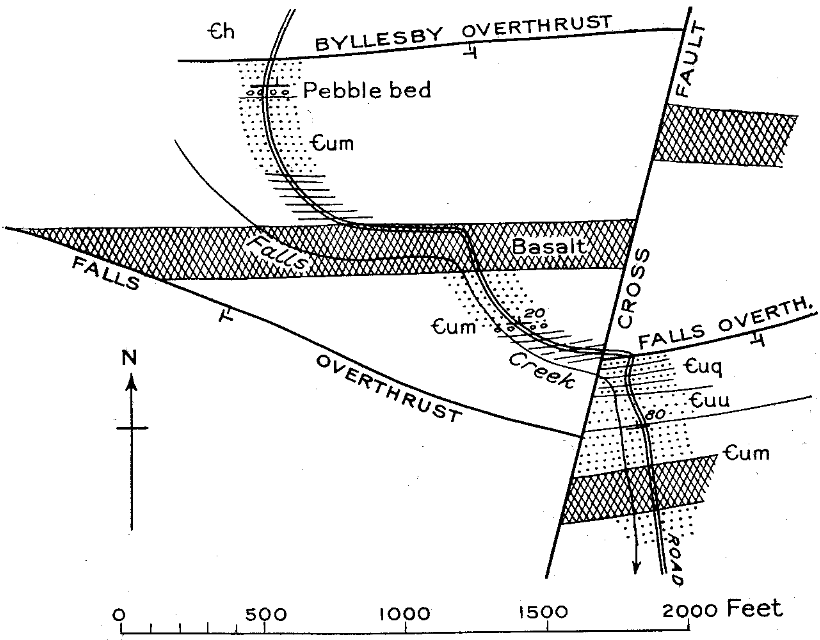

FIGURE 18.—Sketch geologic map of Unicoi formation north of Fallville. €h, Hampton shale; €uu, Unicoi formation with upper quartzites; €uq, Unicoi formation with uppermost hard vitreous quartzite; €um, Unicoi formation with basalt flows and black argillite.

In the gorge of Falls Branch, north of Fallville, 1 mile east of the section on a branch of Knob Fork, just referred to, 40 feet of white quartzite of the upper member make prominent falls (Pl. 12B), from which the village of Fallville, 1½ miles to the southwest, was named[39]. Amygdaloidal basalt, 80 to 100 feet thick, of the middle member is exposed south of the falls, and thick hard, pebbly arkosic quartzite of the lower member makes a prominent spur on the south face of the south ridge of the Iron Mountains. North of the falls and of the Falls overthrust, a section of the middle member of the formation is as follows:

GEOLOGIC SECTION 5.—EXPOSED ON FALLS BRANCH, NORTH OF THE FALLS OVERTHRUST, GRAYSON COUNTY, VIRGINIA

	Thickness Feet
Unicoi formation	
Middle member	
6. Amygdaloidal basalt	50±
5. Very massive arkosic quartzite with dark-colored matrix and pink feldspar fragments (estimated)	100±
4. Coarse pebble bed of rounded white quartz and black, dense argillite pebbles	10±
3. Hard, dense, dark-green banded, granular argillite; probably tuffaceous (estimated)	50±
2. Amygdaloidal basalt	100±
1. Covered interval (argillite?)	50±
	360±

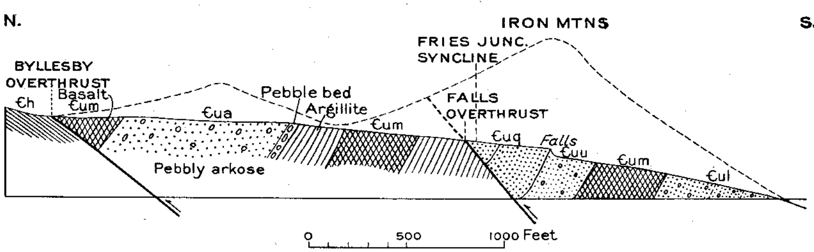

FIGURE 19.—Sketch section of Unicoi formation along Falls branch. Ꞓh, Hampton shale; Ꞓuu, Unicoi formation with upper quartites; Ꞓuq, Unicoi formation with uppermost hard vitreous quartzite; Ꞓum, Unicoi formation with basalt flows and black argillite; Ꞓua, Unicoi formation with medial arkose; Ꞓul, Unicoi formation with lower arkose, conglomerate, and quartzite.

[39] A picture of these falls, called Hales Falls by Boyd, is used as a frontispiece in his report on the "Resources of south-west Virginia," New York, John Wiley and Sons, 3rd ed., 1881.

In this section the arkosic quartzite between the basalt flows is uncommonly thick bedded, weathers to white quartzite masses, and makes a prominent medial ridge. This great thickness of arkose is present only in this belt. The section along Falls Branch, as interpreted by the writers, is given in Figure 19.

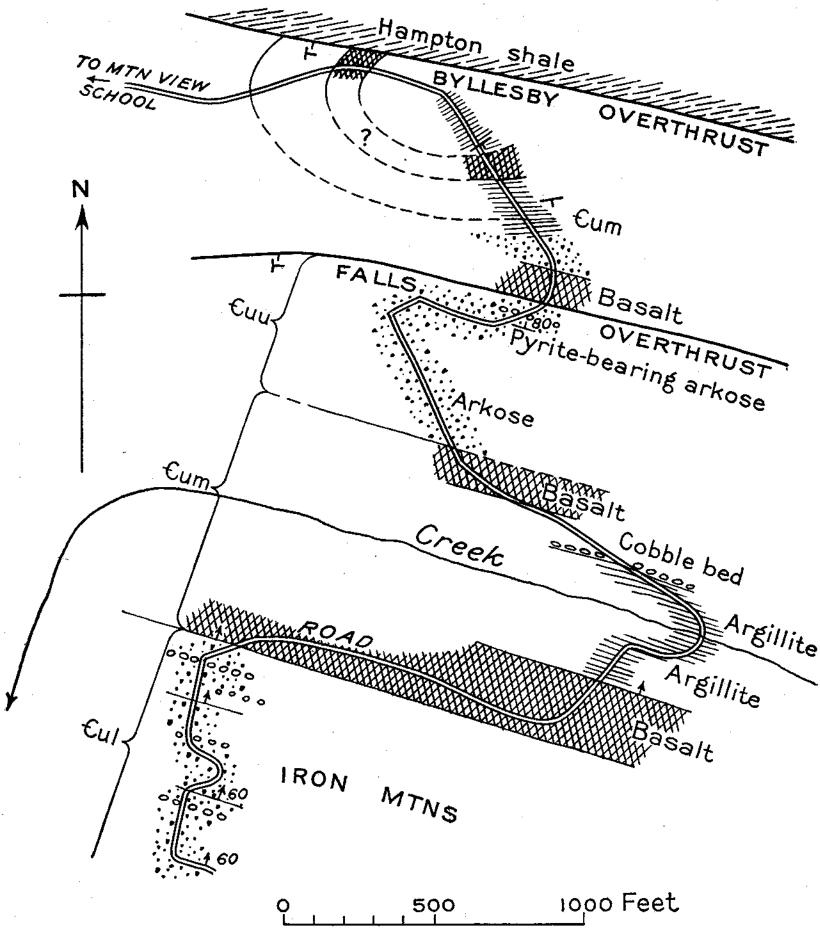

FIGURE 20.—Sketch geologic map of Unicoi formation north of Spring Valley. Єuu, Unicoi formation with upper quartzites; Єum, Unicoi formation with basalt flows and black argillite; Єul, Unicoi formation with lower arkose, conglomerate, and quartzite.

Another good partial section of the formation (Fig. 20), in the Fries Junction syncline, is exposed on the Spring Valley-Mountain View

School road that ascends Iron Mountain north of Spring Valley and crosses the divide to Shiloh. This section is as follows:

GEOLOGIC SECTION 6.—ALONG SPRING VALLEY-MOUNTAIN VIEW SCHOOL ROAD NORTH OF SPRING VALLEY, GRAYSON COUNTY, VIRGINIA

	Thickness Feet
Unicoi formation	
Upper member (500 feet)	
Hard, coarse, pebbly arkosic and rust-colored and full of pyrite where fresh; underlain by soft, reddish arkose with pebbles and coarse grains of quartz and pink feldspar; thickness estimated	500±
Middle member (250 feet)	
Amygdaloidal basalt	20±
Hard, coarse, green, pebbly, arkosic quartzite	60±
Coarse "pebble bed," composed of 3-inch rounded pebbles in a quartzose matrix	20±
Green argillite and fine graywacke (estimated)	50±
Amygdaloidal basalt (estimated)	100±
Lower member (estimated thickness 450± feet)	
Hard, pebbly, arkosic quartzite with coarse grains of red feldspar	
Softer gray arkose	
Hard, pebbly, arkosic quartzite (ridge maker)	
Softer arkose and buff sandy shale	
Thick, pebbly, white arkosic quartzite with bed of 3-inch pebbles at base (a ridge maker).	
Hard, red shale and 10-foot bed of conglomerate with argillaceous pebbles.	
Hard, tough, gray argillite (5 feet).	
Conglomerate with coarse, angular quartz and feldspar grains and fragments of greenstone schist (15 feet)	
Pre-Cambrian injection gneiss.	

The rocks in the section given above lie north of the Falls overthrust and are much confused by folding. The exposed rocks seem to be tuffaceous argillite, arkose, and metabasalt of the middle member.

On the northeast plunging end of the Elk Creek anticline, north of Fries, the beds dip more gently north and the outcrops of the individual beds are correspondingly wider. The sequence of the beds is unbroken and not confused by minor folds, but the exposures are not continous and an accurate measured section, could not be obtained. A section with estimated thicknesses is as follows:

GEOLOGIC SECTION 7.—SOUTHWEST OF FRIES JUNCTION, CARROLL COUNTY, VIRGINIA

	Thickness Feet
Unicoi formation	
Upper member (400± feet)	
Thick, white quartzite with large grains and pebbles of feldspar and quartz, and fine, white, feldspathic quartzite. Hard, vitreous, dark-and white-banded, feldspathic quartzite (50 feet thick) Hard, dark-colored pebbly arkose and quartzite.	400±
Middle member (320± feet)	
Argillite and arkose	200±
Amygdaloidal basalt	50±
Arkose	20±
Amygdaloidal basalt and coarse volcanic breccia with pink feldspar and buff tuffaceous fragments	50±
Lower member (710± feet)	
Green pebbly arkose, platy to shaly arkose, graywacke, and conglomerate of white quartz and pink feldspar pebbles	60±
Massive white vitreous quartzite and arkosic quartzite	50±
Buff to gray shale Hard, ferruginous, green, pebbly arkosic quartzite (10 feet) Black shale and shaly arkose Current-bedded, arkosic conglomerate and shale.	200±

Thin gray shale. Thick bed of hard quartzitic conglomerate (100± feet) White, pebbly arkose with scattered pebbles of white quartz and white feldspar in 20- to 40-foot beds (about 150 feet thick a ridge maker). Rust-colored pebbly arkose. Crumbly arkose and shale	400±
	1,430±

Pre-Cambrian granite complex.

The thickness of the middle member on the plunging end of the Elk Creek anticline in the above section is 320 feet, as compared with 430 feet in the measured section on U. S. Route 21. The estimated thickness of the lower member in this section is somewhat greater than in the measured section on the highway.

The ridge-making beds in the lower member, 150 feet thick in the above section, have been separately mapped (Pl. 1). They form the crest of the south ridge of Iron Mountain as far west as Falls Branch, west of which they form a bench on the south slope of the mountains to the head of Wolfpen Branch northwest of Comers Rock village, where the lower member is cut off by the Falls overthrust.

The lower arkosic beds of the formation, as seen along State Highway 94 near Whiteoak Grove School, are highly feldspathic. The pink feldspar has weathered to white kaolin, and the disintegrated rock is stained by limonite. The arkose above these lower beds is conspicuously white and weathers spheroidally, as is well shown just east of Whiteoak Grove School on the road from State Highway 94 to New River in cuts on the highway about 1 mile north of the school (Pl. 42A). The ridge-making beds exposed just to the south are hard, blue pebbly arkose. The shale beds near the base of the lower member vary somewhat in lithology. Most of them are gray to green, but in places they are red to purple. Such reddish beds are exposed on the Spring Valley-Mountain View School road and eastward to a point north of Liberty Church (Fig. 13).

Certain beds in the middle member are variable in extent and thickness. The coarse pebble bed is a good key horizon, but its extent along the strike is limited. It is prominently exposed from the western edge of the Gossan Lead district to a point near Comers Rock lookout, on U. S. Route 21 south of Dry Run Gap, and on the Spring Valley-Jones Knob road, but is absent eastward to the plunging end of the Elk Creek anticline. It is absent also in much of the region west of the Gossan Lead district. The pebbles are in a green quartzose arkosic matrix. They range from coarse grains to cobbles 6 inches in diameter. Most of them are rounded (Pl. 41), but some are subangular. The pebbles comprise white and red quartzite, red flinty jasper, black flint, pink granite, pink feldspar, white vein quartz, rhyolite and quartzite. Some of the red feldspar fragments have sharp outlines, and some of the granite pebbles are angular. Black flint pebbles are numerous and characteristic, but their source is unknown. The pre-Cambrian rhyolite flows southwest of the Gossan Lead district contain red jasper which probably was the sourse of the jasper pebbles. Some of the rounded pebbles have a highly polished surface and a black coating, similar to pebbles with desert varnish, which suggests that they may have been formed under subaerial conditions. Pebbles weathered out of the conglomerate strew the surface so thickly that they resemble a gravel deposit. The matrix and pebbles were veined with quartz subsequent to the consolidation of the conglomerate.

In most of the area south of the Falls overthrust in the Gossan Lead district, the arkosic quartzite between the basalt flows is 40 to 60 feet thick, but north of the overthrust, especially in the syncline near the falls of Knob Fork, its thickness is 100 feet. This arkosic quartzite is separately mapped (Pl. 1). Throughout most of the Gossan Lead district there are two basalt flows, one at the base and the other at the top of the middle member, but in the area west of Fries Junction the two flows are not generally separable. A bed of arkose, 20 feet thick, is present in the middle of the basalt series for a distance of three-fourths mile west of Fries Junction.

The upper member of the Unicoi formation may be divided in places into two parts, which are mapped separately in the Fries Junction syncline—a lower part, composed of hard arkosic quartzite, and an upper ridge-maker of hard vitreous quartzite. The basal arkosic beds of this member are manganiferous at several places. Higher arkosic beds contain fine-grained, green quartzite or quartzose argillite, which, on the ridge southeast of Comers Rock lookout, weathers to banded buff argillite with black partings and seams, in places stained red and containing sun cracks and other markings on the bedding surfaces.

The upper harder quartzite of the upper member is best developed in the Fries Junction syncline south of the Falls overthrust. South of

Comers Rock lookout and eastward it forms the crest of the southern ridge of Iron Mountain, and makes the high falls on Falls Branch of Knob Fork north of Fallville (Pl. 12B). Its full thickness is exposed on U. S. Route 21 south of Dry Run Gap and illustrated in Figure 14. High Knob to the east is capped by this upper quartzite in a minor syncline. Its outcrop is wider east and west of State Highway 94 because of the gentle dip of the beds in the Fries Junction syncline in this vicinity. Argillite and arkosic quartzite at the top of the middle member are also exposed here.

Basalt flows.—The basalt flows which occur in the middle member are dense green volcanic rocks with vesicular layers at the tops of flows. The denser layers are in the lower part of the flows. The massive basalt makes falls in some of the streams. The vesicles are filled with a variety of minerals, chiefly green epidote, pink feldspar, red jasper, and colorless quartz (Pls. 42B-42C). Where chlorite is the filling and the basalt has been closely compressed, the amygdules appear as dark-green blebs or spots on the schistose planes of the basalt (Pl. 43B). Green basalt is the most common variety, but in places, as in the lower flows seen on the Spring Valley-Mountain View School road, the basalt is bluish gray. The vesicles are filled with epidote, quartz, red jasper, calcite and deep-pink feldspar as shown in Plate 42B. A few vesicles in the rock illustrated in Plate 42B contain epidote. North of the Falls overthrust on the road north of Spring Valley, the amygdules in the green basalt are composed of jasper. On the top of Iron Mountain, west of Comers Rock lookout, white and pinkish-white chalcedony form the amygdules in the lower flows. The amygdules are roughly spherical in shape and stand out as knots on the weathered surface of the basalt. The groundmass is composed of fine-grained hornblende and feldspar.

West of Comers Rock lookout the upper flow is overlain by 20 feet of interbedded, purple-banded arkose and thin purple flows and tuffs. Some layers show flow-banding and contain vesicles filled with white and red chalcedony. These beds directly underlie the purple-banded quartzite at the base of the upper member of the Unicoi formation.

In thin section the green basalt shows an ophitic texture in which the earlier-formed, lath-shaped feldspar was enclosed in the other constituents. The original dark-colored mineral, augite, is now present as green hornblende and chlorite. Sericite and quartz also occur. The feldspar, originally of the calcic variety labradorite, has been altered to a more sodic variety and the original lime has probably combined with silica to form epidote. Quartz was released during the chemical changes. Magnetite and ilmenite commonly are present in all types of flows.

Most of the amygdules are zoned; in many places pink feldspar forms an outer shell with epidote and quartz in the center, or quartz may form the outer part with a center of chlorite. Where calcite fills the amygdules, it is intergrown with green chlorite (Pl. 42C).

Volcanic Breccia and tuff have been found associated with the basalt at two places—one east of State Highway 94, ¾ mile southwest of Fries Junction, and the other on the top of Iron Mountain west of Comers Rock lookout. The volcanic breccia southwest of Fries Junction contains angular fragments of basalt in a green matrix. The middle member of the Unicoi formation on U. S. Rout 21, south of the Falls overthrust and south of Dry Run Gap, contains interbedded purple and green argillites which underlie the coarse pebble bed. Although the argillites contain no flattened blebs characteristic of many tuffaceous rocks, they resemble purple and green tuffs found elsewhere in the middle member of the Unicoi. A light-gray to black, banded argillite occurs in the middle member north of the Falls overthrust on the Spring Valley-Mountain View School road up Iron Mountain. This argillite resembles a very dense basalt suggestive of tuffaceous origin. It is interbedded with a fine-grained, dense, green arkose.

East of Troutdale, southwest of the district covered by this report, there is more variation in the basalt flows. West of the Flat Ridge-Sugar Grove road a pink variety of the basalt occurs in the top of the lower flows. It is a vesicular rock containing abundant pink feldspar, quartz, and epidote in a grayish-blue matrix. At this locality a purple volcanic rock, with vesicles filled with epidote and calcite, occurs interbedded with a red tuffaceous shale. In places the basalt is a dense green rock with ophitic texture, and contains white euhedral feldspar crystals a half inch in length.

Distribution and Character Northeast Part of the District

The Unicoi formation occurs in a narrow belt northeast of Toby Knob, east of New River in Carroll County. This belt extends across the area from the Fries overthrust on the south to the Byllesby overthrust on the north. A nearly complete section of this formation on the north side of the Bowers Ferry overthrust, is exposed on Poor Branch, in the Max Meadows quadrangle, from a point just south of McGee School northward for three-fourths mile to the mouth of Stoots Branch. The lower member here is composed of thick-bedded arkose and conglomerate with pebbles of rounded white quartz and pink feldspar that measure as much as half an inch in diameter. The dark green matrix is composed of quartz, feldspar, green muscovite, and chlorite. The conglomerates are interbedded with and overlain by fine-grained, green quartzite. North of the conglomerate beds, the higher part of the section consists of basalt flows, dark-colored quartzose argillite, and quartzite of the middle member. The basalt flows occur in two thin layers separated by thin arkose. All beds of the middle member lie on the edge of the Byllesby overthrust block, and are closely folded, fractured, and veined with quartz.

Other exposures of the arkosic and conglomeratic beds of the lower member of the Unicoi may be seen on Brush Creek northwest of Fries Junction, on New River south of Byllesby, on the road to Fowler Ferry, and on Rocky Branch southeast of the ferry. The basalt of the middle member, which lies northwest of these beds, extends from the mouth of Stoots Branch to a point just west of Byllesby. It occurs also in a short belt that crosses Brush Creek east of State Highway 94. Argillite of the middle member overlies the basalt in both places. At Byllesby the basalt and the underlying arkose are exposed in a quarry west of the dam of the Appalachian Power Company's hydro-electric plant. The overlying argillite is well exposed in the small hill west of the tailrace and the basalt and argillite are exposed also on the east side of New River north of the dam where the basalt forms cliffs on the road along the river southwest of Fowler Ferry. In these outcrops the basalt and argillite are closely folded and sheared.

Northeast of Poor Branch, on the east side of New River, the conglomerate beds of the lower member are less prominent. In exposures of the Unicoi on Shorts Creek south of the Byllesby overthrust, the formation is composed of a dark-colored quartzite with shiny slate, broken by closely spaced slip planes. The sequence could be determined here.

The Unicoi formation, south of the Bowers Ferry overthrust, occurs in a belt not more than 1 mile wide. This belt extends from Toby Knob at New River, north of Fries, northeastward across the Gossan Lead district. The rocks are mostly arkose and conglomerate, probably of the lower member. The middle member is represented by argillite and a small body of basalt, which crops out on the south side of this belt at Stoneman Hill. The basalt is sheared, and cut by quartz veins that contain pyrite. A larger area of basalt and associated argillite, which lies north of the white quartzite, was traced from Chestnut Creek northeastward to the road that leads from River Hill School to Bowers Ferry. The argillite extends northeastward to where it is cut out by the Bowers Ferry overthrust. Dark green quartzite that lies northwest of the belt of argillite is exposed from Chestnut Creek to a point northeast of Bowers Ferry, where it also is cut off by the Bowers Ferry thrust fault. In this belt of Unicoi exposed on U. S. Route 52, which follows Shorts Creek, and in the bends of Little Reed Island Creek to the northeast, a thin layer of greenstone schist occurs between sheared argillite and dark-green quartzite. The greenstone schist is traceable northeastward from Shorts Creek for 4 miles. It is well exposed in the railroad cuts northwest of Sylvatus.

Metamorphism.—The Unicoi formation generally is but little metamorphosed, but in the belt in the northeast part of the district, just discussed, comprising the McGee School anticline in the Max Meadows quadrangle, and the belt between the Bowers Ferry and Fries overthrusts, south of this anticline, it is strongly folded, the bedding and cleavage dip south, and the beds near the thrust faults are dispaced by slipping, are veined with quartz, and in many places are ground out into a mylonite. The conglomeratic arkose has a dark-green matrix composed of green chlorite, muscovite, quartz, and feldspar. Grains and pebbles of pink and red feldspar, which stand out prominently in the dark-colored matrix, are much broken, and the quartz grains are granulated. In thin section the feldspars are seen to be microcline, perthite, and plagioclase, which are granulated along cracks. The quartz is granulated and shows strain shadows. The fine-grained green quartzites contain chlorite and muscovite. Their metamorphism is of a low rank. An arkosic quartzite occurring at the mouth of Crooked Creek, is a dense, finely layered mylonite in which the layers of fine quartz and muscovite pinch and swell around larger residual grains of quartz and feldspar. The massive green quartzite near the mouth of Chestnut Creek is a dense, green, vitreous, laminated rock with small residual blue quartz grains. In thin section these mylonitic rocks are seen to be a layered quartz-muscovite schist. The quartzose layers are very fine grained, owing to the grinding out of the constituents, and are separated by muscovite partings. Mylonitic quartzite is exposed in a quarry on Poor Branch just south of its junction with Stoots Branch, where the rock contains numerous quartz veins.

In the area north of the Falls overthrust and northeast of State Highway 94 and New River the basalt flows are folded and sheared. In the belt between the Bowers Ferry and Fries overthrusts, near the mouth of Chestnut Creek and southeast of Shorts Creek village, the basalt appears as a fine-grained greenstone schist that exhibits closely spaced, shiny, dark-colored ribbons half an inch wide, which are parallel to the linear direction of the foliation (Pl. 43B). Because of the fineness of grain, the constituents, except epidote, could not be determined with a hand lens. In thin section the shiny ribbons are seen to be composed of chlorite and a fibrous, pale-green hornblende. Other constituents are lath-shaped feldspar, titanite, ilmenite, epidote. Traces of an original diabasic texture are sometimes detectable but a schistose layering is the dominant structure (Pl. 43A). The mineral composition is characteristic of a metamorphosed basalt in which the plagioclase apparently has reacted with augite to produce chlorite and hornblende, and the feldspar has altered to a more sodic plagioclase, and epidote.

The argillite on Brush Creek and at Byllesby is thin layered. At Bowers Ferry it is a finely laminated slate characterized by irregular, dark-colored, shiny, slickensided cleavage surfaces. Thin sections of the argillite show fine-grained clastic quartz, with fine scales of muscovite and chlorite on the layers. It appears from the cataclastic texture of the rock that its thin layering has been the result of a microbrecciation of quartz and feldspar, and that the larger grains are remnants of original relatively larger grains. The muscovite and chlorite probably were developed during metamorphism and cataclastis.

In the Shorts Creek section, north of the road to Round Knob School, the quartzite mylonite is a layered quartzose rock with graphitic slaty partings, and to the north, where U. S. Route 52 bends westward, a grayish-black slate with thin quartzose layers is well exposed. These beds show a lenticular structure caused by slipping. The harder quartzose layers move as a unit, and are inclined at an angle of 40° to 50° SE. The weaker argillaceous layers show variable angles of dip, which are greater close to the hard beds, but in general the dip is only 20° SE. The layers of such rocks have a curved cleavage and break into irregular rhombs bounded by the two sets of intersecting slip planes, which have irregular slickened surfaces (Pl. 53B). It occurs in rocks that have beds of unequal hardness at many places on the edge of the Blyllesby and Falls overthrust blocks northeast of Fries Junction and along the Fries overthrust to the south.

Age and correlation.—No fossils have been found in the Unicoi formation. Some tubular markings in the quartzite of the upper member exposed in the anticline that crosses Dry Run just south of the mouth of East Fork may be *Scolithus* tubes. The formation is conformably overlain by the Hampton shale, also unfossiliferous. The Erwin quartzite, which lies conformably above the Hampton shale, contains Lower Cambrian fossils. The Unicoi formation is therefore regarded as of Lower Cambrian age because it is the lower part of a continuous, conformable sedimentary series of arenaceous and argillaceous rocks in which Lower Cambrian fossils are found in the upper part.

The Unicoi formation from its type locality in Tennessee northeastward to Roanoke, Virginia, has similar lithology, and contains basalt flows about 700 feet above the base.

Resser[40] includes the Erwin quartzite in the Cambrian system because its upper-most beds contain Lower Cambrian fossils, but he places the Unicoi formation and Hampton shale in the pre-Cambrian "Beltian series." Although the Cambrian age of the Unicoi formation and Hampton shale cannot yet be proved by fossils, the fact that they are conformably overlain by similar clastic rocks, that contain Cambrian fossils throughout the Appalachian region, indicates that there is no diastrophic break between them. The Unicoi formation unconformably overlies pre-Cambrian rocks described above as the injection complex, and the Mount Rogers volcanic series. It was deposited after a period of erosion which removed the volcanic series in a large part of the area, and for that reason is separated from the pre-Cambrian rocks by a marked stratigraphic break. The Unicoi formation, therefore, belongs in the Cambrian system.

HAMPTON SHALE

Distribution.—The Hampton shale overlies the Unicoi formation conformably. Its occurrence is confined mainly to a belt which has a maximum width of 2½ miles, on the north side of the Unicoi formation. This belt of Hampton shale extends from the western edge of the district eastward to New River. Northeast of New River a narrow belt of Hampton shale lying on the northwestern slope of Poplar Camp Mountain extends to Little Reed Island Creek.

The main body of Hampton shale, west of New River is divided into two parts (Pl. 1) by the Brush Creek overthrust, the belt south of the Brush Creek fault and the belt north of the Brush Creek fault.

The belt south of the Brush Creek fault is interruped by a number of exposures of the upper member of the Unicoi formation brought to the

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[40] Resser, C. E., Preliminary generalized Cambrian time scale: Geol. Soc. America Bull., vol. 44, no. 4, pp. 735-746, 1933. Cambrian system (restricted) of the southern Appalachians: Geol. Soc. America Spec. Paper 15, pp. 2, 20, 1938.

surface in anticlines. The quartzite of the Unicoi forms mountains, the Hampton shale occupies the lower ridges and valleys.

The belt north of the Branch Creek fault is irregular in trend, narrow in places, and contains numerous infolded synclinal areas of Erwin quartzite.

South of the two main belts small areas of the Hampton shale are infolded in the Unicoi formation. One of these areas occurs on U. S. Route 21 about 1 mile south of Dry Run Gap. Another and a larger area lies south of Bournes Branch, 8 miles east of the former area.

The south slopes of Chestnut Knob and the ridges southwest of the knob are made up of Hampton shale. This shale also occurs in a narrow sinuous belt south of Gleaves Knob. These occurrences are all located in the Gleaves Knob thrust block (Figs. 23 and 24).

Character and thickness.—The Hampton shale is a homogeneous argillaceous formation which contains no distinctive key beds. It tends to form valleys, lowlands, and low ridges, between the mountains composed of the Unicoi and Erwin formations. It is generally a gray to black shale. The shale in places is grayish green, with beds of a bluish-gray banded argillite that contains thin quartzose layers. The quartzose layers are finely banded and ripple marked. Near the top of the formation these quartzose layers are more numerous (Pl. 44A). The formation weathers to a buff shale that yields small shaly fragments in a thin, gray, infertile soil. The main streams, such as the headwaters of Dry Run and Francis Mill Creek, Brush Creek and its two tributaries, Little Brush Creek and Bournes Branch, have eroded deep valleys into this shale. The belt of Hampton shale west of New River is crossed by two main north-south highways along which the shale is well exposed. On U. S. Route 21 a hard, bluish-gray, banded argillite is well exposed in a deep new cut at Dry Run Gap. A large concretionary sandy mass found in the shale near the gap is illustrated in Plate 44B. Similar quartzose argillite and black shale are exposed on State Highway 94 north of the bridge over Brush Creek, 1½ miles northwest of Fries Junction. There are few roads within the shale area, the main ones being the road that extends up East Fork of Dry Run and crosses the divide to Francis Mill Creek, and the road along Brush Creek that extends north to Little Wythe Furnace.

A dark argillaceous rock, exposed in a small area on U. S. Route 21, three-quarters mile south of Dry Run Gap, has been tentatively assigned to the Hampton shale. This rock, however, does not have the typical shaly character of the Hampton and may represent transition beds. It is a compact, dark-colored, banded, argillaceous, fine-grained quartzite with buff laminations. It overlies a pebbly quartzite of the upper part of the Unicoi formation. An area south of Bournes Branch contains a shale that is a dark-colored, platy rock which weathers to a buff-colored shale typical of the Hampton formation.

This formation is closely folded and has a well-developed cleavage which obscures all bedding except in the quartzose layers. Because of its homogeneous character, the absence of key beds, and the close folding, the sequence of beds and thickness of the formation could not be accurately determined. In most places the whole thickness of the formation is not exposed because of thrust faults that break up the mass. South of the Brush overthrust, in the valleys of East and West forks of Dry Run, three outcrops of quartzite, that were tentatively regarded as Erwin, occur in the Hampton shale between anticlines of upper Unicoi formation. If these quartzites be Erwin, the entire section of Hampton would be present here, but, due to close folding, lack of observable bedding, and poor exposures, the thickness could not be accurately determined. From the width of outcrop of the shale and an assumed average dip of the beds, it was estimated that the formation in this area has a thickness of 1,500 feet.

Age and correlation.—No fossils have been found in the Hampton shale; however, it is probable that they once existed but have been obscured or destroyed by the great compression of the rocks which developed the cleavage. The Hampton shale conformably underlies the Erwin quartzite which contains fossils of Lower Cambrian age, and it is therefore also regarded of that age. It is approximately equivalent to the Harpers shale of Maryland and Pennsylvania, which underlies the Antietam quartzite, the equivalent of the Erwin, and overlies the Weverton quartzite, the equivalent of the upper part of the Unicoi formation.

ERWIN QUARTZITE

Distribution.—The Erwin quartzite conformably overlies the Hampton shale and forms the top of the Lower Cambrian arenaceous series. Like the Unicoi formation, it is composed of quartzites that are resistant to erosion and that form mountains and ridges. These ridges lie just south of the limestone lowlands of the Great Valley.

The Erwin quartzite in the district mapped (Pl. 1) occurs in three structural belts. The most southerly belt lies south of the Poplar Camp overthrust and north of the Brush Creek overthrust, (Fig. 23), and extends across the Gossan Lead District in an east to northeast direction. In the western part of this belt the Erwin forms a series of discontinuous mountains and ridges surrounded by the Hampton shale. The most northerly ridge of Erwin quartzite south of the Poplar Camp overthrust ends in Sindion Point, west of Dry Run and southwest of Speedwell. Eastward the quartzite forms Porter Mountain, Horse Heaven ridge, and Devils Den Mountain. Just west of New River it forms Farmer Mountain, and east of New River it forms Poplar Camp Mountain. Near Little Reed Island Creek the Erwin quartzite bends sharply north to make Dry Pond Mountain, which terminates just south of Boom Furnace. Three small areas of Erwin quartzite lie in the Hampton shale south of the Brush Creek overthrust.

The second belt of Erwin quartzite which occurs in the Gleaves Knob thrust block (Fig. 24), extends from Gleaves Knob southeastward through Raven Cliff to the northern part of Ewing Mountain and Chestnut Knob. In the southwestern part of Ewing Mountain, the Erwin forms linear ridges that trend westward to Shiloh. At the east end of the Gleaves Knob block the Erwin quartzite is closely folded and broken by thrust faults. It forms several linear ridges, which include Cold Ridge, west of New River, and Short Hill and Little Mountain east of the river.

The third belt of Erwin quartzite comprises two anticlines that rise out of the Great Valley. The western anticline is the Fry Hill anticline, which includes Little Horse Heaven ridge and other front ridges and spurs to the west. The eastern anticline forms Fosters Falls Mountain. The quartzite is exposed also in a minor anticline along the same general axis southwest of Hematite Mountain in the New River valley bottom.

A small hill of Erwin quartzite occurs in Collins Cove on Cove Branch, southeast of Cripple Creek, and another small area forms a hill north of High Rocks Mill, southeast of Patterson. A very narrow band of Erwin quartzite, 5 miles in length, extends from a point 1 mile west of Dry Run and 1 mile northwest of Speedwell southwestward to the western edge of the Gossan Lead district.

Character and thickness.—The Erwin quartzite in the Gossan Lead district is composed essentially of quartzites, so distinct in character that in most of the area it is possible to separate it into four members, each with a characteristic lithology. A generalized section is as follows:

GEOLOGIC SECTION 8.—IN GRAYSON AND WYTHE COUNTIES VIRGINIA

Erwin quartzite

Upper member

Thin-bedded quartzite with pebbly quartzite layers, at the top fossiliferous beds weather rust-colored.

Middle member

Laminated argillaceous quartzite, generally not well exposed, and thin white quartzite beds.

Ridge-making member

Massive white quartzite with quartz-conglomerate beds at the base.

Lower member

Thin-bedded, dark-banded quartzite, that weathers to a rust-colored rock, and interbedded black shale.

The lithology and the thickness of the Erwin quartzite differ in each of the three structural belts. Quartzites, now lying close together because of folding and thrust faulting, apparently were deposited some distance from each other across the strike and, therefore, have different characteristics.

The southern belt comprises the rocks in the Poplar Camp-Holston Mountain Overthrust block. In this belt, the Erwin quartzite occurs in synclines in the Hampton shale. The upper member is not preserved in any of the synclines and the middle member in only a few. East of New River, on the south slope of Poplar Camp Mountain and in Dry Pond Mountain, the Erwin quartzite is folded into synclines in which the overlying Vintage dolomite is enclosed.

West of New River the ridge-making member of the Erwin quartzite forms some of the highest mountains in this part of the Gossan Lead district. They include Horse Heaven ridge, which culminates in a peak 3,900 feet in altitude, Porter Mountain and Devels Den peak. These ridges and peaks have a synclinal structure in which the ridge-making quartzite caps the crests while the lower member of the Erwin quartzite is exposed on the slopes.

In this area a bed of a dense white quartzite that contains closely packed and well-cemented pebbles and grains of milky quartz occurs at the base of the ridge-making quartzite. This bed is a very useful horizon marker in mapping the divisions of the Erwin. Both this bed and the overlying vitreous white quartzite show current bedding. Some of the higher quartzite beds of the ridge-making member contain *Scolithus* tubes. All of these beds of the ridge-making member crop out on Horse Heaven ridge and form cliffs in the peak at the northeast end of the ridge. The ridge-making member weathers to a thin sandy soil that contains blocks which strew the steep slopes of the mountains and choke the ravines. The crests and steep slopes of these mountains are generally forested and sparsely settled.

Because of the ruggedness of the mountains made by the Erwin quartzite, the few north-south roads that cross it, west of New River, follow stream valleys. U. S. Route 21 descends the valley of Dry Run. Secondary roads follow Francis Mill Creek and Cold Run. State Highway 94 follows the headwaters of Little Brush Creek, and a secondary road east of State Highway 94 crosses the southwest end of Farmer Mountain and extends along the left side of New River. The Erwin quartzite is best exposed along these highways. Throughout the rest of the area the formation may be seen best along trails which, as shown on the topographic map, follow the main valleys and ridge tops.

The ridge-making quartzite member which caps Farmer Mountain, northwest of Byllesby, descends to the river in prominent ledges south of Buck Station. North of the station this quartzite is repeated in two tightly compressed minor synclines. The dark-colored, argillaceous, rhythmically banded quartzite of the lower member is well displayed to the north of the northern minor syncline. The ferruginous quartzite of the middle member is exposed along the river west of Byllesby School.

From Farmer Mountain northeastward to Little Reed Island Creek, the Erwin quartzite, that forms Poplar Camp Mountain, lies on the south limb of an anticline. The lower member of the Erwin is exposed on the north slope of Popular Camp Mountain. The crest of the ridge is composed of the ridge-making member. In Shorts Creek gorge along U.S. Route 52 the rocks of the Poplar Camp block are well exposed, but, due to repetition by folding and the alteration of the rocks, the thickness of the beds could not be measured. A composite section with estimated thicknesses of the rocks in Poplar Camp Mountain, exposed along U. S. Route 52 north of the mouth of Porter Branch, is as follows:

GEOLOGIC SECTION 9.—IN SHORTS CREEK GORGE, CARROLL COUNTY VIRGINIA

	Thickness
Shady dolomite	*Feet*
Blue siliceous dolomite with many glassy quartz grains	
Erwin quartzite	
Upper member not exposed	
Middle member (135± feet)	
Thinly banded, platy quartzite in beds 1 to 2 inches thick, with slate partings, and a bed of fine-grained, white quartzite, 18 inches thick (estimated)	120±
Dark-colored slaty quartzite with black slate partings	15±

Ridge-making member	
Hard blue quartzite bed, 3 feet Thinly banded quartzite with slate partings Thick bedded, granular quartzite, and conglomerate Massive-bedded quartzite, 20 feet	60–80
Lower member	
Thin-bedded quartzite with black shale partings Rhythmically banded quartzite beds 3 to 4 inches thick, with black shale parting Dark-colored argillaceous quartzite, banded with light-gray to purplish sandy layers	200±

The ridge-making member, composed of thick-bedded quartzites with thin black shale partings and conglomerate layers, makes ledges dipping 60° S. The lower member, exposed to the north, shows characteristic thin-bedded quartzites banded with a dark-colored argillaceous slaty quartzite. This banding is markedly rhythmical toward the base (Pl. 45). The general dip of these beds is 70° S. The middle and upper members of the Erwin and the overlying Vintage dolomite to the south are so tightly squeezed in the syncline that their distinctive characters are obscured.

Elsewhere in this part of the Poplar Camp block the rocks are closely folded and poorly exposed. The upper member is well exposed on the south side of Poplar Camp Mountain in two synclines which contain the overlying Vintage dolomite along Poor Branch and northeast of Shorts Creek village. At both places the upper member contains a dark-green, banded quartzite and a calcareous quartzite. These quartzites weather to a porous rock stained with limonite in which molds of fossils are preserved.

On Dry Pond Mountain, (Fig. 27 and Pl. 46A-B) which lies northeast of Poplar Camp Mountain, the four members of Erwin quartzite have been recognized and mapped, but nowhere is there a continuous section exposed. Outcrops are poor on the mountain except on the west face along Little Reed Island Creek and in the deep hollows that have been cut into the west face of the mountain. The main ridge is composed of pebbly, current-bedded, vitreous, *Scolithus*-bearing quartzite of the ridge-making member, exposed in an anticline. The lower member of the Erwin, composed of dark-colored argillaceous quartzite, crops out in a gorge of a branch of Little Reed Island Creek at the north end of

Dry Pond Mountain, south of Boom Furnace, and in a sharp bend of Little Reed Island Creek south of High Rocks Mill. (Figs. 25, 26, 27)

At the mouth of Alum Hollow, where Alum Creek joins Little Reed Island Creek and southward to the mouth of Moccasin Branch, there are cliffs 300 feet high of folded, dark-colored sheared quartzite. Beds above the ridge-making member make the west flank of Dry Pond Mountain. Southeast of the crest of the mountain, along Buck Island Hollow, the upper member of the Erwin is exposed in a small sharp syncline which also inclosed the overlying Vintage dolomite. The upper beds of the Erwin are ferruginous, and weather to a dark-red soil.

The full section of Erwin quartzite of the second belt is present from Gleaves Knob southeast to Ewing Mountain. The quartzite overlies Hampton shale on the south and dips gently north under Vintage dolomite. In the vicinity of Ewing Mountain the maximum width of the quartzite belt across the strike is 2 miles. Sections of Erwin quartzite are exposed in the gorges of Rock Creek, southwest of Raven Cliff, and along Cripple Creek just west of the mouth of Cove Branch. In the Cove Branch gorge, which is cut into the north slope of Ewing mountain 1 mile south of Eagle, the section of Erwin quartzite is as follows:

GEOLOGIC SECTION 10.—IN COVE BRANCH GORGE SOUTH OF EAGLE, WYTHE COUNTY, VIRGINIA

	Thickness Feet
Vintage dolomite	
Massive blue dolomite	
Erwin quartzite	
Upper member (40± feet)	
Thin-bedded, gray and fossiliferous, green phosphatic quartzite	10±
Thin-bedded, irregular-layered, granular quartzite	30±
Middle member	
Irregularly bedded, thick-and thin-bedded quartzite weathering rust-colored	140±
Ridge-making member	
Thick-bedded white quartzite	20±
Lower member	
Dark-colored, argillaceous quartzite laminated with thin white bands	250±
	450±
Hampton Shale	

From Gleaves Knob eastward along the ridges and spurs of the northwest branch of Ewing Mountain to Chestnut Knob and eastward to the headwaters of Power Mill Branch, the crest of the mountain is formed by the hard, ridge-making member, composed of pebbly conglomerate, vitreous, current-bedded quartzite, and *Scolithus*-bearing quartzite. The lower member underlies it on the upper slopes of these mountains. The ridge that extends from the crest of Ewing Mountain southwest along the Carroll-Wythe County line, and a higher parallel ridge to the northwest, are in part capped by the ridge-making member, while the lower member is exposed on their southern slopes. Just west of these ridges and west of Cold Run three hills, capped by quartzite of the ridge-making member of the Erwin and surrounded by Shady dolomite, are outliers of the Gleaves Knob overthrust block resting on the dolomite. (Figs. 41, 46.)

Outcrops of the ridge-making member in the gorges of Rock Creek and Cove Branch and also on Chestnut Knob dip 20° to 25° NE. Along Power Mill Branch, which has cut a deep valley in the north slope of Ewing Mountain, the exposures of the argillaceous quartzite are few.

Currier[41] states that the Erwin quartzite of Ewing Mountain was thrust northward on the Ewing Mountain overthrust, that the thrust dips at a low angle to the south, and that, where it passes southwest into Ewing Mountain 2½ miles west of Ivanhoe, the displacement is at its maximum. The writers, however, saw no evidence of this thrust fault on the north side of Ewing Mountain.

There the upper member is well exposed from a point on Cripple Creek, west of Raven Cliff, eastward to Powder Mill Branch. Along Cripple Creek the upper member, exposed in cuts along an abandoned railroad, dips north at about 10°. Here and on Cove Branch the highest bed is a five-foot layer of rust-colored, calcareous quartzite with green phosphatic clay pellets, which is underlain by a rusty-green-colored, calcareous quartzite with poorly preserved fossils. Similar beds, containing *Obolella* and fragments of trilobites, were seen in ravines in the northeast flank of Ewing Mountain, southwest of Ivanhoe. These beds, characteristic of the uppermost Erwin dip 5° NE beneath the overlying Vintage dolomite. The rocks at these contacts show a continuous section with no

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[41] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, p. 59, 1935.

evidence of movement, therefore, the writers regard the sequence there and on Powder Mill Branch as normal and unbroken, and have shown[42] it as such in a published report.

On Powder Mill Branch a pebbly quartzite, at the base of the upper member, makes a low falls in the stream. Higher up the valley a ledge made up of thin-layers of quartzite of the middle member forms a second falls and still higher up the valley the vitreous ridge-making quartzite produces a third falls. Southeast of the headwaters of Powder Mill Branch the Erwin quartzite, in the Gleaves Knob block, is folded into two tightly compressed, nearly east trending, faulted anticlines, in which the ridge-making member forms Cold Ridge and a narrow ridge north of it. The upper member of the formation on the north limb of the Cold Ridge anticline is well exposed on State Highway 94 (Fig. 42). The uppermost beds contain round manganese-stained quartz grains and green phosphatic clay pellets. These beds overlie red, weathered, fossil-bearing quartzite.[43] Quartzites, with similar lithology, near the contact with the overlying Vintage dolomite, are exposed in a hollow west of the divide. The upper member is exposed in road cuts along the west side of New River, east of Round Top, and in ravines on the north slope of Cold Ridge. These upper beds are ripple marked.

The Erwin quartzite of the third structural belt is exposed in the Fry Hill (Fig. 21) and Fosters Falls Mountain anticlines. (Fig. 40) The

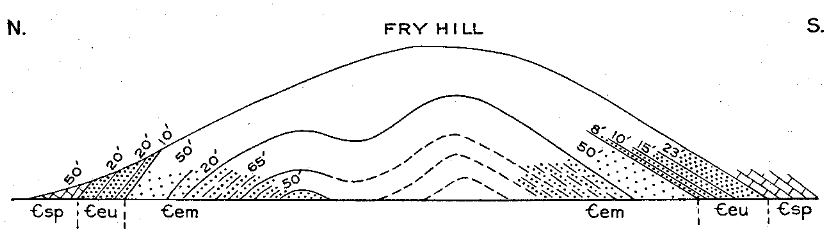

FIGURE 21.—Sketch section of upper part of Erwin quartzite north of Little Wythe Furnace in Fry Hill. €sp, Shady dolomite, Patterson member; €eu, Erwin quartzite, calcareous, €em, Erwin quartzite, argillaceous.

quartzite in this Fry Hill anticline extends from Fry Hill 1¼ miles south of Cripple Creek village, westward along the mountain front to Dry Run.

[42] Stose, G. W., and Jonas, A. I., A southeastern limestone facies of lower Cambrian dolomite in Wythe and Carroll counties, Virginia: Virginia Geol. Survey Bull. 51, Pl. 1, 1939.

[43] Beds of this type and at this horizon carry manganese ores in Shady Valley and Stony Creek Valley, Tennessee.

GEOLOGIC SECTION 11.—IN THE FRY HILL ANTICLINE, SOUTHWEST OF CRIPPLE CREEK VILLAGE, WYTHE COUNTY, VIRGINIA

	Thickness Feet
Erwin Quartzite	
Upper member	
4. Thin-bedded quartzite that weathers rust-colored	90±
Middle Member	
3. Shaly to thin-bedded, harder white quartzite, with a few black shale partings (caps small front knobs)	90±
Ridge-making member	
2. Hard, white, vitreous quartzite and a conglomerate layer of densely packed, small quartz pebbles	45±
Lower member	
1. Black- and white-banded, softer quartzite in thick to thin platy layers, in part rhythmically banded	160±
	385±

The upper member is well exposed at three places on Francis Mill Creek near Little Wythe Furnace (Pl. 1), where fossiliferous beds containing phosphatic pellets, trail-marked bedding planes, and other stratigraphic details are well shown.

Partial sections of the formation (Fig. 21), are exposed in cuts of an abandoned railroad at Little Wythe Furnace south of Cripple Creek village.

A partial section of Erwin Quartzite on the south limb of the Fry Hill anticline is as follows:

GEOLOGIC SECTION 12.—SOUTH OF LITTLE WYTHE FURNACE, WYTHE COUNTY, VIRGINIA

	Thickness Feet
Shady dolomite	
Knotty blue dolomite and gray dense siliceous dolomite	
Erwin quartzite	

Upper member (56 feet)

Gray fossiliferous quartzite with irregular bedding surfaces; lower part granular	23
Thick-bedded, fossiliferous granular quartzite with coarse quartz grains and small greenish phosphatic nodules	15
Hard, thin-bedded, fine-grained, blue quartzite	10
Granular quartzite composed of coarse grains and small pebbles of glassy quartz with rusty fossiliferous partings	8

Middle member (65 feet)

Thin-bedded, hard gray quartzite, and some dark— and light-banded quartzite	50
Thick-bedded, laminated white quartzite (base not exposed)	15
	121

In Rocky, Laurel, and Jackson hollows, gorges cut in the north slope of Horse Heaven ridge, ledges of Erwin quartzite are exposed on the north limb of the Fry Hill anticline. On the west side of Rocky Hollow, the ridge-making quartzite dips northwest and caps the ridge that is followed by the trail that ascends Horse Heaven ridge from the mouth of Laurel Hollow. In a saddle in the front spurs to the west, at an altitude of 3,200 feet, these ridge-making beds are cut off by the Poplar Camp overthrust. The middle member makes a few outcrops in the gorges in the north slope of Horse Heaven ridge. The upper member dips steeply north under the Shady dolomite. In Rocky and Laurel hollows the sequence of beds in the Erwin is well shown, but thicknesses could not be determined. A fairly complete section of the formation is expressed in Jackson Hollow, 1½ miles south of Speedwell, but, due to folding, the thicknesses could be only estimated at 460 feet.

The Erwin quartzite in the Fry Hill anticline is best exposed 2 miles south of Speedwell along U. S. Route 21, which follows Dry Run. The cross section of this anticline is shown in Figure 22. The ridge-making member on the north limb of the anticline crosses Dry Run just north of the mouth of Henley Hollow. Half a mile to the south, on the south limb of the fold, this member makes ledges and cliffs where it crosses Dry Run. Ledges of these hard quartzites ascend the steep slope to the top of the mountain and apparently join the quartzite ledges of the north limb to form a great arch, not visible from the highway. The lower member of the formation, in the core of the anticline, is well exposed on the highway. The upper 60 feet of this member, a very thick-bedded soft black argillaceous quartzite, is well exposed on the north limb of the fold near the mouth of Henley Hollow, where it dips 20° N. This thick bed is underlain by black rhythmically banded argillaceous quartzite and black shale also of the lower member.

The upper and middle members of the Erwin are well exposed in cuts along U. S. Route 21 north of Henley Hollow. (Fig. 22) Green phosphatic pellets are present in the uppermost beds and some layers are rhythmically banded (Pl. 45B). The measured stratigraphic section is as follows:

GEOLOGIC SECTION 13.—ALONG DRY RUN NORTH OF HENLEY HOLLOW, WYTHE COUNTY, VIRGINIA

	Thickness Feet
Erwin Quartzite	
Upper member (88± feet)	
5. Thin black argillite at top, underlain by green phosphatic calcareous quartzite, which has weathered to a rust-colored rock	18
4. Thin-bedded, irregularly bedded green to rusty, laminated quartzite and a few thicker quartzite beds, in part rhythmically banded	70
Middle member	
3. Upper part concealed; hard dense, fine-grained green quartzite below	90
Ridge-making member	
2. Hard, vitreous, white quartzite; a 10-foot bed of conglomerate at base is composed of closely packed round pebbles	45±
Lower member (160± feet)	
1. Upper part, black agrillaceous quartzite in 20-foot beds; black and white, rhythmically banded and laminated argillaceous quartzite, in part ripple marked, in part thicker bedded; base not exposed	160±
	383±

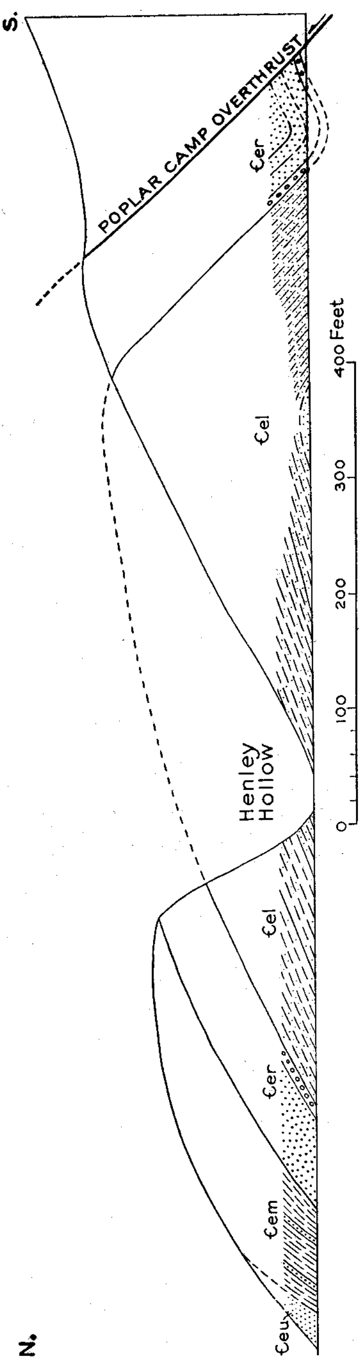

FIGURE 22.—Sketch section of Erwin quartzite along U. S. Route 21. Ꞓeu, Erwin quartzite, calcareous; Ꞓem; Erwin quartzite, argillaceous; Ꞓer, Erwin quartzite, ridge-making; Ꞓel, Erwin quartzite, interbedded dark shales.

On the north limb of the Speedwell syncline, the Erwin quartzite occurs in a narrow band which extends for 2½ miles in the area west of U. S. Route 21. The upper member of the quartzite, with a maximum exposed thickness of 50 feet, dips gently south beneath the Shady dolomite. The upper 25 feet of these beds is composed largely of tightly packed, rounded grains of quartz. Some layers contain small phosphatic nodules. The lower 20 to 25 feet are dark ferruginous quartzites, that weather to a rust-colored rock and contain molds of fossils. The north side of the quartzite is a fault contact with the Rome formation.

The Erwin quartzite in the Fosters Falls Mountain anticline, rises out of the lowland that is underlain by the Patterson member of the Shady dolomite. The best section of the Erwin quartzite in this anticline is exposed in Periwinkle Branch three-fourths mile southwest of Patterson in eastern Wythe County. The section is as follows:

GEOLOGIC SECTION 14.—IN PERIWINKLE GORGE, SOUTHWEST OF PATTERSON, WYTHE COUNTY, VIRGINIA

	Thickness Feet
Shady dolomite	
Blue dolomite	
Erwin quartzite	
Upper member (20 feet)	
4. Granular calcareous quartzite with rust-colored laminae showing molds of fossils	10
3. Thin-bedded to thick-bedded knotty, dark-colored ferruginous quartzite with molds of fossils	10
Middle member	
2. Thin-bedded, rust-colored ferruginous quartzite	180
Ridge-making member	
1. Thick-bedded, hard quartzite; (contains conglomerate beds on the adjacent mountains)	33
	233

The lowest quartzite exposed in the Fosters Falls Mountain anticline (Fig. 40) is the thick-bedded quartzite of the ridge-making member, which forms the center of the anticline in the gorge of Periwinkle Branch and also the crest of Fosters Falls Mountain west of the gorge. The upper member is very thin and, except for the uppermost beds, is not readily distinguishable from the thin-bedded layers of the middle member below it. On the south limb of the anticline, beds directly below the Shady dolomite are calcareous quartzite and rust-banded quartzite containing fossil fragments. At Fosters Falls village the upper beds of the Erwin, which make the falls in New River, dip 30° S. under the Patterson member of the Shady dolomite. A small quartzite area, exposed in the channel of New River half a mile southwest of Hematite Mountain, is on an anticlinal uplift along the Fosters Falls Mountain axis.

The upper member of the Erwin quartzite, in this anticline, is exposed on the north side of New River on U. S. Route 52, 1 mile west of Jackson Ferry (Pl. 47A). Here the beds are almost horizontal and the uppermost beds have trail-marked bedding surfaces. The contact of the Erwin quartzite and Shady dolomite, on the south side of the anticline, is exposed in the cut of the Norfolk and Western Railway south of the river.

The Erwin quartzite is exposed also in the Periwinkle anticline west of High Rocks Mill, and in a low hill in the limestone valley of Little Reed Island Creek just north of the mill. These exposures are north of the Poplar Camp overthrust, and are part of overridden blocks. In the Periwinkle fault block the ridge-making member and overlying members are exposed on the south limb of the anticline southwest of High Rocks Mill. The upper member, which dips beneath the Shady dolomite, crops out in the deep oxbow of Little Reed Island Creek, half a mile southwest of High Rocks Mill (Fig. 27), has fossiliferous beds at the top. Similar fossiliferous beds were observed in the upper layers of the Erwin just north of High Rocks Mill, where they dip beneath the Shady dolomite.

A comparison of the sections of the Erwin quartzite in the three belts across the strike shows the following changes: The general character and thickness of the upper member is the same in all sections but the uppermost beds become more calcareous, fossiliferous, and phosphatic in the northern belts. The middle member becomes less argillaceous toward the north while some of the upper beds are trail marked and contain phosphatic nodules in the most northern belt. The ridge-making member thins greatly in the northern belts, is not conglomeratic, and is thinner bedded and less resistant. The lower member is not fully exposed in the northern belts, but its characteristic lithology seems to persist across the strike. The general change in lithology indicates that the source of the terrigenous material was from the south and that the formation in general thins and becomes less quartzose and more calcareous and more phosphatic northward, away from the old shore line.

Age and correlation.—*Scolithus* tubes, which occur in the hard pure quartzite of the ridge-making member of the Erwin, are the oldest evidence of life in the rocks of the region. These long slender tubes, perpendicular to the bedding and now filled with granular quartz, were the burrows of sea worms. Molds of other fossils, which occur locally in the upper 10 to 30 feet of the formation, are visible on the bedding planes of calcareous, limonite stained layers. These fossils are molds of spines and other parts of the trilobite *Olenellus* and the small brachiopod *Obolella*. The fossil localities are mentioned in the above descriptions of the upper member of the Erwin Quartzite, and are shown on the geologic map (Pl. 1). These fossils are of Lower Cambrian age. The Erwin is approximately equivalent to the Antietam quartzite of Maryland and Pennsylvania, which contains similar fossils.

LOWER AND MIDDLE CAMBRIAN CARBONATE ROCKS

General Statement.—The carbonate rocks, which include limestone and dolomite, that occur in the Gossan Lead district (Pl. 1) are of lower and middle Cambrian age. These carbonate rocks belong to the following formations (which are generally recognized in the Great Valley): The Shady dolomite, which rests on the Erwin quartzite; the Rome formation, which overlies the Shady dolomite; and the Elbrook limestone, which is stratigraphically above the Rome formation. The Shady dolomite and Rome formation are lower Cambrian, while the Elbrook limestone is Middle Cambrian.

In the area of the Gleaves Knob overthrust block (Fig. 24), southwest and northeast of Austinville, Wythe County, the carbonate rocks are different lithologically from the corresponding ones in the Great Valley. These formations, are the Vintage dolomite which rests on the Erwin quartzite, the Kinzers formation, and the Ledger dolomite at the top. The writers regard the above formations, which underlie the Rome formation and overlie the Erwin quartzite to be equivalent to the Shady dolomite of the Great Valley. A detailed description of the distribution, character, and thickness of these formations follows:

SHADY DOLOMITE

Distribution.—The Shady dolomite in the part of the Great Valley included in the Gossan Lead district, rests conformably upon the Erwin quartzite and underlies the Rome formation. In the vicinity of Speedwell a wide synclinal belt of Shady dolomite encloses the Rome formation. The Rome formation is in fault contact with and surrounds the Patterson member of the Shady dolomite east of Sugar Run. South of Cripple Creek village are anticlinal area of the upper member of the Shady dolomite lies within the area of the Rome formation.

Another belt of Shady dolomite extends from Dry Run, south of Speedwell, northeastward to Collins Cove which is on Cove Branch. The Shady dolomite is here overridden by the Gleaves Knob overthrust block. An arm of this area of Shady dolomite extends southwestward across Francis Mill Creek. A small area of this dolomite is exposed 1 mile south of Cove Branch School in the gorge of Cove Branch. This is a window (fenster) in the Gleaves Knob block.

A belt of Shady dolomite, south of Ivanhoe, extends northeastward along the New River valley to the mouth of Galena Creek, where a minor gentle anticline exposes a small oval area of the underlying Erwin quartzite in New River (Pl. 1). The Shady dolomite continues eastward on the south side of the area of Erwin quartzite that forms Hematite and Fosters Falls mountains, where it is cut off on the south of the Gleaves Knob overthrust. A small area of the dolomite is exposed on the southeast limb of the Periwinkle anticline in Little Reed Island Creek, half a mile southwest of High Rocks Mill. North of Fosters Falls Mountain the Shady dolomite forms a wide area of low hills, west of the Poplar Camp overthrust at the base of Dry Pond Mountain.

Character and thickness.—The Shady dolomite in this part of the Great Valley is divisible into two members (Pl. 1). The lower member, which was named the Patterson limestone member by Butts[44], is composed of blue, argillaceous, banded dolomite and impure limestone with irregular bands and eyes of coarse-grained white dolomite (Pl. 46C). Some beds are blue limestone, banded with thin argillaceous layers that contain small round concretions, possibly of algal origin. The upper member is a thick-bedded, light-colored, saccharoidal dolomite which was named the Austinville dolomite member by Butts[45]. This name is not used in this report because the dolomite exposed at Austinville is regarded by the writers as Ledger dolomite and not part of the Shady dolomite. A section of the Shady dolomite was not measured in detail by the writers. A composite section of the Shady dolomite on the north limb of the Speedwell syncline west of Speedwell, is as follows:

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[44] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, p. 3, 1933.

[45] Butts, Charles, Geology of the Appalachian Valley in Virginia: Virginia Geol. Survey Bull. 52, pt. 1, p. 41, 1940.

GEOLOGIC SECTION 15.—NORTH OF BOWLING GREEN MOUNTAIN, WYTHE COUNTY, VIRGINIA

	Thickness Feet
Rome formation	
Red shale and sandstone	
Shady dolomite (1300± feet)	
Saccaroidal dolomite member	
Thick-bedded, granular, white to light-gray dolomite and some impure limestone and dolomite	600
Patterson member	
Dark-blue, impure, knotty dolomite	
Blue mottled limestone with wavy argillaceous banding; contains small round concretions, possibly of algal origin	700±
Pure blue limestone	
Dark-blue, impure, laminated dolomite and knotty dolomite with white coarsely crystalline dolomite blebs and lenses	
Light-blue, fine-grained, siliceous dolomite, white at base	
Erwin quartzite	
Thin-bedded, fossiliferous quartzite containing phosphatic clay nodules	

Sections of the Shady dolomite in this part of the Great Valley have been published by Butts[46], Currier[47], and the writers[48].

In the vicinity of Patterson and northward in the valley of Little Reed Island Creek, the Patterson member is exposed in many outcrops and in an abandoned quarry in Buckeye Hollow. Throughout this area, the beds are largely impure, banded blue limestone with small round concretions. Massive, dark-blue dolomite is present in places, chiefly along the east side of the area. (Pl. 47B) The saccharoidal dolomite member is generally poorly exposed in this area. It has weathered to a dark-red soil containing large residual masses of chert with pitted surfaces.

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[46] Butts, Charles, Idem, pp. 41-50, 1940

[47] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, pp. 19-34, 1935.

[48] Stose, G. W., and Jonas, A. I., op. cit., p. 15.

The Shady dolomite is well exposed, on the Norfolk and Western Railway south of Fosters Falls. There the basal beds are blue limestone, with wavy argillaceous partings, that contain small round concretions and some knotty dark-blue dolomite. In the overlying more pure limestones the writers found trilobite fragments (*Paedeumias sp.*) and structures resembling algal reefs. Similar beds containing scanty trilobite fragments are exposed also along the road that follows the valley southeast of Fosters Falls. In the section on the railroad the beds are apparently repeated by faulting, making an unusually wide belt of dolomite. White granular dolomite of the saccharodial dolomite member is infolded in a faulted syncline in the middle of these outcrops. The exposure of the contact of the Erwin quartzite and the Shady dolomite on U. S. Highway 52, west of Jackson Ferry, was mentioned by Currier[49] and a section of the lower part of the Shady dolomite was given in his report. The Patterson limestone member is well exposed in a local, gentle anticline at "Chiswell's Hole", 1 mile southwest of Austinville (Pl. 48A). Here white-banded, dark-gray dolomite, impregnated with sphalerite and galena, is exposed in a low cliff. It is overlain on the north side by massive dolomite of the saccharoidal member. On the east side, a similar pure gray dolomite, the Ledger dolomite, is overthrust along the Gleaves Knob overthrust onto the knotty dolomite of the Patterson member of the Shady dolomite. The saccharoidal dolomite member is a massive, blue to white, coarse-grained dolomite.

Massive ribbed dolomite of the Patterson member crops out in Collins Cove on Cove Branch as far south as the Gleaves Knob overthrust. Farther southward, where erosion has cut through the Gleaves Knob overthrust block, a small area of dolomite is exposed in a window in the thrust plate. (Pl. 1) West of Cove Branch the Patterson member is overlain by the bluish-white dolomite of the saccharoidal dolomite member. The contract of Shady dolomite and red shale may be seen at the south entrance of the gorge of Rock Creek.

Massive dolomite of the Patterson member is exposed southeast of Cripple Creek village in the valley of Cold Run near Shiloh and southwestward up the valley for half a mile. In the valley of Francis Mill Creek, West of Little Wythe Furnace, dolomite of the Patterson member may be seen in a large quarry. South of Fry Hill, in the same valley, it is exposed in deep abandoned iron ore pits (Pl. 48B). In the hollows on the north side of Fry Hill anticline, east of Francis Mill Creek, it crops out to an altitude of 2,680 feet.

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[49] Currier, L. W. Idem., p. 14

East of Simmerman, along Cripple Creek and in cuts on an abandoned branch of the Norfolk and Western railway, the Patterson member is a light-blue limestone mottled by irregular argillaceous bands containing small round concretions. Toward the base of the formation, impure, finely laminated, blue limestone and dolomite occur. The light-gray dolomite of the saccharoidal dolomite member is exposed west of Simmerman and also in Cave Hill west of Speedwell, and where it makes high cliffs west of U. S. Route 21. The road that follows Cripple Creek west of Speedwell to Ward Branch crosses exposures of the saccharoidal dolomite member on the north side of Bowling Green mountain. The Patterson member is exposed on Ward Branch, where the upper part is a blue limestone with earthy mottling and contains small concretions.

Age and Correlation.—A few fragments of the trilobite *Paedeumias sp.* were obtained from the Patterson limestone member southeast of Fosters Falls. Small round concretions, that resemble algal growths, occur at many places in this member. Fossil algae of *Archeocyathid* type were collected by G. W. Stose from the upper beds of Shady dolomite at a point 4 miles west of Sugar Grove in the Rural Retreat quadrangle. These fossils are of Lower Cambrian Age. The Shady dolomite is equivalent to the Tomstown dolomite of northern Virginia, Maryland and Pennsylvania.

ROME FORMATION

Distribution.—The rocks of the Rome formation, which overlie the Shady dolomite, are mainly confined to two discontinuous belts along the northern border of the district. The more easterly of these two belts which is about 13 miles long, with an average width of about 1½ miles, extends from Huddle northeastward to Bertha on New River. It lies north of the Gleaves Knob overthrust block (Fig. 24). The second belt, with an average width of about 1 mile extends from Brown Hill Church southwestward to the western limits of the district, a distance of about 11½ miles. Areas south of these two belts, and one east of them are shown on Plate 1.

The more westerly belt has its greatest width, about 1½ miles, at Cripple Creek village. West of this village the formation surrounds the Speedwell syncline, (Fig. 23), north of Bowling Green Mountain, and as far as Sindion Point.

Character and thickness.—Currier[50] describes the Rome formation

[50] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, pp. 37-39, 1935.

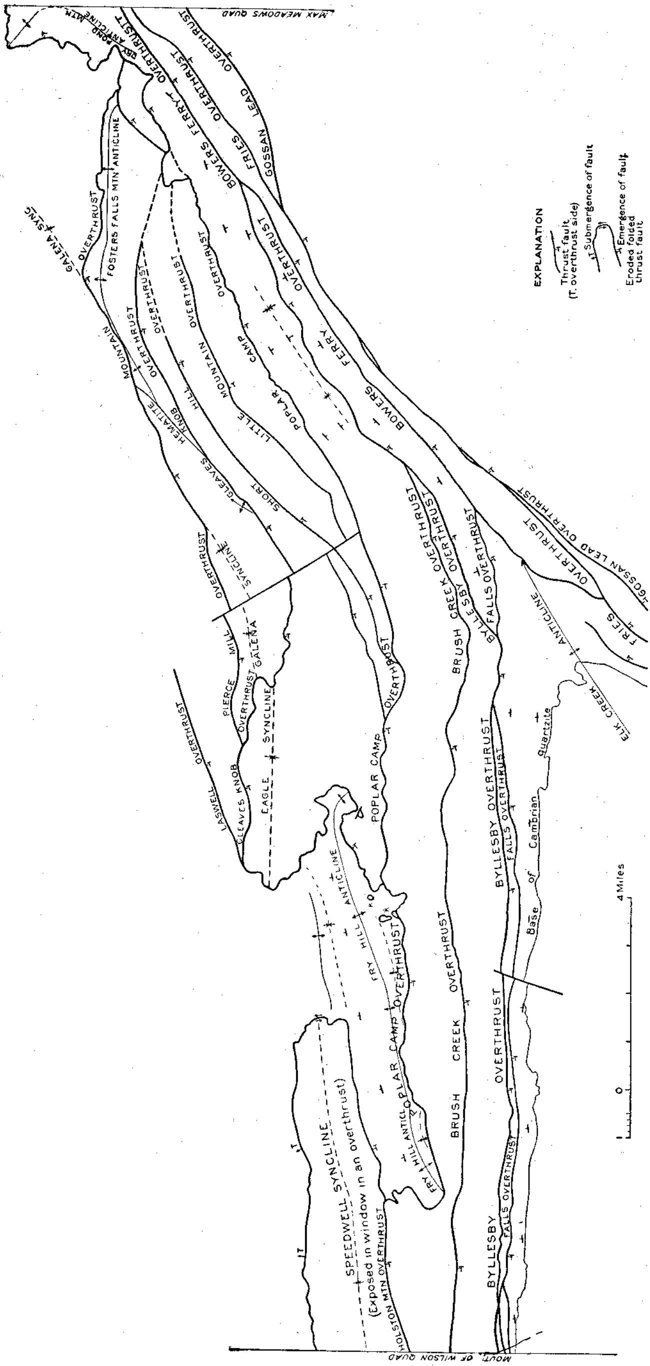

FIGURE 23.—Map showing larger overthrusts and fold axes of the district.

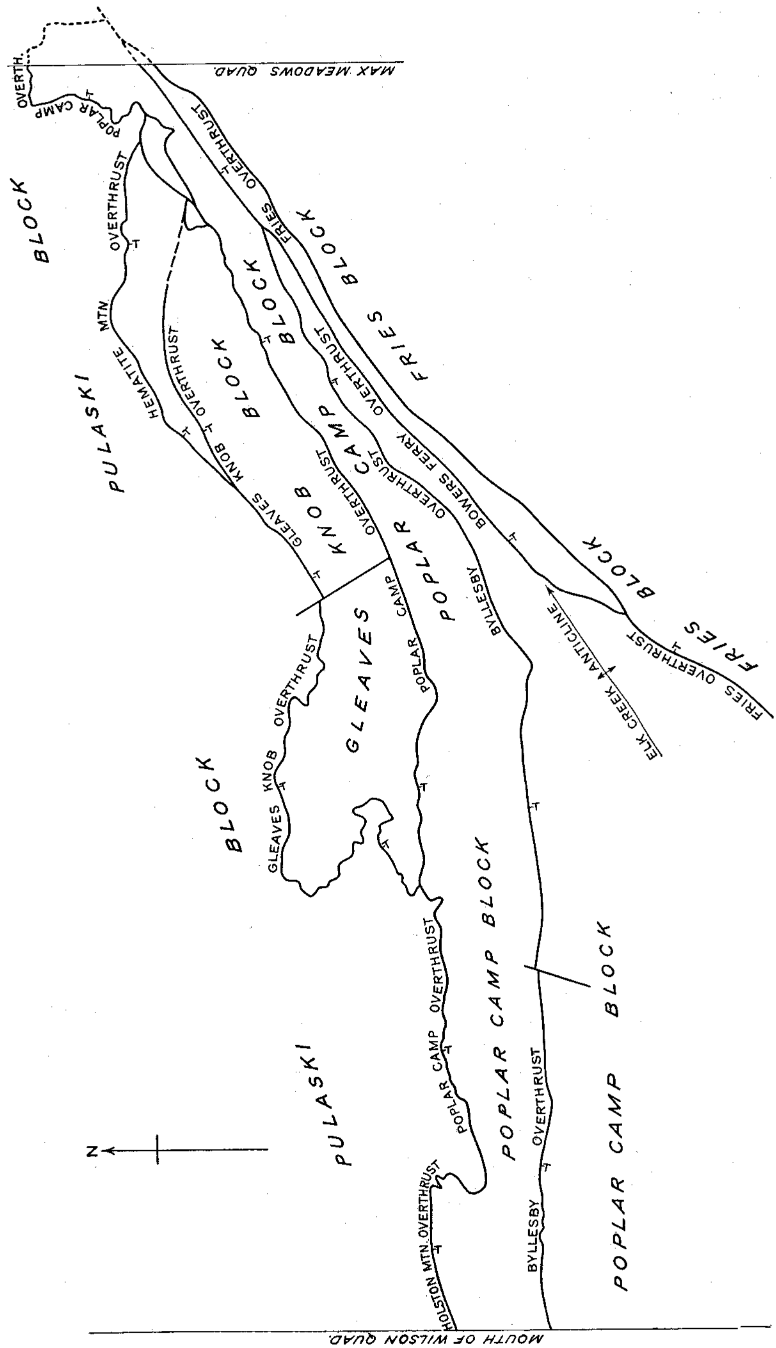

FIGURE 24.—Generalized structural diagram of the district showing major fault blocks.

as "a heterogeneous formation consisting of shale, sandstone, limestone, and dolomite. . . . The most characteristic feature is an abundance of red shales and, subordinately, red sandstones, which in places have a quartzitic texture . . . the red beds probably constitute much less than 50 per cent of the formation and . . . dolomite beds are, in many places, much more abundant. . . . In many places the Rome shales show prominent sun cracks and ripple marks. . . . Limestone beds in the Rome are somewhat numerous but comparatively thin. These beds are commonly dense textured, rather massive, and of medium to dark-gray color. . . . The formation is relatively very weak. . . . The Rome exposures commonly display, steep dips, close, folds, and slight overturning of beds." He[51] gives a section along the highway south of Porter Crossroads and north of Cripple Creek bridge, of the lower 470 feet of the formation. He states that the formation is about 2,150 feet thick south of Porter Crossroad. This does not include the underlying Ivanhoe limestone member which he regards as part of the Shady dolomite.

Pure limestone that underlies the red shale of the Rome, half a mile northeast of Ivanhoe station, was named by Currier[52] the Ivanhoe limestone member of the Shady dolomite, and he states that it has a thickness of between 525 and 550 feet northward of Ivanhoe but thins to the east, and west. Currier[53] states that east of this locality it disappears as a mappable unit, and to the westward it thins to 50 feet at Porter and is not recognized beyond that point. The massive beds of limestone in this member are reported to average more than 98 per cent $CaCO_3$. This is no doubt an exceptional and local development of pure limestone, observed only in the Ivanhoe syncline. The writers believe that it more closely resembles beds in the heterogenous Rome Formation than those of the Shady and should be included in the Rome. It was not mapped separately in this report.

Flint nodules, in gray dolomite that overlies red sandstone near the middle of the formation, are characteristic of the Rome in the Gossan Lead district. In exposures along the road in Andrews Hollow, 1½ miles west of Speedwell, the ridge-forming red sandstone is ripple marked and sun cracked and the overlying dove-colored limestone has magnesian layers which contain abundant round, black flint nodules. On the south side of the ridge formed of red sandstone and shale of the Rome in the area from Rock Creek, east of Cripple Creek village, westward beyond

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[51] Currier, L. W., Idem, pp. 39-40.
[52] Currier, L. W., Idem., p. 27
[53] Currier, L. W. Idem., p. 29

Rocky Hollow, the gray dolomite beds contain an abundance of flint nodules, some of which are composed of a light-gray to white chalcedonic flint.

Age and correlation.—The Rome formation in the region near Roanoke, Virginia, and 2 miles south of Max Meadows has yielded[54] *Olenellus remensis* Resser and Howell, *Hyolithes wanneri* Resser and Howell. These fossils are of Lower Cambrian age. The Rome formation is approximately equivalent to the Waynesboro formation of northern Virginia, Maryland, and Pennsylvania.

ELBROOK LIMESTONE

General statement. The Elbrook limestone in the Gossan lead district is confined to a narrow belt, ¼ to ½ mile wide and about 10 miles long that extends from a point about ½ mile north of Ivanhoe northeastward to a point about ½ mile west of Bertha, on New River. This belt is in the Galena Syncline north of the Hematite Mountain overthrust (Fig. 24). The formation is poorly exposed in this area. It is described by Currier[55] as a thick series of thinly laminated, shaly to massive, even-bedded, light-gray to dark-gray dolomite weathering buff and slabby, and some white limestone. The thickness in this area is stated to be about 1,200 feet. The Elbrook is poorly exposed along Galena Creek south of Galena and 1 mile north of the ferry across New River on the road from Austinville to Porter.

No fossils have been found in the Elbrook limestone in this area. Fossils collected elsewhere from this formation are of Middle Cambrian age.

CARBONATE ROCKS IN THE GLEAVES KNOB FAULT BLOCK

General statement. A belt of carbonate rocks, which are of the same age as the Shady dolomite, but differ lithologically and in faunal content, occurs north of Poplar Camp Mountain. This belt, which has a maximum width of 2 miles, extends from the southeast foot of Gleaves Knob eastward and northeastward to the vicinity of New Castleton School, a distance of about 15 miles. These rocks are confined to the

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[54] Resser, C. E., and Howell, B. F., Lower Cambrian *Olenellus* zone of the Appalachians: Geol. Soc. America Bull., vol. 49, p. 221, 1938.

[55] Currier, L. W., Zinc and lead region of Southwestern Virginia: Virginia Geol. Survey Bull. 43, pp. 41-42, 1935.

Gleaves Knob overthrust block. They overlie the Erwin quartzite. Some layers of these rocks are highly fossiliferous.

The youngest formation in this belt is lithogically similar to the saccharoidal dolomite member of the Shady dolomite, and the oldest formation lithologically resembles the Patterson member of the Shady dolomite. Between these formations occurs a fossiliferous formation, which includes pure limestone beds, argillaceous and arenaceous beds, and some dolomite, not found in the Shady dolomite of the main part of the Great Valley.

The writers believe that these formations are a facies of the Shady dolomite, deposited in the southeastern part of the submerged basin under conditions that differed from those of the Great Valley proper. Currier[56] recognized that these rocks differ from equivalent rocks in the Great Valley, and suggested that they were brought into their present relations by overthrusting from the southeast. The formation which the writers recognized and mapped in the Gleaves Knob overthrust block are the Vintage dolomite, at the bottom; Kinzers formation, in the middle, divided into three mapped members; and the Ledger dolomite, at the top. These formations are lithologically and faunally similar to formations in southeastern Pennsylvania with which the writers have correlated them[57]. The formation to which the name Vintage dolomite is here applied, closely resembles the Vintage dolomite of southeastern Pennsylvania while the formation, named the Ledger dolomite, closely resembles the Ledger dolomite of southeastern Pennsylvania, so that the identity of these two formations with those in Pennsylvania seem clearly established. The intermediate formation, to which the name Kinzers is here applied, is a variable assemblage of highly fossiliferous pure limestones with a zone of argillaceous to sandy limestone and coarse limestone conglomerate. The Kinzers formation of southeastern Pennsylvania, which is also a heterogeneous formation with fossiliferous pure limestones and sandy limestone, has a fossiliferous shale at the base, which is not present in Virginia.

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[56]Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, pp. 30-35, 1935.

[57]Stose, G. W., and Jonas, A. I., Geology and mineral resources of the Middletown quadrangle, Pennsylvania; U.S. Geol. Survey Bull. 840, pp. 21-36, 1933; A southeastern limestone facies of Lower Cambrian dolomite in Wythe and Carroll counties, Virginia: Virginia Geol. Survey Bull. 51A, pp. 1-30, 1939; Geology and mineral resources of York County, Pennsylvania: Pennsylvania Geol. Survey 4th Ser. Bull. C-67, pp. 47-59, 1939.

[58]Stose, G. W., and Jonas, A. I., The lower Paleozoic section of southeastern Pennsylvania: Washington Acad. Sci. Jour. vol. 12, No. 15, pp. 368-366, 1922.

In Pennsylvania these rocks occur in a limited area on the southeast side of the Great Valley and were regarded by the writers[58] as a southeastern facies of the Tomstown dolomite of that part of the Great Valley. In both Pennsylvania and Virginia they occupy the same stratigraphic position in the Appalachian geosyncline or sedimentary basin, and therefore their correlation seems warranted.

The fossiliferous series in the Gleaves Knob overthrust block (Fig. 43) occurs in three anticlines broken by thrust faults, and the resultant blocks, from south to north, have been named the Little Mountain, Short Hill, and Austinville blocks[59].

VINTAGE DOLOMITE

Distribution. The Vintage dolomite was named from Vintage, Lancaster county, Pennsylvania. In the Gossan Lead district it is limited to the Austinville block where it forms a belt with a maximum width of 1½ miles (Pl. 1), south of Cattron between the foothills of Ewing mountain and the northwest edge of the Gleaves Knob thrust block (Fig. 24) south of Ivanhoe. The belt narrows eastward. Southwest of Ivanhoe it is overlain by the Kinzers formation.

It crops out in a long narrow syncline on the northwest flanks of Cold Ridge, south of Ivanhoe, in a small synclinal area north of the east end of Cold Ridge, and in a somewhat larger syncline in the headwater valley of the north branch of Little Brush Creek west of Cold Ridge. East of New River the Vintage dolomite occurs in two small areas east of Short Hill and Little Mountain.

Lower Cambrian dolomite of Vintage type occurs in four tightly compressed synclines south of Poplar Camp Mountain. Although these areas structurally are not a part of the Gleaves Knob overthrust block, they lie south of it, and the dolomite in them is tentatively classed as Vintage. The largest of these areas extends for 3 miles northeastward from New River along the Valley of Poor and Stoots branches, northeast of Fowler Ferry, and across the southeast spurs of Poplar Camp Mountain. Another synclinal area of similar dolomite, nearly 2 miles long, crosses U. S. Route 52 at Shorts Creek village. A third area along this northeast strike, is exposed in a synclinal valley east of High Rocks Mill at the east edge of the Gossan Lead district. The dolomite of this area is cut off on the south side by the Bowers Ferry overthrust. West of

[59]Stose, G. W., and Jonas, A. I., A southeastern limestone facies of Lower Cambrian dolomite in Wythe and Carroll counties, Virginia: Virginia Geol. Survey Bull. 51A, pp. 23-30, 1938.

Shorts Creek village, at the mouth of Handy Creek, another small mass of impure dolomite is infolded in a tight syncline in Erwin quartzite.

White dolomitic marble, which is exposed on U. S. Route 52 at the mouth of a small stream 1 mile west of Round Knob, has been traced northeastward for a half a mile. It is surrounded by sheared slates and quartzites of the Unicoi formation of the Bowers Ferry overthrust. This dolomite is tentatively mapped as Vintage and is considered to be a small slice brought up along the fault, or a window in the overthrust block.

Character and thickness. The Vintage dolomite, in the Gossan Lead district, consists of a dark-blue, irregularly banded, knotty dolomite at the base and an argillaceous banded, mottled, blue limestone above. It is similar in lithology to the Patterson member of the Shady dolomite in the normal Great Valley sequence. Since it is so poorly exposed, no continuous section was observed and measured. Along the road southwest of Grays School in the Short Hill fault block, the upper beds are not exposed and the highest beds seen are dark-blue, knotty dolomite with some siliceous bands. The lower beds of the formation, exposed on this road, are of a dark-colored dolomite and thin-bedded, smooth-layered, dark-colored, siliceous limestone with black argillaceous partings. The same type of dolomite is exposed to the north in the upper part of the valley that heads near Grays School.

The basal beds of the Vintage dolomite exposed along the road 1½ miles south of Ivanhoe and in the stream gorge to the south are highly siliceous. In the cut on State Highway 94 at the divide at the west end of Cold Ridge (Fig. 42) wavy, folded layers of yellow clay, stained a black color with hydrous manganese oxides, represent the basal beds of the Vintage. In the valley 1¼ miles east of Eagle, south of Cripple Creek, the upper part of the Vintage dolomite is a blue limestone, with small lenses of a coarsely crystalline white dolomite that contain small round concretions similar to those in the Patterson member of the Shady dolomite.

Age. No fossils have been obtained from the Vintage dolomite in the Gossan Lead district. Small round concretions that occur in it may be of algal origin. *Salterella conica* and fragments of other fossils including trilobites, probably *Olenellus* or a related genus, were collected from this formation in Pennsylvania. The Vintage dolomite overlies Erwin quartzite and is overlain conformably by the Kinzers formation, from which a large Lower Cambrian fauna was obtained. The Vintage appears therefore to be of Lower Cambrian age.

KINZERS FORMATION

Distribution. The Kinzers formation was named from Kinzers, Lancaster County, Pennsylvania. In the Gossan Lead district, the formation occupies a wide area southeast of Austinville.

The Kinsers formation is found in each of the blocks within the Gleaves Knob overthrust block. In the Austinville block the formation occurs in a narrow belt that begins west of New River, at a point south of Ivanhoe, and that is terminated by the Short Hill fault, south of Austinville. Two smaller areas of the Kinzers formation occur northeast of Austinville, and north of Jackson Ferry.

In the Short Hill block an extensive area of this formation extends from a point near Grays School northeastward to a point 1 mile southwest of Jackson Ferry. Most of the beds in this area are repeated by a diagonal branch of the Little Mountain overthrust fault.

In the Little Mountain block the Kinzers formation occurs in an area that extends from a point northeast of Sheeptown, northeastward to New Castleton School.

Character and thickness. The Kinzers formation in all of the areas comprises an upper member of blue conglomeratic limestone; a ridge-making member of argillaceous banded and siliceous limestone; and a lower member of highly fossiliferous, coarse-grained, white limestone and pure, blue and gray fossiliferous limestone. The ridge-making member is the best exposed and most easily recognized part of the formation, and serves as the key rock in determining the sequence of beds and the structure of the rocks. In the part of the area crossed by the road from Austinville to Bethany, nearly all of the beds dip southeast, and the faults might not be recognized if the repetition of the ridge-making beds were not observed. By a study of the sections in each of the areas, beginning with the clearly recognizable Erwin quartzite at the base, and the overlying Vintage dolomite, the sequence of beds in the Kinzer formation was established. A continuous section of all the members of the Kinzers formation is not exposed in any one block, but detailed sections of each member were measured and a thickness of about 900 feet was thus estimated for the formation as a whole.

The upper part of the lower member, about 175 feet thick, is best exposed on Buddle Branch, south of the mouth of Clear Branch. The section of these beds just above the mouth of Clear Branch, is about 205 feet thick. Another partial section of the lower member was observed in the quarry of the National Carbide Co., 1 mile south of Ivanhoe. The above mentioned detailed sections of the lower member have been published by the writer[60].

A complete section of the middle member was measured on Clear Branch, west of Bethany, where the measured section was 500 feet thick. The detailed sections of the middle and upper members have been described by the writers[61].

A composite generalized section of the Kinzers formation, based on the published detailed sections, is as follows:

GEOLOGIC SECTION 16.—GENERALIZED COMPOSITE SECTION OF THE KINZERS FORMATION AND ASSOCIATED VINTAGE AND LEDGER DOLOMITES SOUTHEAST OF AUSTINVILLE, VIRGINIA

	Thickness Feet
Ledger dolomite	
Thick series of massive-bedded, granular gray dolomite	600±
	600±
Kinzers formation (910 feet)	
Upper member	
Thin-bedded, platy, blue limestone and thick-bedded, bluish-gray limestone with coarse and fine limestone conglomerate; some beds fossiliferous	500±
Ridge-making member	
Blue, banded, argillaceous to siliceous limestone, that weathers to buff tripoli, and olive shale; some beds highly fossiliferous; some dolomite beds at base	150±
Lower member	
Coarse-grained, white marble, light-blue to gray limestone, and fine-grained dove-colored limestone; highly fossiliferous; some thick *Archeocyathid* reefs and other fossils	260±
	910±

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[60]Stose, G. W., and Jonas, A. I., A southeastern limestone facies of Lower Cambrian dolomite in Wythe and Carroll counties, Virginia: Virginia Geol. Survey Bull. 51A, pp. 10, 11, 1938.

[61]Stose, G. W., and Jonas, A. I., Idem., pp. 12, 13.

Vintage dolomite	
Thick series of knotty and banded blue dolomite and limestone with argillaceous partings	1300±
	1300±

The ridge-making member forms a conspicuous ridge 1¼ miles west of Bethany, but the section is only partly exposed where it is crossed by the road from Bethany to Austinville. Coarse limestone conglomerate at the base of the upper member, and also present in higher beds in this block, is well shown just west of the left fork of Clear Branch 1 mile west of Bethany (Pl. 49A), and also east of the road that leads north from Bethany, three-quarters of a mile north of that village. Here the basal conglomeratic bed is composed of pebbles, as much as 6 inches in diameter, of white marble, dark-colored oolitic and platy limestone, dense black limestone, and dolomite inclosed in a dark-colored limestone matrix. Conglomerate beds in the upper member are also exposed in the valley southeast of Liberty Grove Church and on the east bank of Shorts Creek northeast of Poplar Camp village. On U. S. Route 52, three-fourths of a mile north of Poplar Camp, coarse limestone conglomerate and ribboned and mottled limestone of the upper member of the formation, conformably overlain by coarse-grained saccharoidal Ledger dolomite, are exposed in a road cut.

The ridge-making member makes a discontinuous ridge that is crossed by the road from Bethany to Austinville one-fourth mile east of Buddle Branch. The road cut exposes a blue banded calcareous argillite which has weathered to a much-jointed buff earthy argillite. These beds are in part fairly well exposed in Clear Branch to the east. Excellently preserved trilobites were found in soft gray to buff shale of this member in the ridge farther east and in the cut along the road from Bethany to Jackson Ferry, where it crosses this ridge. The lower member of the formation is well exposed in the lower part of the valley of Clear Branch, where the rocks dip gently to the south. Many of the beds are highly fossiliferous and contain fossil algal reefs in pure white to gray granular limestone. The fossil-bearing beds, including algal reefs, are excellently exposed at Fossil Point at the junction of Clear and Buddle branches (Pl. 49B). The ridge west of the diagonal fault, which trends southwest parallel to, and west of, the road from Austinville to Grays School, is composed of the middle member. Highly fossiliferous beds of the lower member crop out on the west side of this ridge. The best preserved trilobites were obtained by Dr. Michael of Austinville, at a point one-half mile southeast of that town, just south of the sharp bend in the road to Bethany.

The middle member in the Austinville block makes the northwest-trending ridge that follows the east side of New River one mile southeast of Ivanhoe. The fossiliferous lower member is well exposed in the old quarry of the National Carbide Company, one mile southeast of Ivanhoe, west of the river. Reticulate-weathering siliceous beds are well shown here.

Fossils. Fossils which have been collected by several geologists, including the writers, from the Kinzers formation at many localities in this area have been described by Resser[62] and by Butts[63]. Lists of fossils collected in the area by the writers and by others and determined by Resser have been published[64]. The fossils listed were collected chiefly from beds of dove to white crystalline limestone, slabby-weathered limestone, yellow, earthy weathered, sandy limestone, and gray to buff calcareous shales of the middle member. The principal localities where fossils were collected include Fossil Point and the banks of Clear and Buddle branches in the vicinity, road cut one-half mile southeast of Austinville, low hills one mile south of Austinville, on Clear Branch one-eighth mile north of the Bethany-Austinville road, and in road cut one mile north of Bethany. *Archeocyathid* reefs (Pl. 49B) form conspicuous layers in these fossiliferous beds.

No well-defined fossils were observed by the writers in the conglomerate-bearing beds and associated pure limestones of the upper member of the formation. Fossils collected by Butts[65] from blue limestone in the cut of the Norfolk and Western Railway, on the south side of New River east of Jackson Ferry, are considered to have come from the upper member. Currier[66] also collected fossils from a blue limestone inter-bedded with conglomerate at the base of the upper member, 1 mile west of Bethany and south of the Austinville road.

Age. The fauna from the lower member of the Kinzers formation at Fossil Point is stated by Resser to be the same as that occurring in the

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[62]Resser, C. E., Cambrian system (restricted) of the Southern Appalachians: Geol. Soc. America Spec. Paper 15, pp. 24-26, 35-130, 1938.

[63]Butts, Charles, Geology of the Appalachian Valley in Virginia: Virginia Geol. Survey Bull. 52, pt. 1, p. 55, 1940, and Pt. 2, 1941.

[64]Stose, G. W., and Jonas, A. I., A southeastern limestone facies of Lower Cambrian dolomite in Wythe and Carroll counties; Virginia: Virginia Geol. Survey Bull. 51A, pp. 15-20, 1938.

[65]Butts, Charles, op. cit., p. 54, 1940.

[66]Currier, L. W., op. cit. pp. 36-42, 1935.

middle member of the Kinzers formation in the vicinity of York, Pennsylvania. A list of these fossils, given in a recent publication[67], may be compared with those from the Austinville area. A generalized section of the Kinzers formation in that area has also been published[68].

LEDGER DOLOMITE

Distribution. The Ledger dolomite was named from Ledger, Lancaster County, Pennsylvania. It occurs in each of the blocks of the Gleaves Knob overthrust block. In the Austinville block it is present in a belt 6 miles long, that extends from a point 1½ miles east of Ivanhoe, northeastward to the vicinity of Fosters Falls (Pl. 1).

In the Short Hill block the outcrops of Ledger dolomite begin at a point 1 mile southwest of Jackson Ferry and extend east to a point north of New Castleton School. In the Little Mountain block the Ledger dolomite forms a narrow belt, just west of Poplar Camp village, that trends northeast. It is found in another belt northeast of Poplar Camp village where it is adjacent to the Holston Mountain-Poplar Camp overthrust fault. (Fig. 24).

Character and thickness. The Ledger dolomite is a homogeneous, granular gray to white, massive-bedded dolomite. A coarse-grained, thick-bedded, white dolomite is well exposed in the east bank of Shorts Creek southeast of Jackson Ferry. West of Liberty Grove Church, in the vicinity of the Little Mountain overthrust, the rock is crushed to a breccia. At Jackson Ferry, and on the road leading eastward from there, massive, white saccharoidal Ledger dolomite is brecciated along the Short Hill overthrust, and is impregnated with zinc and lead sulphides. White granular dolomite is well exposed to the east, along the road leading southeast from Fosters Falls, and in the cuts of the Norfolk and Western Railway southwest of Fosters Falls. The formation is so massive that bedding can seldom be determined. The thickness is estimated to be about 600 feet.

Age. No fossils have been found in the Ledger dolomite in Virginia. Sponge-like fossils, probably of algal origin similar to the *Archeocyathid* reefs in the Kinzers formation, occur in the Ledger dolomite near

[67]Stose, G. W., and Jonas, A. I., A southeastern limestone facies of Lower Cambrian dolomite in Wythe and Carroll counties, Virginia: Virginia Geol. Survey Bull. 51A, pp. 19-20, 1938.

[68]Stose, G. W., and Jonas, A. I., Geology and mineral resources of York County, Pennsylvania: Pennsylvania Geol. Survey 4th Ser. Bull. C-67, pp. 53-55, 1939; also op. cit., p. 19, 1938.

Lancaster, Pennsylvania. The Ledger is believed by the writers to be older than the Rome formation which overlies the Shady dolomite in the main part of the Great Valley, and to be of Lower Cambrian age.

PALEOZOIC INTRUSIVE ROCKS

MUSCOVITE PEGMATITE

Pegmatite occurs in the central-southern part of the Gossan Lead district at Rutherford Mill and near Dalhart. The largest zone of pegmatite is 40 feet wide at Rutherford Mill on Little River. This pegmatite intrudes hornblende gneiss in a N. 40° E. direction, in general parallel to the structure of the gneiss. The widest dike, 15 feet thick, forms a ledge 10 feet high at Rutherford Mill (Pl. 50A), crosses the river and crops out on the southwest bank. The mill dam is in large part formed by this pegmatite. Thinner sills in the zone range from 6 inches to 2 feet in width. Pegmatite stringers, half an inch wide, injected into the Lynchburg gneiss, are exposed in a tunnel dug for manganese just west of Dalhart and also along the road northeast and southwest of that place.

At Rutherford Mill the pegmatite has a coarse grained, graphic texture. It is composed of white microcline, clear white quartz, muscovite, and light-red spessartite. The garnet is present in euhedral crystals, the largest of which measure 1 inch in diameter. Muscovite occurs as fine to coarse, pale-green blades.

These pegmatites differ from the pegmatites of pre-Cambrian age, described in an earlier part of this report, in the abundant amount of muscovite and euhedral garnets, which are strikingly absent in the older pegmatites. They are also unlike the older pegmatites in that these are undeformed. They contain a clear glassy quartz, whereas the quartz in the older pegmatite is granulated and much of it is blue.

In mineral content and texture the pegmatite in the vicinity of Rutherford Mill in the Gossan Lead district resembles pegmatite which extensively injects the Lynchburg gneiss in northern North Carolina and southern Virginia. There, muscovite pegmatite is definitely related to large intrusive masses of binary granite, such as the one that forms Stone Mountain (Pl. 50B) 12 miles south of Rutherford Mill, which are similar to the granite at Mount Airy, North Carolina, 8 miles southeast of the Gossan Lead district. These granites are undeformed and are believed to be Paleozoic in age. They may be of Ordovician age like the granite that intrudes the Lynchburg gneiss at Spruce Pine, North Carolina, or they may be of late Paleozoic age.

QUATERNARY SYSTEM

ALLUVIUM

Alluvium forms the floodplains of the larger streams. It is composed of sand, gravel, and silt, which makes some of the best soil in the region and is that most generally cultivated. Only the larger areas have been mapped (Pl. 1), the largest of which border New River and Cripple Creek in the Great Valley.

Low terrace gravels are included in places with the mapped alluvium. Gravel on terraces 20 to 40 feet above the flood-plains was seen along both sides of New River west of the bridge on U.S. Route 58. This gravel contains large angular blocks of quartz, rhyolite, and crystalline rocks, and some small fragments of chalcedony. In the steeper gorges on the south slope of the Blue Ridge escarpment, coarse alluvial cones and aprons have been mapped as alluvium.

TERRACE GRAVEL

Gravel occurs on terraces that border New River and Little Reed Island and Cripple creeks in the Great Valley. The small patches of terrace gravel that occur along the streams within the mountains have not been mapped. The terraces bordering New River in the Great Valley are generally broad flat upland areas covered with sandy soil and numerous round cobbles. The higher terraces range from 2,200 to 2,300 feet in altitude, and lie south of the river. They are apparently remnants of a broad sheet of gravel that lay between the course of the present river and the foot of the mountains, which has been dissected by the present streams. They seem to mark the former course of New River during an early stage, probably in early Pleistocene time, but are in part outwash from the steep mountain slope onto the old land surface. The terraces extend from New River, south of Ivanhoe, northeastward to Fosters Falls Mountain. Northeast of Fosters Falls Mountain, smaller patches of terrace gravel at the same altitude suggest that the river, at that time, may have passed through the gap east of Fosters Falls Mountain.

These high gravels are best shown on the flat hilltops north of Grays School, southwest of Jackson Ferry, and around Liberty Grove School and northeastward (Pl. 1). Their thickness is not determinable, but in places the gravel seems to be at least 100 feet thick. The gravel on terraces bordering Cripple Creek is less continuous. The terraces rise from 2,200 feet altitude near the mouth of the creek to 2,500 feet at the mouth of Dry Run. These areas are remnants of gravel from the channel of Cripple Creek when it flowed on an old higher land surface.

Lower terrace gravels bordering New River, chiefly about 2,100 feet in altitude, have been mapped with the high terrace gravel. The largest and most conspicuous of these deposits forms the flat terrace in the southeastern part of Austinville on which the large public school is located, beside the road that leads to Bethany. Gravel on these lower terraces also occurs south of Ivanhoe, in the oxbow northeast of Ivanhoe, north of Austinville, and in the oxbow north of Fosters Falls. These terraces border the present river and were formed after the river occupied its present general course.

TRAVERTINE

Travertine occurs in many caves in the limestones in the part of the Great Valley described in this report. It is of interest because it contains fossils. Travertine is plentiful in caves in the saccharoidal member of the Shady dolomite on Cave Hill, west of Speedwell, where new cuts on U. S. Route 21 have exposed it. Travertine in the Vintage dolomite, exposed in a quarry 1½ miles southeast of Ivanhoe, contains beautifully preserved shells (Pl. 43C). Similar shells were found in the travertine at Cave Hill. Species of land snails, probably of Recent age, determined by J. P. E. Morrison of the National Museum from collections made by the writers, are as follows:

Polygyra tridentata juxtidens Pilsbry
Polygyra strenotrema Ferrussac
Haplotrema concava Say
Ventridens ligera Say
Hawaiia minuscula Binney

GEOLOGIC STRUCTURE

General statement.—The rocks of the Gossan Lead district have been strongly folded and broken by thrust faults. (Fig. 23) The dominant overthrust faults are the Poplar Camp-Holston Mountain, the Fries, and Gossan Lead. The larger thrust blocks (Fig. 24) are broken into smaller blocks by less extensive overthrust faults.

The detailed features of the structure of the Gossan Lead district are considered under the discussion of these major fault blocks. Further details of the structure of the district as a whole, or of individual fault blocks or portions of a fault block are shown in Figures 24-47 and Plates 1 and 61.

POPLAR CAMP-HOLSTON MOUNTAIN BLOCK

This block comprises the Elk Creek anticline and its folded mantle of Lower Cambrian rocks. The Poplar Camp overthrust crosses the district from northeast to southwest and there merges with the Holston Mountain overthrust. The closely folded rocks on the northeastern border of the thrust have ridden over less closely folded Cambrian rocks of the Great Valley.

The Elk Creek anticline is a broad uplift in the western part of the Poplar Camp-Holston Mountain block (Figs. 23 and 24). It was named from Elk Creek which flows southwest across it. It has a maximum width of 12 miles at the western border of the district and extends from this border for 17 miles in a N. 45° E. direction to its northeastern plunging end near Stevens Creek Village.

The early pre-Cambrian injection complex and small areas of the overlying Mt. Rogers volcanic series are exposed in this uplift. They are overlain on the north limb by north dipping Lower Cambrian rocks. These rocks are folded into a series of elongate folds which trend in an easterly or northeasterly direction and extend across the district. They form the northern part of the Poplar Camp-Holston Mountain block.

The Lower Cambrian rocks extend from the north limb of the Elk Creek anticline around the northeast plunging nose of the fold. On the southeast limb they are overridden by the Fries overthrust and completely cut off southwest of the mouth of Elk Creek.

The Lower Cambrian Unicoi formation on the north limb of the Elk Creek anticline is enclosed in two synclines. They lie South of the Byllesby overthrust. This fault, and others, break up the northern part of the Poplar Camp block and trend more or less parallel to the Poplar Camp overthrust (Fig. 23). The Byllesby overthrust extends nearly across the district. Northeast of Byllesby it passes into the Brush Creek overthrust (Figs. 30-31).

Trace of the Poplar Camp-Holston Mountain overthrust.—This fault is recognized by the discordance of the rocks on opposite sides of the fault, as shown on the geologic map (Pl. 1). This discordance is well exhibited along the north foot of Poplar Camp Mountain from New River to a point southeast of Rackettown. There the Hampton shale of the overthrust block is brought in contact with various limestones and dolomites of the Great Valley. The presence of this fault is indicated by: structures in the adjacent rocks; the brecciation and shearing of the harder beds; the crumpling of shale; deposits of iron and ferruginous chert where limestone is at the fault contact, and springs. The fault zone is especially well marked by iron deposits east of New River, where limestone lies north of the fault (Pls. 1 and 61). Limonite and ferruginous chert are plentiful along the fault around Sindion Point and westward. Ferruginous chert breccia (Pl. 53A) lies at the fault contact with dolomite at Shiloh and at the west foot of Dry Pond Mountain. The overthrust Erwin quartzite here is sheared and veined with quartz. The quartzite near High Rocks Mill is broken and sheared at the fault, while east of Rackettown, the Hampton shale is crumpled and crushed. This shearing in the Poplar Camp-Holston Mountain block, however, is confined to its northwest margin and has not greatly disturbed the structure within the block.

At Poplar Camp, on U. S. Route 52, the road cuts, at the mouth of the gorge, expose crushed and limonite-stained Hampton shale adjacent to the limestone of the Kinzers formation and the Ledger dolomite. An old iron pit is located at the fault contact in the hill just west of the highway, while several other iron pits lie along this contact in the foothills to the southwest and northeast.

Southeast of Rackettown the fault contact bends sharply north around hills of Hampton shale in the vicinity of New Castleton School where the exposures are partially concealed by terrace gravel. One mile southwest of High Rocks Mill, in an abandoned oxbow of Little Red Island Creek, a small body of Vintage dolomite, that overlies a south-dipping fossiliferous quartzite of the Erwin, is exposed north of the fault. An old iron pit is near the contact. The fault plane here is nearly horizontal, and its outcrop swings sharply south, up the oxbow valley. On the west side of the oxbow lowland, crushed Hampton shale and thin quartzite of the lower member of the Erwin is thrust over a porous

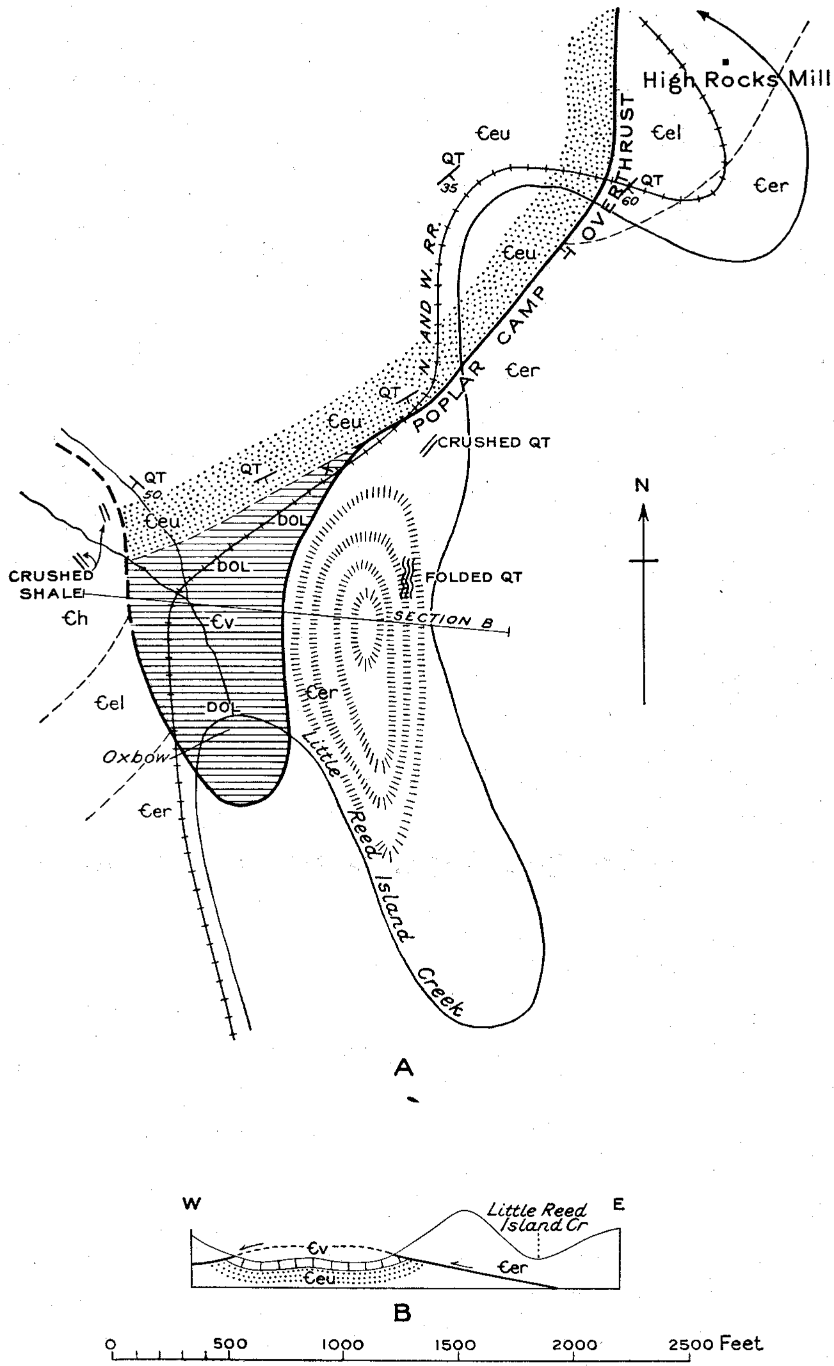

FIGURE 25.—Geological map and section of Poplar Camp overthrust southwest of High Rocks Mill. Qt, terrace gravels; Ꞓv, Vintage dolomite; Ꞓh, Hampton shale; Ꞓeu, Erwin quartzite, calcareous; Ꞓer, Erwin quartzite, ridge-making; Ꞓel, Erwin quartzite, interbedded dark shales.

rust-colored quartzite of the upper member of the Erwin. The interpretation of the structure here is shown in Figure 25.

The hard quartzites of the overthrust block make high cliffs east of the creek on both sides of the gorge of Alum Hollow (Pl. 46 and Fig. 26). The fault passes around the west end of the promontory, on the lower slopes of which, dolomite is exposed at about 2,100 feet altitude. The fault rises rapidly northeastward, for dolomite is exposed beneath the fault at about 2,260 feet altitude at the low saddle on the north side of the hill (Fig. 26). Northward along the west slope of Dry Pond Mountain, the fault plane is nearly horizontal and gently rolling. In an old iron pit at the fault contact (Fig. 27) on the south side of Buckeye Hollow, the fault between quartzite and dolomite, which is indicated by much ferruginous chert, is about 2,200 feet in altitude. On the road that ascends the mountain north of the hollow, dolomite at the fault contact rises to about 2,280 feet altitude. The fault has not been mapped along the east side of Dry Pond Mountain because of the lack of a topographic map, but it apparently swings southward to the south end of the mountain, as shown in Figure 26.

West of New River the Poplar Camp overthrust follows the strike of the rocks on the south slope of Cold Ridge. West of the head of North Branch of Brush Creek the fault cuts directly across the several members of the Erwin quartzite in the Cold Ridge and Powder Mill anticlines and also across the Vintage dolomite in the intervening synclines in the Gleaves Knob block. This is fairly well shown on State Highway 94, just southwest of the Cold Ridge divide, and on the road that leaves this highway and ascends the North Branch of Brush Creek. Dolomite is exposed up the Cold Run valley as far south as Shiloh, and large residual masses of ferruginous chert breccia in the valley bottom at this point mark the fault contact (Pl. 53A). Fragments of dolomite and iron-cemented quartzite breccia, which occur in an old iron pit a quarter of a mile farther south, show that the fault contact makes a deep narrow re-entrant up the valley to that point. The trace of the fault on the east side of this re-entrant valley is nearly horizontal.

In the valley of Francis Mill Creek and westward along the foothills, the fault is indicated by the relations of the adjacent formations, shown on the geologic map (Pl. 1). The fault, however, is not clearly exposed, because the Hampton shale of the overthrust block is not markedly different from the lower member of the Erwin, with which it is in contact. On U. S. Route 21, in the rocky gorge of Dry Run, road cuts expose the fault. Nearly vertical black shale, with inter-bedded thin

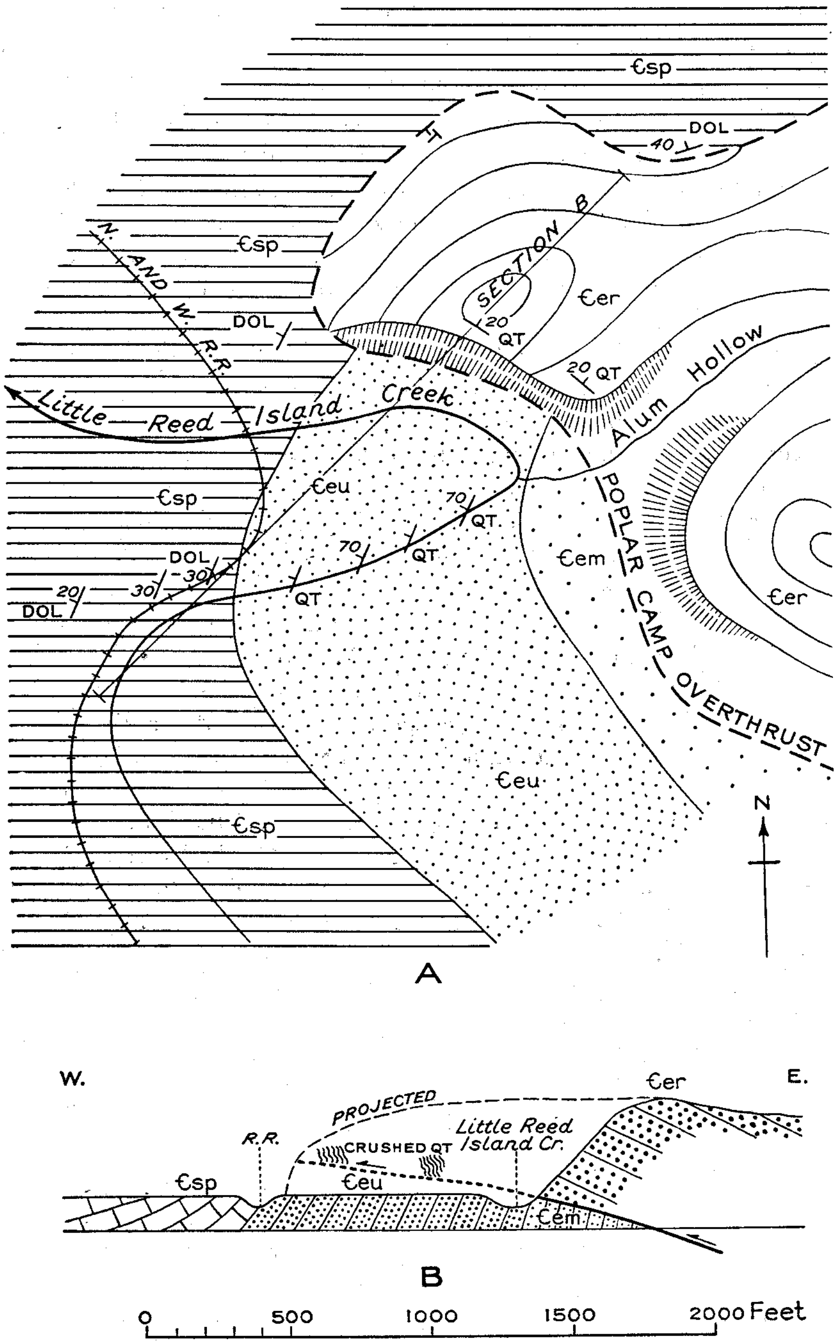

FIGURE 26.—Geological map and section at mouth of Alum Hollow. Qt, terrace gravels; €sp, Shady dolomite, Patterson member; €eu, Erwin quartzite, calcareous; €em, Erwin quartzite, argillaceous; €er, Erwin quartzite, ridge-making.

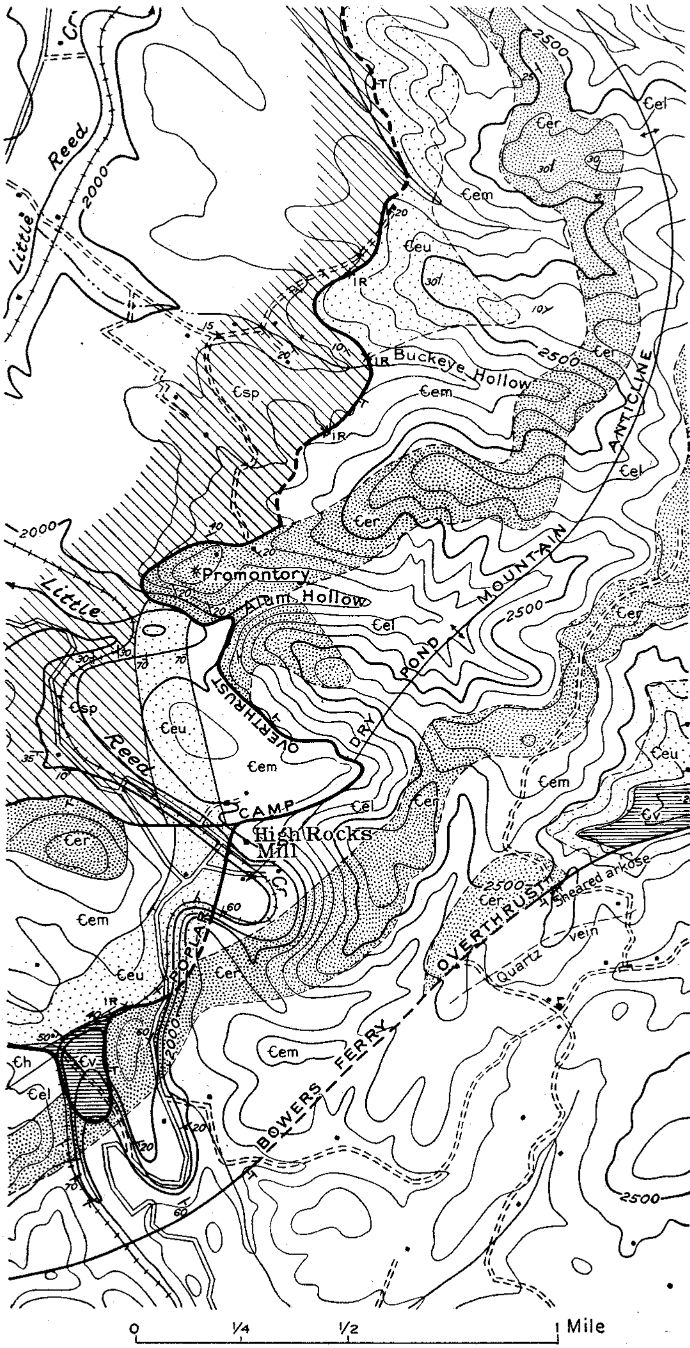

FIGURE 27.—Geological map of south end of Dry Pond Mountain. Ꞓsp, Shady dolomite, Patterson member; Ꞓv, Vintage dolomite; Ꞓeu, Erwin quartzite, calcareous; Ꞓem, Erwin quartzite, argillaceous; Ꞓer, Erwin quartzite, ridge-making; Ꞓel, Erwin quartzite, interbedded dark shale; Ꞓh, Hampton shale.

quartzites of the middle member of the Erwin in the Poplar Camp block, are in contact with horizontal thick-bedded quartzite of the ridge-making member of the Erwin in the overridden block (Pl. 51 and Fig. 28). The fault crosses Little Dry Run half a mile above its mouth,

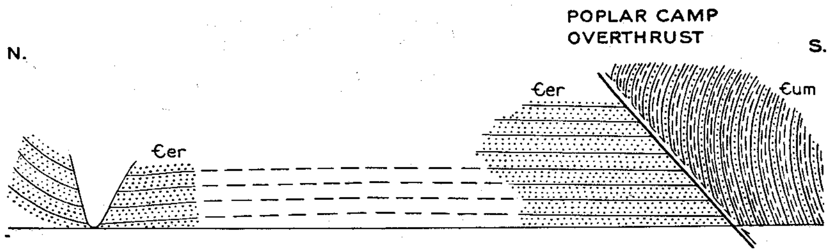

FIGURE 28.—Sketch of Poplar Camp overthrust on U. S. Route 21. €er, Erwin quartzite, ridge-making; €um, Unicoi formation with basalt flows and black argillite.

where Shady dolomite, on the north limb of the Fry Hill anticline, crops out in the stream. The overthrust at this point bends sharply north and follows the foot of the steep slope of the mountains to Sindion Point. The dolomite of the overridden block is exposed at the deep re-entrant in the overthrust at Little Dry Run. Southeast of Sindion Point, the fault swings sharply around a small detached knob which is composed of limonite-cemented brecciated quartzite. The severed ends of the quartzite beds in this knob strike north and abut against the limestone in the lowland. The knob is nearly, if not completely, separated from the main fault block as a klippe (Fig. 29). The fault similarly swings sharply around Sindion Point (Fig. 30), which is also composed of cemented brecciated Erwin quartzite. The hill northeast of Sindion Point is capped by dolomite which contains much iron, and the soil derived from the dolomite is filled with residual limonite. At the saddle between this hill and Sindion Point, limonite and numerous masses of yellow ferruginous chert lie at the contact.

Portion of block north of Brush Creek overthrust.—The portion of the Poplar Camp-Holston Mountain block, north of the Brush Creek overthrust, is composed at the surface of Hampton shale with Erwin quartzite which is enclosed in shallow synclines (Pl. 1). In most places Hampton shale lies at the northwest border of the overthrust block. The synclines of Erwin quartzite strike northeastward, oblique to the bounding overthrusts. The structures appear to have a radial trend (Fig. 30) west of Farmer Mountain. Most of the synclines of Erwin

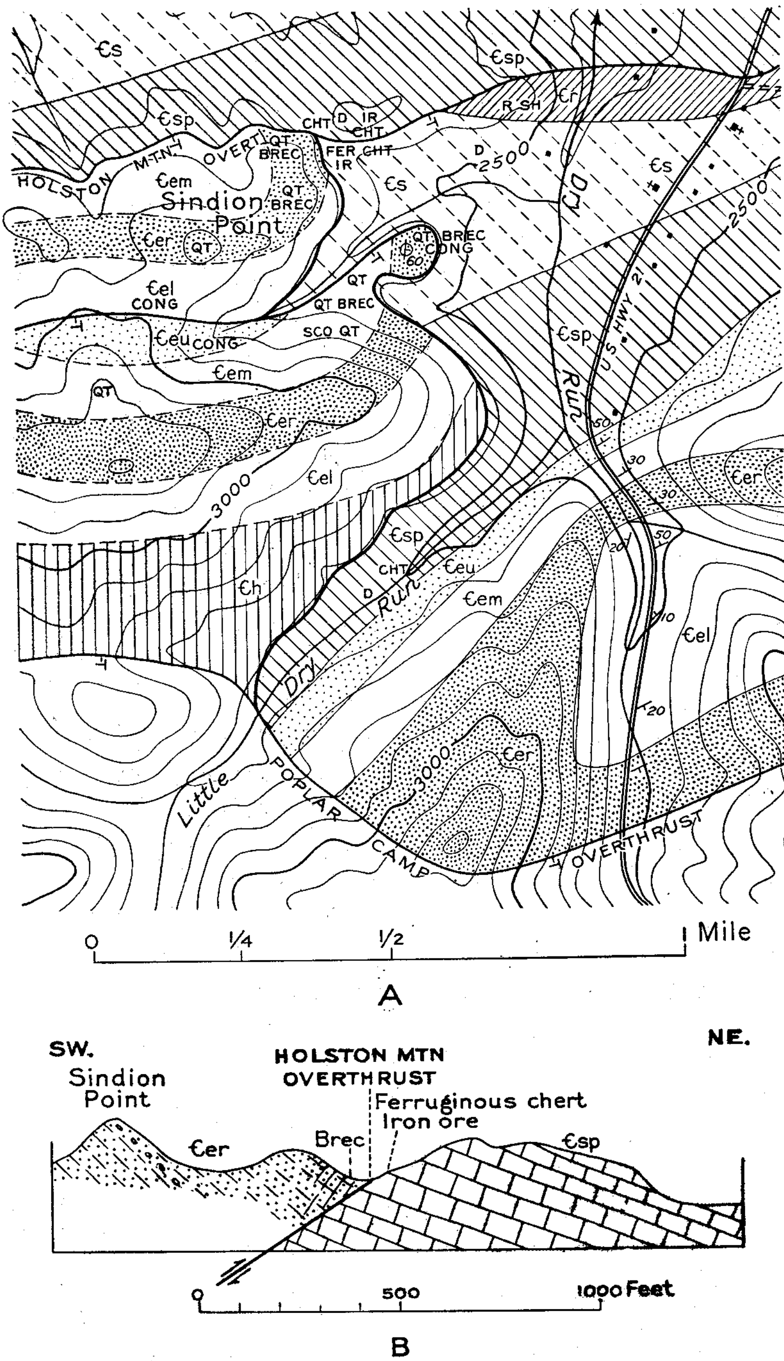

FIGURE 29.—Geological map and section of Holston Mountain overthrust in vicinity of Sindion Point. Qt, terrace gravels; Ɛr, Rome formation; Ɛs, Shady dolomite; Ɛsp, Shady dolomite, Patterson member; Ɛeu, Erwin quartzite, calcareous; Ɛem, Erwin quartzite, argillaceous; Ɛer, Erwin quartzite, ridge-making; Ɛel, Erwin quartzite, interbedded dark shales; Ɛh, Hampton shale.

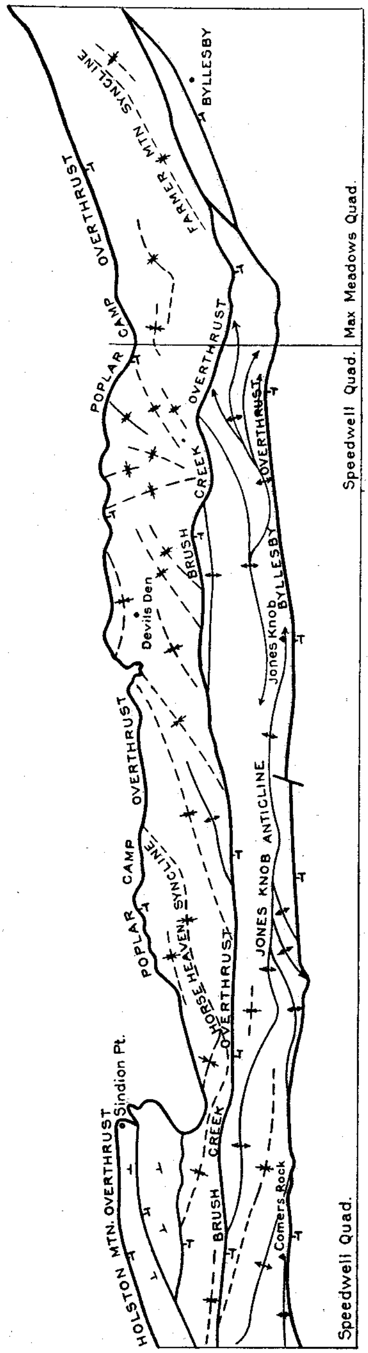

FIGURE 30.—Structural map of northern part of the Poplar Camp block.

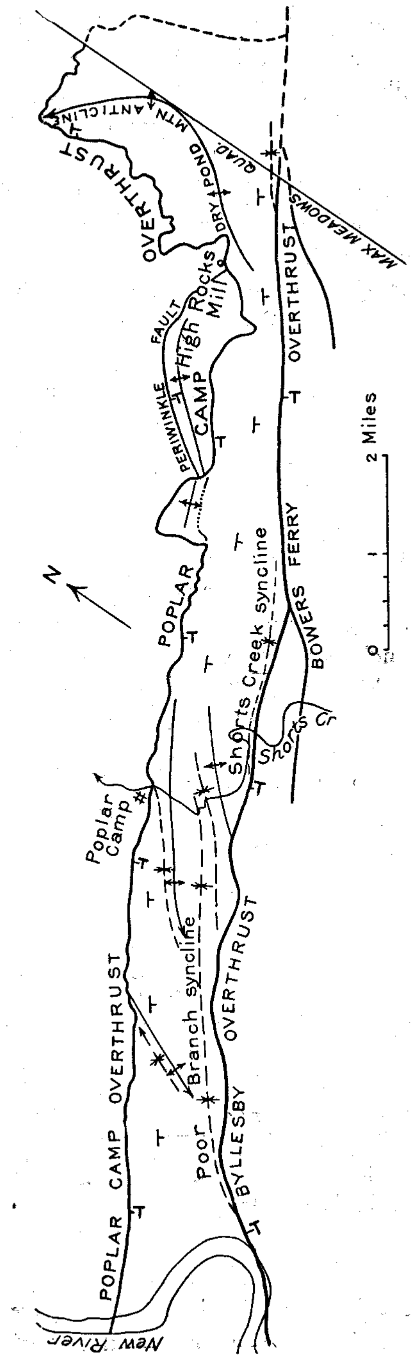

FIGURE 31.—Structural map of Poplar Camp block east of New River.

quartzite are shallow, and generally enclose only the lower members of the formation. Horse Heaven syncline, the longest and deepest of these synclines, is over 5 miles long. The ridge-making member of the Erwin, on its south limb, makes a long nearly continuous prominent ridge called Horse Heaven. West of Little Dry Run the Horse Heaven syncline is cut off by a branch of the Poplar Camp overthrust, which splits from the main fault where it bends sharply north (Pl. 1 and Fig. 30). North of this branch fault there are two north-dipping monoclinal blocks that enclose Erwin quartzite. These are separated by another branch of the main overthrust. The northern block terminates at the east in the high peak of Sindion Point. The deep syncline at Devils Den, which encloses the ridge-making member, that makes the high rocky peak and spurs of the Devils Den, may be an eastward continuation of the Horse Heaven syncline. Northeast of Brush Creek, near New River, the ridge-making member of the Erwin quartzite lies in a syncline and forms Farmer Mountain.

East of Byllesby the Poplar Camp-Holston block is a south-dipping monocline of Erwin quartzite, the ridge-making member of which makes the crest of Poplar Camp Mountain. Two synclines that lie near the middle of the block enclose Vintage dolomite, which is overridden by the Byllesby overthrust block (Fig. 31). In the western syncline, called the Poor Branch syncline, the Vintage dolomite is exposed along the Poor Branch valley for more than a mile. The details of this syncline exposed on the road over Poplar Camp Mountain southeast of Sheeptown are illustrated in Figure 32. The eastern syncline, called the Shorts

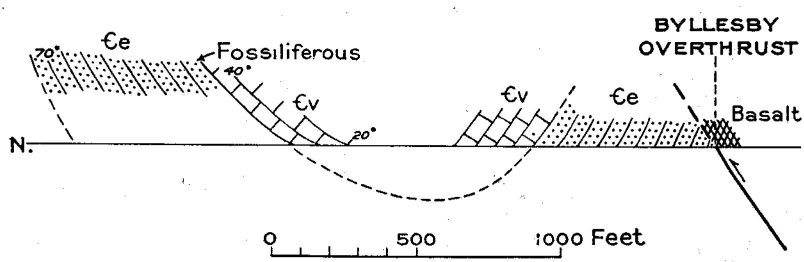

FIGURE 32.—Sketch section of Poor Branch syncline. Ꞓv, Vintage dolomite; Ꞓe, Erwin quartzite.

Creek syncline, is crossed by U. S. Route 52. Its detailed structure is shown in Figure 33. Southwest of Poplar Camp village, several minor folds pitch northeast, but in the area south and east of the village the

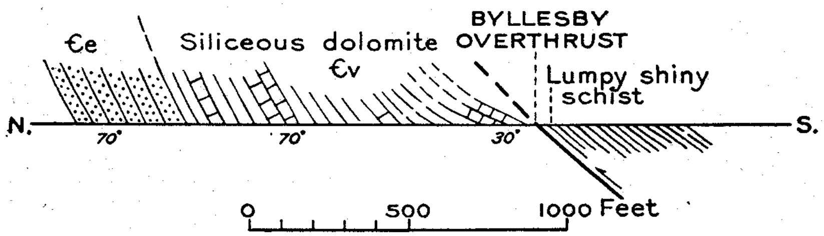

FIGURE 33.—Sketch section of Shorts Creek syncline. Ꞓv, Vintage dolomite; Ꞓe, Erwin quartzite.

strike becomes more easterly (Fig. 31). Half a mile south of the village, a minor fold, trending easterly, encloses a small body of Vintage dolomite which is crossed by U. S. Route 52. This syncline is so tightly compressed that it pitches steeply in both directions toward its center, and the enclosed Vintage dolomite is so silicified and stained with limonite that it closely resembles the associated Erwin quartzite.

East of Little Reed Island Creek, the south end of the Dry Pond Mountain anticline, made up of Erwin quartzite, is cut off by the Bowers Ferry overthrust (Fig. 27). The axis of this anticline curves northward with the crest of the mountain and plunges at its north end near Boom Furnace (Fig. 31).

West of High Rocks Mill a branch of the Poplar Camp-Holston Mountain overthrust, called the Periwinkle overthrust, encloses an anticline of Erwin quartzite that composes Periwinkle Mountain (Fig. 31). This anticline did not rise as high as did the Dry Pond Mountain anticline and was apparently overridden by later movement on the main overthrust.

Portion of block south of Brush Creek overthrust.—The Brush Creek thrust fault extends from the western edge of the Gossan Lead district almost due east to the Byllesby overthrust at New River (Pl. 1). The portion of the Poplar Camp-Holston Mountain south of this fault is composed of the upper beds of the Unicoi formation brought up on anticlines in Hampton shale. The axes of these anticlines, tend more or less parallel *en echelon* to the Brush Creek overthrust. The Unicoi formation in the Jones Knob anticline is nearly continuously exposed for 9 miles east of Jones Knob (Fig. 30). East of the Knob a parallel *en echelon* anticline exposes the Unicoi for 4 miles to the point where it splits up into several east-plunging anticlines. Northwest of Perkins Knob minor plunging anticlines strike southwestward from the main anticline, one of which extends to the western border of the district. The quartzite in this anticline makes the long high spur northwest of Comers Rock lookout (Fig. 30). Comers Rock and the ridge extending westward mark another anticline. A few small areas of Erwin quartzite are enclosed in synclines between the anticlines.

Portion of block south of Byllesby overthrust.—The Byllesby overthrust tends due east from the western edge of the district to the point where it crosses Brush Creek. There it bends northeastward and continues to a point east of Shorts Creek. The rocks south of the Byllesby fault are quartzites of the Unicoi formation, which overlies the pre-Cambrian rocks of the Elk Creek anticline (Pl. 1 and Fig. 34).

Northeast of the plunging end of the Elk Creek anticline, the upper member of the Unicoi formation is enclosed in the Fries Junction syncline, which trends east and pitches gently in that direction. East of Fries Junction, the syncline is cut off across the strike by the Bowers Ferry overthrust. Its north limb is cut off by the Falls overthrust, a longitudinal thrust fault within the block. This thrust fault extends for three miles from State Highway 94 eastward to New River. Near the river it is marked by a narrow zone of schistose slate and basalt which is exposed north of Bowers Ferry (Pl. 43B). West of State Highway 94 this thrust fault merges with the Byllesby overthrust for 2 miles but separates again to the westward. The Falls overthrust trends parallel to the Byllesby overthrust across the Speedwell quadrangle to the western edge of the Gossan Lead district. The Cambrian quartzites south of the Falls overthrust dip north into a syncline which encloses the hard white quartzite of the upper member of the Unicoi formation. This syncline is probably the westward extension of the Fries Junction syncline. A minor syncline, to the south, encloses a hard white quartzite of the upper member of the formation that forms High Knob (Pl. 5B). The quartzite in the long narrow fault, between the Falls and Byllesby overthrusts, dips north and makes up the south limb of another syncline.

Trace of the Byllesby overthrust.—The presence of the Byllesby overthrust is recognized by the discordance of formations on either side of the fault as shown on the geologic map (Pl. 1). At Comers Rock, the upper basalt of the middle member of the Unicoi in the Byllesby block, is nearly in contact with the hard white quartzite of the upper member of the formation that forms Comers Rock, and is in contact with the Hampton shale to the east. The fault is exposed in a road cut on the north slope of the Iron Mountain on a CCC road. Here thick white quartzite of the upper member of the Unicoi in the Byllesby block dips 65° N. A rust-colored white clay gouge marks the fault contact with the

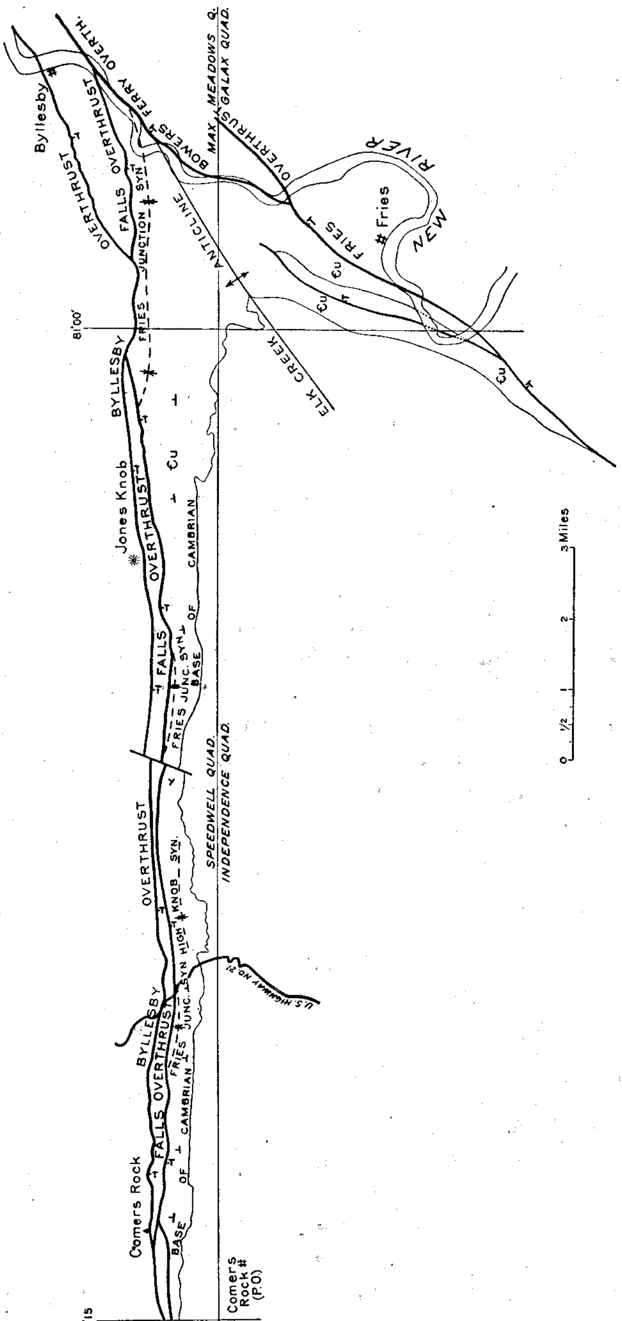

FIGURE 34.—Structural map of Poplar Camp block south of Byllesby overthrust.

Hampton shale. At the head of Falls Creek, an amygdaloidal basalt and an underlying thick coarse arkose are in fault contact with the Hampton Shale to the north. A spring issues at the fault contact. On a road that ascends Iron Mountain north of Spring Valley to Jones Knob, the rocks of the middle member of the Unicoi, south of the fault, are much folded and confused (Fig. 20). Farther east, in Bournes Branch, basalt and argillite of the middle member of the Unicoi dip steeply north toward the fault, and highly contorted gray shale of the Hampton lies north of the fault.

At the point where State Highway 94 crosses Brush Creek, the hard, pebbly, arkosic quartzite of the upper member of the Unicoi, and the underlying closely folded black-banded argillite of the upper part of the middle member of the formation, lie almost horizontal in the Fries Junction syncline south of the Byllesby fault. The argillite is much sheared and contains veins of quartz and pyrite. The cleavage planes are marked by shiny sericite close to the fault contact. North of the fault, the Hampton, shale is closely folded and limonite stained. Its cleavage planes dip 40° S., parallel to the fault. The green argillite exposed near the fault at Byllesby, is closely folded. Sericite is developed on the southward dipping cleavage planes. North of Byllesby, and south of Farmer Mountain, a lenticular shear zone of Hampton shale, 2 miles long, lies between the converging Byllesby and Brush Creek faults. In this zone the shale is sheared into a shiny black phyllite that contains veins of quartz stained with limonite. It is well exposed on the railroad north of Byllesby (Pl. 1).

East of New River, the basalt and argillite of the middle member of the Unicoi, south of the Byllesby overthrust, are closely compressed into pitching folds (Pl. 52A) with strikes that curve more easterly. The amygdules in the basalt are drawn out into ribbons made up of black chlorite (Pl. 43B). The argillite, on the edge of the thrust, east of Byllesby, is closely folded and sheared into lenticles. The sheared argillite is well exposed on New River near the mouth of Rocky Branch and eastward along the south side of Poor Branch. The basalt, of the middle member of the Unicoi, is cut off by the fault at the mouth of Stoots Branch. Eastward the lower member of the Unicoi lies along the thrust. The Byllesby thrust block is only three quarters of a mile wide where U. S. Route 52 crosses it. One mile east of the highway, the Byllesby block is overridden by the Bowers Ferry overthrust.

The rocks north of the Byllesby overthrust show a marked structural discordance with those of the Byllesby block. From the mouth of Poor

Branch eastward, the Poor Branch syncline lies north of the thrust (Fig. 31). A short distance up Poor Branch, the Vintage dolomite overlies the Erwin quartzite in the syncline. The fault follows the creek on the south side of the dolomite for about a mile to a point where Poor Branch bends sharply south around a hill of Erwin quartzite which is on the south limb of the Poor Branch syncline (Pl. 1). South of the hill, along the Shorts Creek-McGee School road, a sheared amygdaloidal basalt and an argillite are in fault contact with the sheared and limonite-stained Erwin quartzite. Another syncline of Vintage dolomite lies north of the Byllesby overthrust at Shorts Creek. On the north side of the fault the dolomite is highly silicified and weathers with a rusty buff-colored coating. The silicification and the discoloration of these rocks were caused by solutions that came up along the fault.

Steep-angle strike faults.—A number of east-west faults cut the pre-Cambrian rocks in the Poplar Camp-Holston Mountain block west of Fallville. These can be recognized only where flat-lying, late pre-Cambrian or Cambrian sedimentary rocks are down faulted in the injection complex (Fig. 35). An east-west normal fault which occurs just

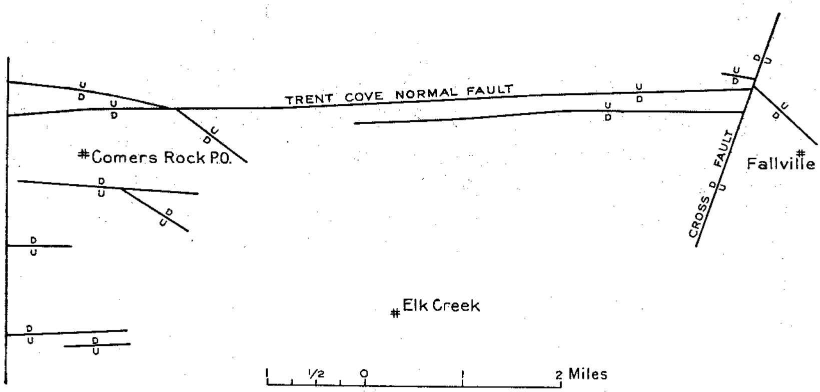

FIGURE 35.—Sketch map showing strike faults in Poplar Camp-Holston Mountain block.

west of the Gossan Lead district is marked by a prominent valley called the Trent Cove Valley and for this reason the fault has been named the Trent Cove fault. This fault has been traced almost continuously, from the west edge of the district to the cross fault one mile northwest of Fallville (Pl. 60).

A diagonal fault trends southeast toward Fallville east of this cross fault. Another strike fault was observed farther east, at Liberty Church (Pl. 1.) A long fault, lying south of and nearly parallel to the Trent Cove fault, has been mapped from the cross faults, west of Fallville, westward beyond Turkey Fork. A diagonal fault, with a southeast trend, crosses the Trent Cove fault north of Comers Rock village. Four short east-west normal faults and one diagonal normal fault were observed south of Comers Rock village.

The throw on all these faults is small. The sedimentary rocks that cap the hills on the south side of the strike faults dip gently north and are down faulted at their north borders, but rest normally on the older rocks at their south borders. The downthrow on all of them is on the south side. The cross fault west of Fallville has a downthrow on its west side, as shown by the Cambrian rocks on the west spur of Brierpatch Mountain. It offsets the Cambrian rocks and their structural features on the north limb of the Elk Creek anticline northwest of Fallville, and therefore is later than the major structures of the region. Inasmuch as the strike faults terminate at the cross fault west of Fallville, they are related structures. This normal faulting, therefore, took place at the close of, or just after, the period of compression that folded the rocks of the region and produced the great thrust faults.

PULASKI BLOCK

General description.—The rocks of the Great Valley in this district that lie northwest of the Poplar Camp-Holston Mountain overthrust and the Gleaves Knob overthrust are part of the Pulaski block (Fig. 24). In this district the block is composed of Lower Cambrian limestone, dolomite, shale, and quartzose rocks. The Elbrook limestone of Middle Cambrian age is present in the Galena syncline. The rocks in the Pulaski block are folded into anticlines and synclines and in places are broken by minor thrust faults. The block is overridden, on its southside, by the rocks of the Poplar Camp-Holston Mountain and Gleaves Knob overthrust blocks. The major structures of the Pulaski block, within the Gossan Lead district are: the Fry Hill anticline; the Speedwell syncline; the Galena syncline; and the Fosters Fall Mountain anticline (Fig. 23).

Fry Hill anticline.—The Fry Hill anticline lies just north of the western part of the Poplar Camp-Holston Mountain overthrust. It extends for 6 miles from Collins Cove on Cove Branch through Fry Hill and Little Horse Heaven southwestward along the foothills to Dry Run. Its anticlinal character is best shown in the gorge of Francis Mill Creek, west of Fry Hill (Pl. 1 and Fig. 21), where the upper member of the

Erwin quartzite on the north limb dips 40° N., beneath the Shady dolomite; the middle member is exposed in the middle of the fold; and south of the axis the quartzite beds dip 20°-50° S. beneath the Shady dolomite. The dolomite lies in a sharp syncline that pitches northeast. To the southwestward its axis passes just south of Little Horse Heaven. The uppermost beds of the Erwin on the south limb of the syncline are well exposed on the road up Francis Mill Creek, where they dip 25° N. The Erwin quartzite in Fry Hill marks the east-plunging end of the fold where it passes normally beneath the Shady dolomite. The quartzite barely reaches the north-south road at the east foot of the hill, where dolomite is exposed around it (Pl. 1 and Fig. 36).

The axis of the Fry Hill anticline passes southwestward through Little Horse Heaven and trends across the spurs of Horse Heaven Mountain to the west. It is expressed by the rise of the ridge-making member to a crest on all the spurs. The anticline is well exposed also in the gorge of Dry Run and in Henley Hollow (Fig. 22). The ridge-making member on the north limb rises on the spur north of Henley Hollow, and the underlying dark-colored argillaceous quartzite and shale of the lower member, dipping gently north, are well exposed along U. S. Route 21 up Dry Run (Fig. 22). On the south limb of the fold, the ridge-making member dips steeply south at the highway. In the stream bed of Henley Hollow, east of the highway, the hard pebbly white quartzite, of the ridge-making member on this limb of the fold, are vertical. West of Dry Run the Poplar Camp-Holston Mountain overthrust bends sharply north and cuts abruptly across the Fry Hill anticline. South of Cove Branch School and north of the southwest prong of Ewing Mountain, the eastern extension of the anticline is cut off by the Gleaves Knob overthrust. That some folding took place along this axis after the Gleaves Knob overthrusting is indicated by the upbowing of the fault plane along this strike, as shown in Figure 46.

Speedwell syncline.—The Speedwell syncline (Fig. 37) begins 2 miles west of Cripple Creek village, north of the Fry Hill anticline, and extends westward beyond the Gossan Lead district. The syncline encloses the Rome formation, which is surrounded by the saccharoidal Patterson member of the Shady dolomite. A narrow band of Erwin quartzite occurs on the north edge of the syncline. The rocks within the syncline dip uniformly towards the middle, those on the north limb dip about 40° S., while those on the south limb dip north with dip angles of as much as 75°. Even in the minor folds of the Rome formation in the syncline west of Speedwell, the dips are gentle and the beds are not crumpled.

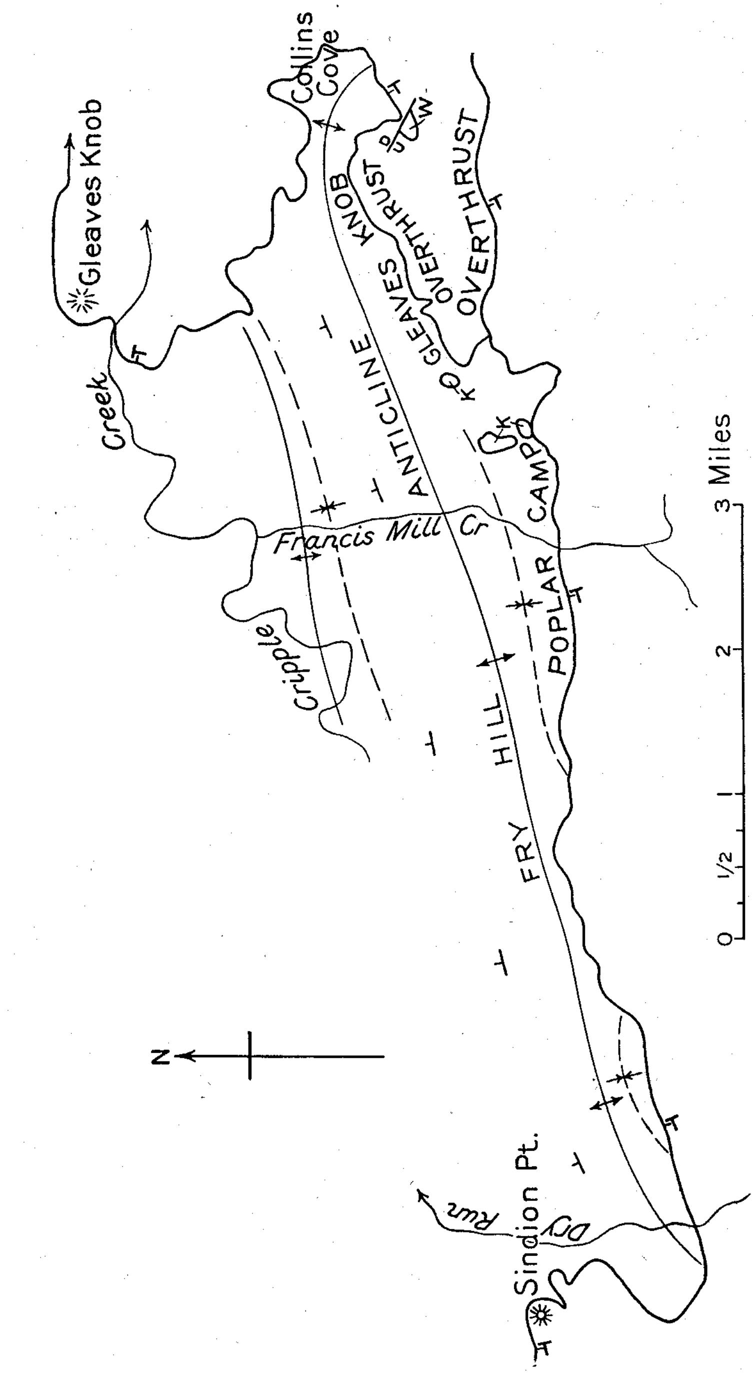

FIGURE 36.—Structural map of Fry Hill anticline.

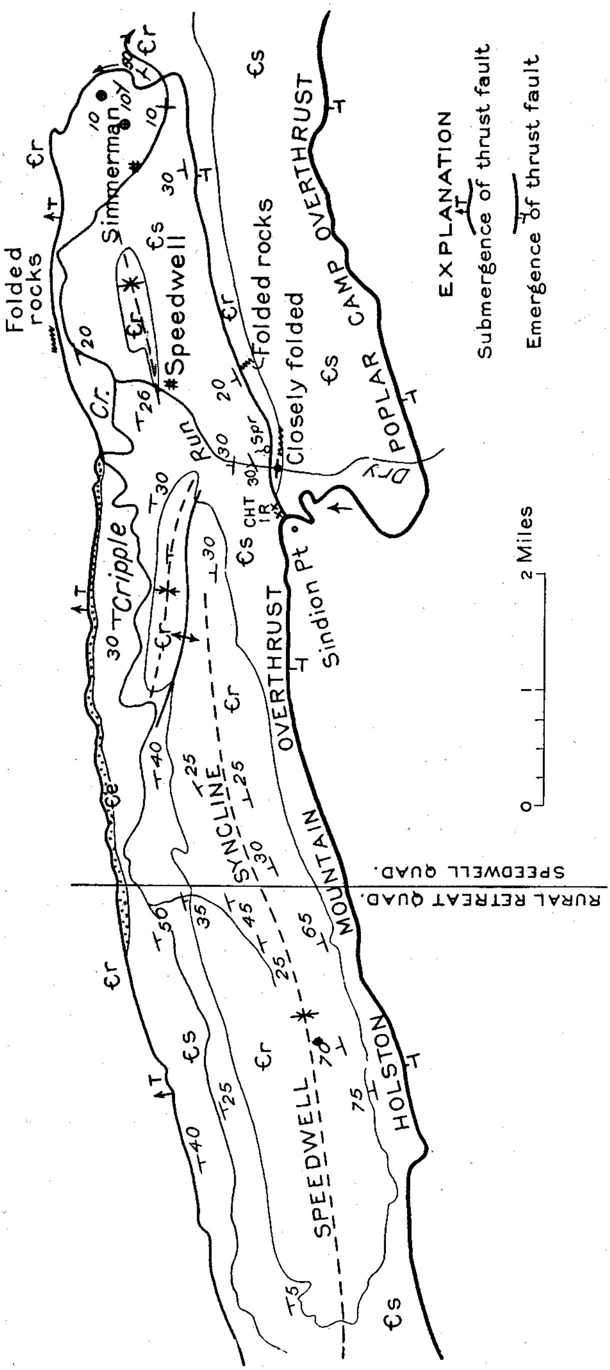

FIGURE 37.—Structural map of Speedwell syncline. Єr, Rome formation; Єs, Shady dolomite; Єe, Erwin quartzite.

This syncline is largely encircled by the Rome formation in fault relations (Pl. 1 and Fig. 37). From Sindion Point eastward, the Rome, south of the syncline, lies adjacent to the Patterson member of the Shady dolomite to a point one mile southeast of Simmerman. There it bends sharply north, around the Patterson member in the syncline, then continues westward along the north side of the Erwin quartzite which is exposed at the north edge of the syncline. This contact of Rome and the older rocks is evidently a fault. Currier[69] who named the fault the Sugar Grove overthrust, interpreted the syncline as a klippe that had ridden over the surrounding Rome formation. The Erwin quartzite exposed in the narrow band along the north rim of the syncline, adjacent to the fault, is not sheared, slickensided, crushed, or veined with quartz, as it probably would be if it were the sole of an overthrust.

The Rome formation that surrounds this syncline is everywhere closely folded, crumpled, and veined with quartz. In many places the quartzose beds are silicified. Their deformation is in marked contrast to the gently folded and undisturbed character of the Rome within the syncline. The fact that the rocks outside the encircling fault were greatly deformed during the faulting and those inside were only gently folded, suggest that the Rome formation was thrust over the relatively undistrubed rocks in the syncline. These were later exposed by erosion as a window in the overthrust. At the east end of the fault block, along the Cripple Creek-Speedwell road where it crosses Thorn Creek, the Rome overlies the Patterson member of the Shady dolomite in fault relation (Fig. 38). The dolomite in the lowland west of the contact is nearly horizontal and is not crushed or crumpled, whereas the red shale of the Rome to the east is steeply tilted and crumpled and makes a high hill. The Patterson member of the Shady dolomite, exposed on the north slope of a small hill south of the road at this point, is discordantly overlain by the folded Rome formation.

From the observed relations at the above-mentioned contact and the condition of the rocks involved, the writers conclude that the Rome formation, surrounding the Speedwell synclinal area, was thrust over the relatively undistrubed rocks in the syncline and that the latter were exposed by erosion as a window in the overthrust. The Rome is a yielding formation that seems to have been crumpled and pushed forward in front of, or dragged on the bottom of, the northward moving Holston

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[69]Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bulletin 43, page 60 and Pl. 1, 1935.

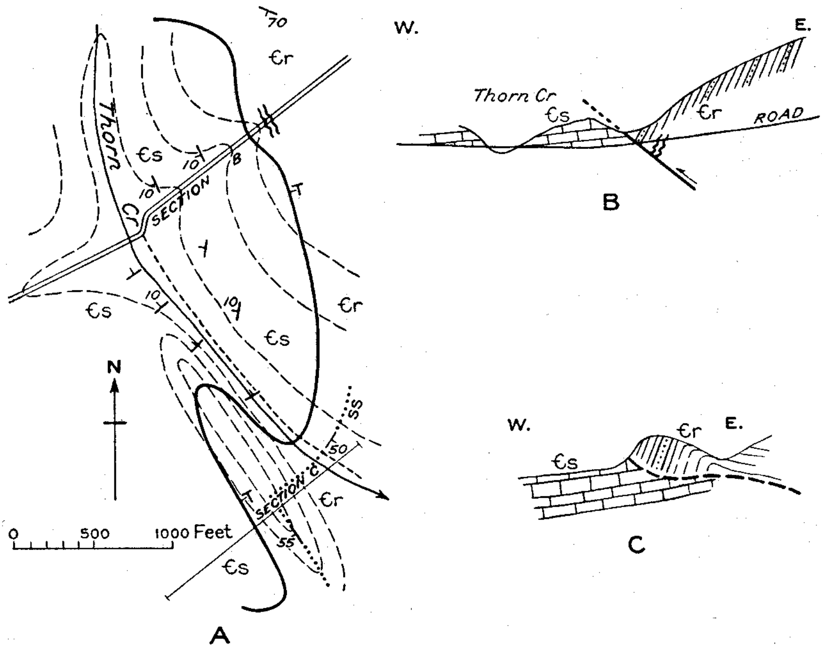

FIGURE 38.—Sketch map and sections of east end of Speedwell syncline. Єr, Rome formation; Єs, Shady dolomite.

Mountain overthrust mass, and to have ridden over the little disturbed rocks in the syncline.

Galena syncline.—The Galena syncline lies east-northeast of Gleaves Knob and north of the Gleaves Knob overthrust. It is a double fold, broken lengthwise by the Pierce Mill overthrust. It is bounded on the north side by the Laswell overthrust, which splits from the Gleaves Knob fault just north of Gleaves Knob (Fig. 39). The beds on the north limb of the northern fold dip about 40° S. A long narrow band of Elbrook limestone, which is enclosed in the syncline, is cut off on its south side by the Pierce Mill overthrust, which crosses U. S. Route 52 south of Galena. The Elbrook extends northeastward nearly to New River, west of Bertha, where it is enclosed by the Rome formation. At the west, the Pierce Mill overthrust passes beneath the Gleaves Knob overthrust east of Cattron.

In the vicinity of Patterson a fault, which is a split from the Hematite Mountain overthrust, passes northeastward into the Shady dolomite in the Galena syncline. Southwest of Austinville, an anticline exposing the

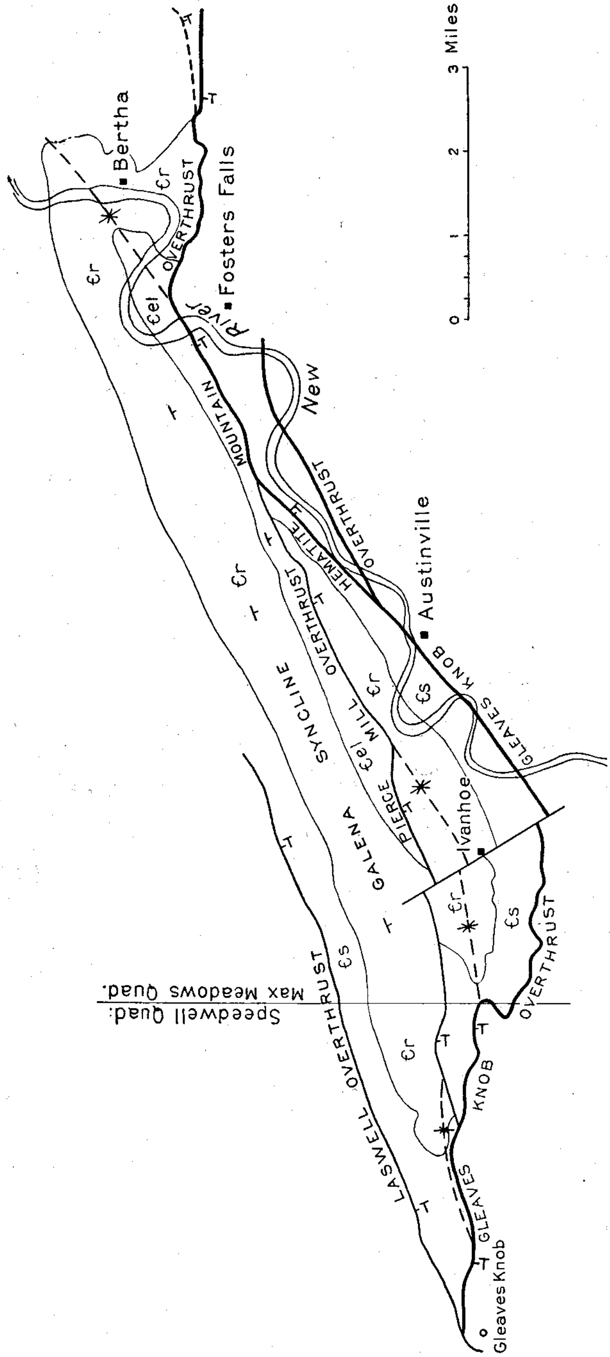

FIGURE 39.—Structural map of Galena syncline. €r, Rome formation; €s, Shady dolomite; €el, Erwin quartzite, interbedded dark shales.

Patterson member of the Shady dolomite, is overridden by the Gleaves Knob overthrust.

Fosters Falls Mountain anticline.—The ridge-making member of the Erwin quartzite, at the axis of an anticline, makes the ridge crest of Fosters Falls Mountain (Fig. 40). On Periwinkle Branch southwest of

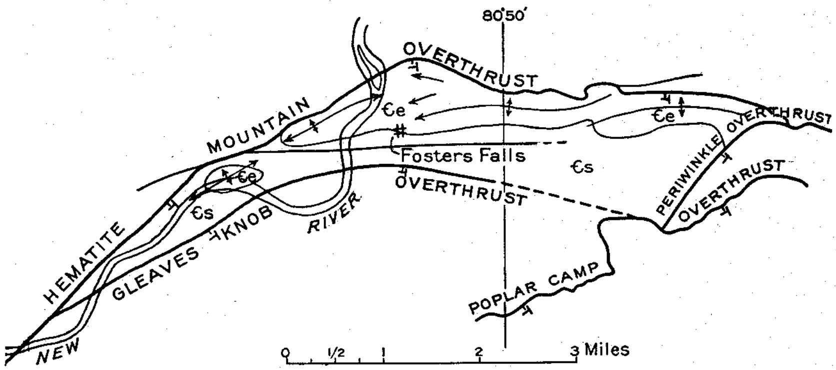

FIGURE 40.—Structural map of Fosters Falls Mountain anticline. Єs, Shady dolomite; Єe, Erwin quartzite.

Patterson at the east end of the anticline, the quartzite on the north limb of the fold dips 60° N., and on the south limb 30° S. The overlying members of the Erwin dip more gently southwest as they pass under the Shady dolomite. Just east of Periwinkle Branch, where the anticline is cut off abruptly by the Periwinkle overthrust, the rocks of the Gleaves Knob block strike nearly at right angles to those in Fosters Falls Mountain. The eastern part of Fosters Falls Mountain is offset from the western part by a minor diagonal syncline (Pl. 1). At the west end of Fosters Falls Mountain the anticline splits into several minor folds, which pitch westward, while the ridge-making member of the Erwin quartzite passes beneath the surface. It again appears west of the river in Hematite Mountain along the rising axis of the fold. The fold again pitches steeply southwestward at the high peak of the mountain, and at the west the Erwin passes beneath the Shady dolomite. A small inlier of the Erwin quartzite, along another gentle uplift on this axis, is exposed in the New River valley southeast of Galena. A minor east-west thrust fault, in the Shady dolomite on the south limb of the Fosters Falls anticline, repeats the Patterson member and widens the belt of Shady dolomite south of Fosters Falls.

The north limb of the Fosters Falls Mountain anticline is broken by the Hematite Mountain overthrust, which passes under the Periwinkle overthrust east of Periwinkle Branch. Westward the overthrust follows the north foot of Fosters Falls Mountain to New River, where it bends sharply southwest and follows the northwest slope of Hematite Mountain. The Hematite Mountain overthrust is terminated northeast of Austinville where it is overridden by the Gleaves Knob overthrust. The Hematite Mountain fault was formerly considered to be continuous with the overthrust north of Ivanhoe[70] now called the Pierce Mill overthrust, but that fault is apparently only a minor fault within the Galena syncline which branches from the Hematite Mountain overthrust southeast of Galena. The course of the Hematite Mountain overthrust, one mile northeast of Austinville, is marked by large masses of ferruginous brecciated chart (Pl. 53A). North of Fosters Falls Mountain its course is indicated by many old iron ore pits.

At Hematite Mountain the ridge-making member of the Erwin quartzite in the Fosters Falls Mountain anticline is thrust over the Elbrook limestone in the Galena syncline on the Hematite Mountain fault. The stratigraphic break on this fault is at least 5,000 feet. The horizontal displacement on the overthrust is estimated to be more than 5 miles.

GLEAVES KNOB OVERTHRUST BLOCK

General description.—The Gleaves Knob block (Fig. 24) lies north of the Poplar Camp-Holston Mountain overthrust. It is bounded on the north by the Gleaves Knob overthrust, which has overridden the rocks of the Pulaski block in the Great Valley, and is terminated on the south by the Poplar Camp-Holston Mountain overthrust. The Gleaves Knob block extends from Shiloh and Gleaves Knob at the west to New Castleton School and Periwinkle Branch at the east, a distance of 16 miles. It is 3½ miles wide at its broadest part. It has been previously described in detail by the writers.[71] The Gleaves Knob block is composed largely of folded Lower Cambrian limestone, shale, and dolomite and the underlying Erwin quartzite. This quartzite is exposed in uplifts in the southwestern part where it forms Gleaves Knob (Pl. 54A), Ewing Mountain, and several smaller hills (Fig. 41). The western part of the Gleaves Knob

[70] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, Pl. 1, 1935. Stose, G. W. and Jonas, A. I., A southeastern limestone facies of Lower Cambrian dolomite in Wythe and Carroll counties, Virginia: Virginia Geol. Survey Bull. 51, Pls. 1 and 5, 1939.

[71] Stose, G. W., and Jonas, A. I., Idem, pp. 24-30, 1939.

block is shown to be a thin plate by the flatness of its sole exposed along the mountain slope south of Gleaves Knob and by the fact that three klippen of Cambrian quartzite of this block, resting on Shady dolomite of the Pulaski block, are preserved near the headwaters of Cold Run (Fig. 45). These are the westernmost remnants of the Gleaves Knob block. The small window exposing Shady dolomite on Cove Branch, brought to the surface by a minor normal fault, also indicates the thinness of the Gleaves Knob plate at this place.

The Gleaves Knob block is broken longitudinally by several thrust faults and by a cross near Ivanhoe (Fig. 43).[72] The Ivanhoe cross fault, which trends N. 15° W. through Ivanhoe, divides the main Gleaves Knob block into two portions: portion of block west of the Ivanhoe cross fault; and, portion of block east of the Ivanhoe cross fault.

Portion of block west of Ivanhoe cross fault.—The western part of the Gleaves Knob block, west of Cove Branch, is mainly a northeast-dipping monocline, which terminates at the west in the Eagle syncline (Fig. 41). This syncline is well shown west of Eagle, where the Erwin quartzite extends around the end of the fold and then pitches east. The quartzite on the north limb of the Eagle syncline is cut off by the Gleaves Knob overthrust east of Eagle Cliff (Pl. 1). The Cambrian quartzites that form the Chestnut Knob mass lie on the north limb of the Ewing Mountain anticline and dip gently north beneath the Vintage dolomite. The Erwin quartzite, in two minor synclines, makes prominent ridges that extend southwest from the crest of the Chestnut Knob ridge, one of which is followed by the Wythe-Grayson-Carroll county line. The minor anticline between these folds follows the headwater valley of Cove Branch. A small window, one mile south of Cove Branch School, which exposes Shady dolomite of the Pulaski block, is along this anticlinal axis. The window is a triangular mass of Shady dolomite surrounded by Erwin quartzite that is cut off on its north side by a normal fault that trends northwest.

To the east, the Ewing Mountain anticline pitches eastward and splits into several minor folds. The Erwin quartzite in the northernmost anticline passes beneath the Vintage dolomite west of the National Carbide Company plant on New River. South of Powder Mill Branch the hard quartzite of the Erwin, in a tightly compressed fold, the Powder Mill anticline, makes a ridge 2½ miles long that trends northeast. The quartzite in the anticline pitches beneath the Vintage dolomite southwest

[72]Currier, L. W., Idem., page 103, 1935.

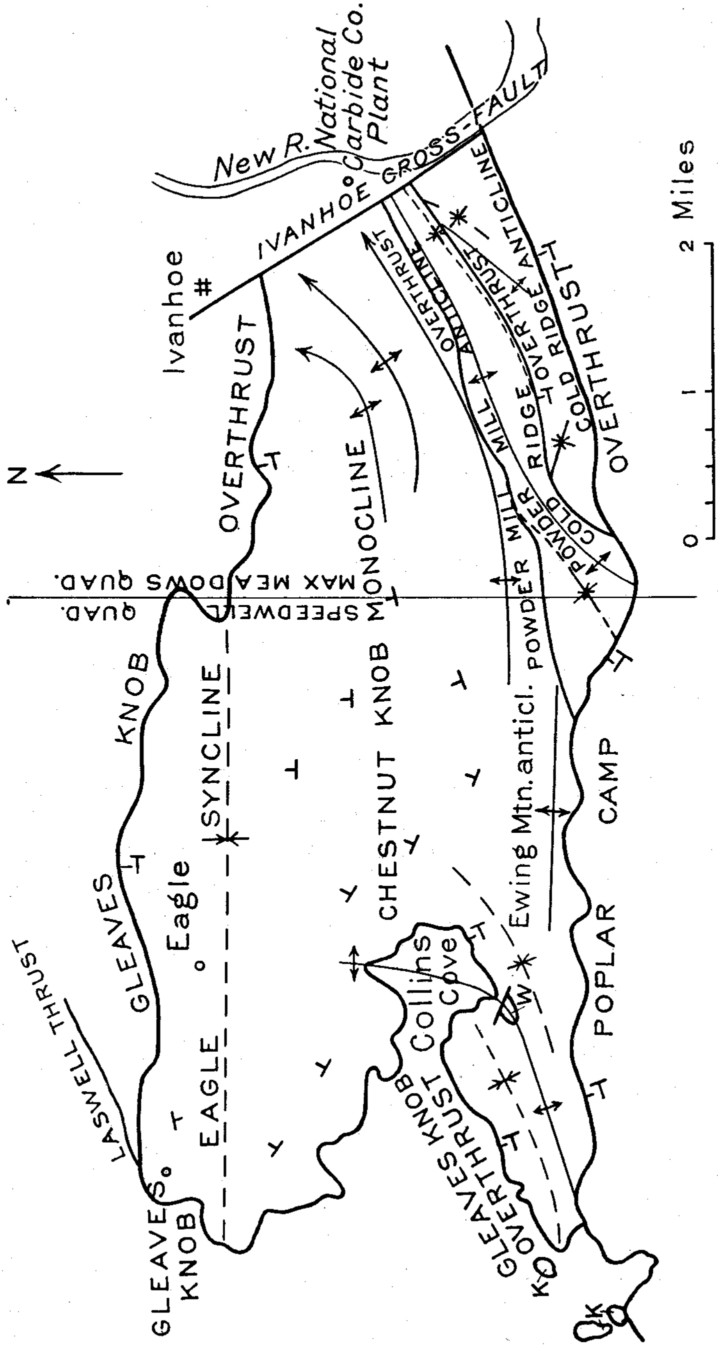

FIGURE 41.—Structural map of western part of Gleaves Knob fault block.

of the carbide plant. This anticline is broken on its north limb by the Powder Mill overthrust, which cuts sharply across the strike of the quartzites north of it. To the southwest the axis of this anticline bends southward, and a syncline on its north side encloses Vintage dolomite at the head of the west fork of Little Brush Creek. Another tightly compressed syncline south of the anticline similarly encloses a narrow belt of Vintage dolomite which extends 1½ miles westward up a small tributary of New River, southwest of the carbide plant.

South of the Powder Mill anticline the hard quartzite of the Erwin in another tightly compressed fold, the Cold Ridge anticline, makes the long northeast-trending ridge called Cold Ridge. The north limb of this fold is broken by the Cold Ridge overthrust. At the northeast end of the fold a minor northeast-pitching syncline encloses Vintage dolomite between spurs of Cold Ridge. At its southwest end a similar syncline encloses Vintage dolomite, the residual clay of which is exposed along State Highway 94 at the low divide at the west end of Cold Ridge (Fig. 42). Just to the southwest on this highway two minor overthrusts

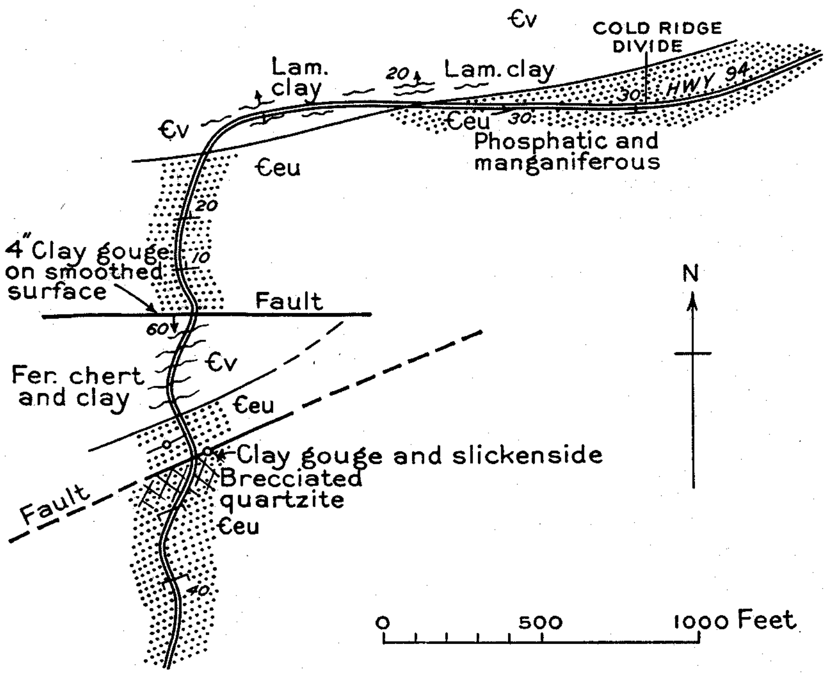

FIGURE 42.—Sketch map along State Highway 94 west of Cold Ridge divide. €v, Vintage dolomite; €eu, Erwin quartzite, calcareous.

are represented by brecciated quartzite, zones of slickensided, white-banded clay, and ferruginuous chert. The south limb of the Cold Ridge anticline is overridden by the Poplar Camp-Holston Mountain overthrust (Fig. 41).

The Cold Ridge and Powder Mill folds may be the same as the Short Hill and Little Mountain folds east of the Ivanhoe cross-fault, next to be described, but they are given separate names for clearness in presentation. Their possible equivalence and continuity are discussed later.

Portion of block east of Ivanhoe cross fault.—That portion of the Gleaves Knob block east of the Ivanhoe cross fault, is broken by thrust faults into 3 blocks, which are named the Austinville, Short Hill, and Little Mountain fault blocks (Fig. 43). The Austinville block is composed entirely of carbonate beds which strike in general northeast, parallel to the Gleaves Knob overthrust. These beds are made up for the most part of Ledger dolomite in which the structure generally could not be determined. Near New River, the limestone beds of the underlying Kinzers formation are exposed. These beds bend sharply northward, to form a syncline that plunges beneath the Ledger dolomite. The strike of these beds is in general parallel to that of the limestone beds west of the Ivanhoe cross fault. They evidently are part of the north limb of the northeast-pitching end of the Ewing Mountain anticline which forms Chestnut Knob.

The Short Hill block is a much broken anticline in which the Hampton shale is exposed at New River and is overlain by Erwin quartzite that forms Short Hill (Pl. 1). Vintage dolomite and higher limestones compose the major part of the block northeast of Short Hill. The Erwin quartzite in Short Hill and the underlying Hampton shale, which have a due north strike, are cut off by the Short Hill fault and are thrust northward over nearly horizontal dolomite of the Austinville block (Pl. 54B). The limestones that directly overlie the Erwin quartzite in the Short Hill block dip east, but the strike changes to northeast, and the southeast-dipping limestones are cut off by a diagonal fault within the block. East of the diagonal fault the limestone members of the Kinzers formation are repeated and continue to strike northeast. Farther eastward they bend northwest and form an anticline with a northeast pitch (Fig. 43). The syncline that formerly lay north of this anticline is largely cut out by the Short Hill overthrust, but its west limb is represented by the synclinal beds southwest of Austinville. The structure

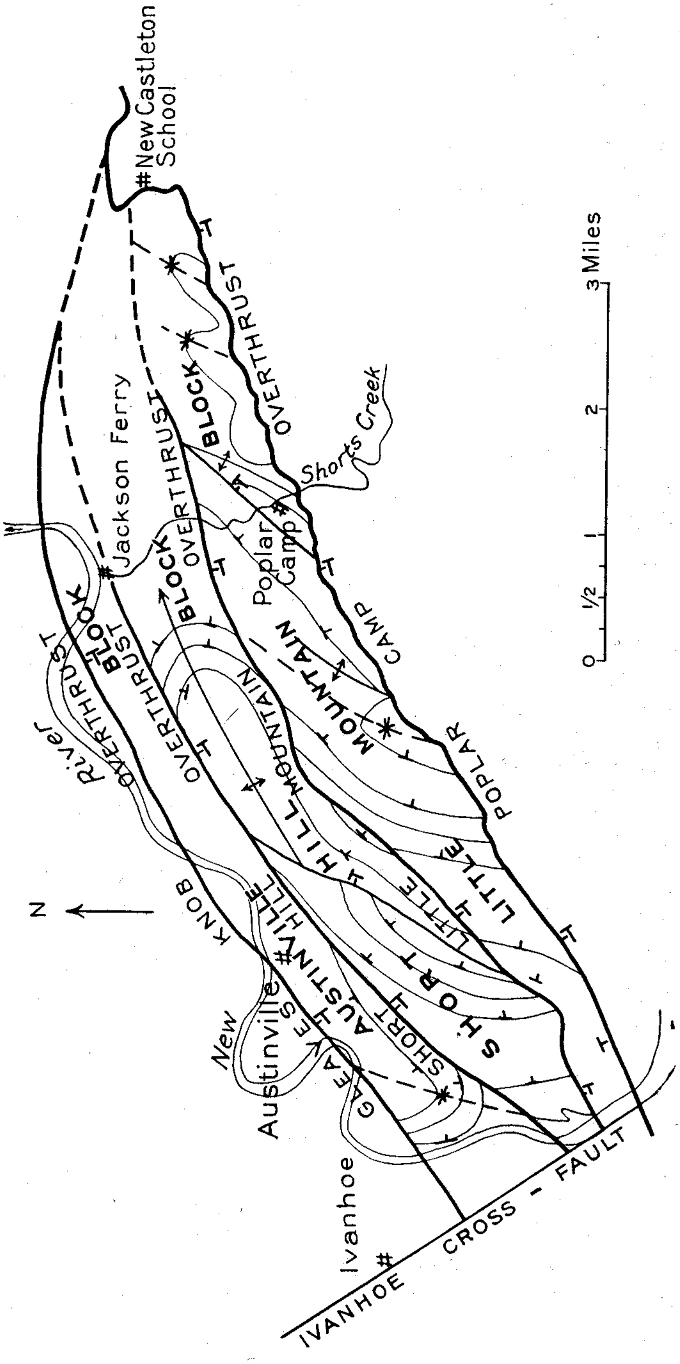

FIGURE 43.—Structural map of eastern part of Gleaves Knob fault block.

of the massive Ledger dolomite in the eastern part of this block, southeast of Jackson Ferry was not determined.

The Little Mountain fault block is composed largely of limestones which form the east limb of an anticline (Pl. 1). The beds strike northeast and dip southeast. The Erwin quartzite beneath the limestones form Little Mountain, which also trends northeast. The Hampton shale in the core of the anticline is exposed on the northwest slope of Little Mountain next to the Little Mountain overthrust. Towards the east, Ledger dolomite, the youngest formation in the block, is present along its southeast side and along a diagonal fault within the block southwest of Liberty Grove Church.

Relations of structures in portions of the block on opposite sides of Ivanhoe cross fault.—The two faulted anticlines—the Powder Mill and Cold Ridge—which lie west of the Ivanhoe cross fault may represent

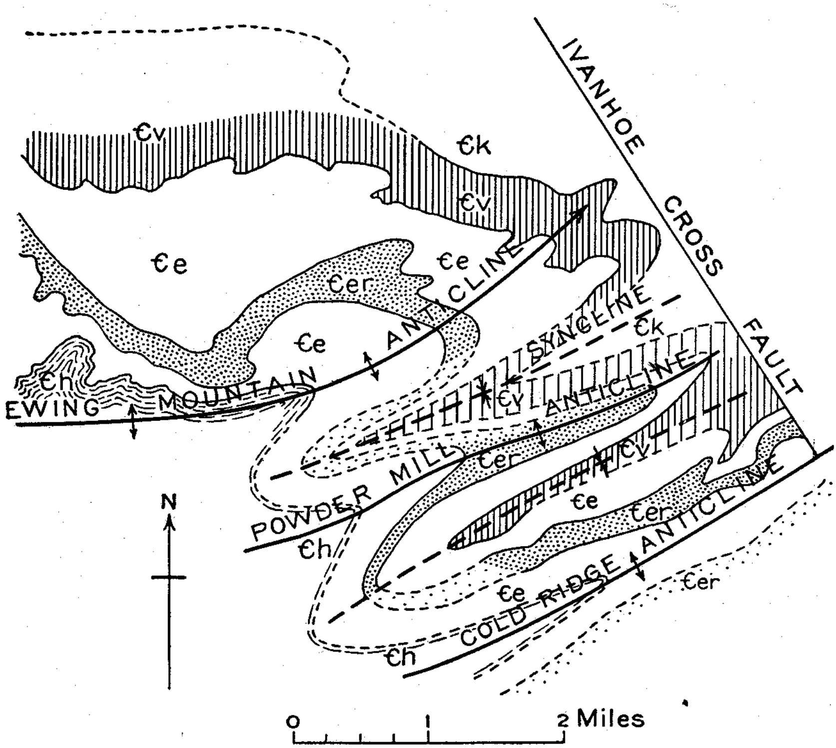

FIGURE 44.—Theoretical restoration of folds west of Ivanhoe cross-fault. Ɛk, Kinzers formation; Ɛv, Vintage dolomite; Ɛe, Erwin quartzite; Ɛer, Erwin quartzite, ridge-making.

the Short Hill and Little Mountain faulted anticlines east of the cross fault, but these folds have reacted to compression so differently that they do not correspond in character. Probably before movement took place on the Poplar Camp overthrust, two attenuated anticlines entended eastward from the plunging end of the Ewing Mountain anticlinorium. The elognate Powder Mill and Cold Ridge anticlines represent these folds west of the Ivanhoe cross fault. Figure 44 is a theoretical restoration of these folds before the overthrusting. The Short Hill and Little Mountain anticlines, which represent these folds east of the Ivanhoe cross fault, rose higher than those to the west, were not so tightly

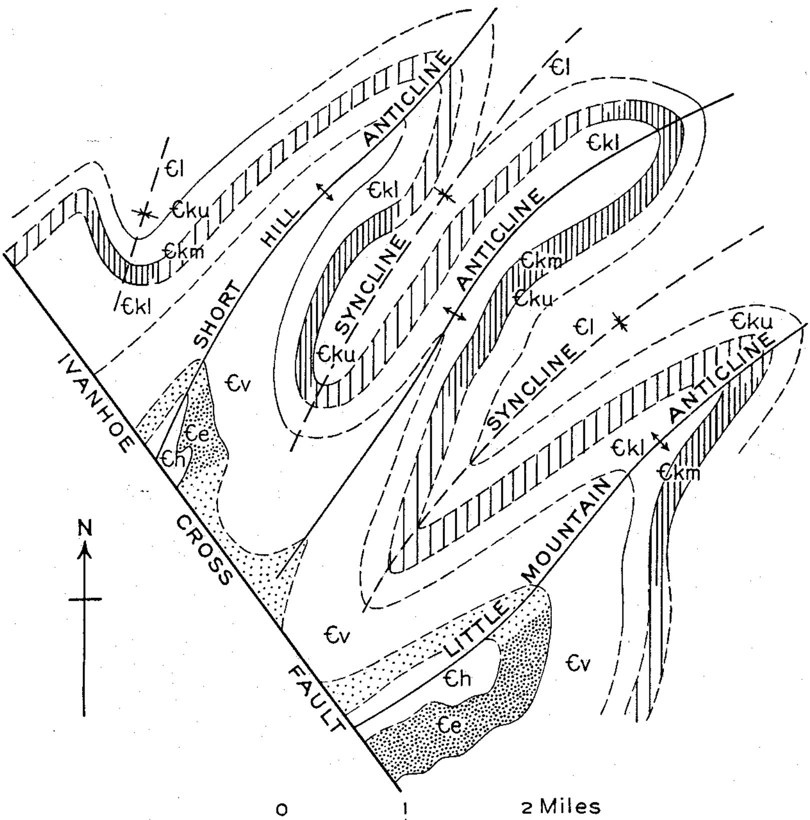

FIGURE 45.—Theoretical restoration of folds east of Ivanhoe cross-fault. €l, Ledger dolomite; €ku, Kinzers formation, blue limestone; €km, Kinzers formation, banded limestone; €kl, Kinzers formation, fossiliferous limestone; €v, Vintage dolomite; €e, Erwin quartzite; €h, Hampton shale.

compressed, but were much more broken by faulting before the Poplar Camp-Holston Mountain overthrusting took place. Their theoretical restoration is shown in Figure 45. The intense folding and breaking of these folds occurred later, apparently at the time of the Poplar Camp overthrusting.

Trace of the Gleaves Knob overthrust.—The Gleaves Knob overthrust is most evident where it curves around Gleaves Knob (Pl. 1), for the Erwin quartzite and Hampton shale in the overthrust block override the Shady dolomite and Rome formation in the lowland to the west. From Gleaves Knob southward to Devils Den, at the west end of Ewing Mountain, the trace of the fault plane is sinuous and can be followed easily. Throughout most of this distance Hampton shale in the thrust block overlies Rome shale and the Shady dolomite. East of Gleaves Knob, the Gleaves Knob overthrust trends nearly east and the fault plane cuts across the end of the Erwin quartzite and passes into the Vintage dolomite, which is overthrust on the upper (saccharoidal) member of the Shady dolomite.

East of Cattron a branch of the Gleaves Knob overthrust passes into the middle of the Galena syncline (Fig. 39). The writers have named it the Pierce Mill overthrust. The Gleaves Knob fault passes south of the Galena syncline and extends eastward through Austinville.

The rocks south of a line passing northeastward through Austinville, are very different from equivalent rocks north of this line. The lithologic and fanual changes are abrupt. These two sequences of sedimentary rocks were evidently deposited in separate areas. The only reasonable explanation of their present proximity is that they have been brought together by faulting. The writers, therefore, believe that the highly fossiliferous limestones of the Kinzers formation and its associated dolomites were thrust northward on the Gleaves Knob fault over its unfossiliferous equivalent, the Shady dolomite.

The Gleaves Knob overthrust is recognized by the discordance of the structure of the rocks on opposite sides of the fault and by the presence of brecciated dolomite, porous ferruginous chert breccia, and limestone containing lead and zinc sulphates. The principal zinc mines of the Ivanhoe Mining and Smelting Corporation are located along the Gleaves Knob overthrust and associated bedding faults where they are intersected by the Ivanhoe cross fault. Just east of New River the beds of the Kinzers formation in the Austinville fault block strike northwest, dip 5-10° NE, and are cut off almost at right angles to their strike by the Gleaves Knob overthrust. Just to the northeast, at Chiswell's Hole,[73] on the east side of New River, Ledger dolomite in the Gleaves Knob block is thrust over a gentle anticline of massive, blue, knotty dolomite of the Patterson member of the Shady dolomite (Pl. 48A). The Ledger dolomite is much brecciated and sheared to shaly layers at the contact with the Patterson member. This shattered zone can be traced from the river level south of Chiswell's Hole northeastward up the cliff to the east. Here the much brecciated Ledger dolomite is mineralized. According to the records of the Ivanhoe Mining and Smelting Corporation, drill holes in the lowland north of the river show the Erwin quartzite to lie at a shallow depth beneath the Patterson member.

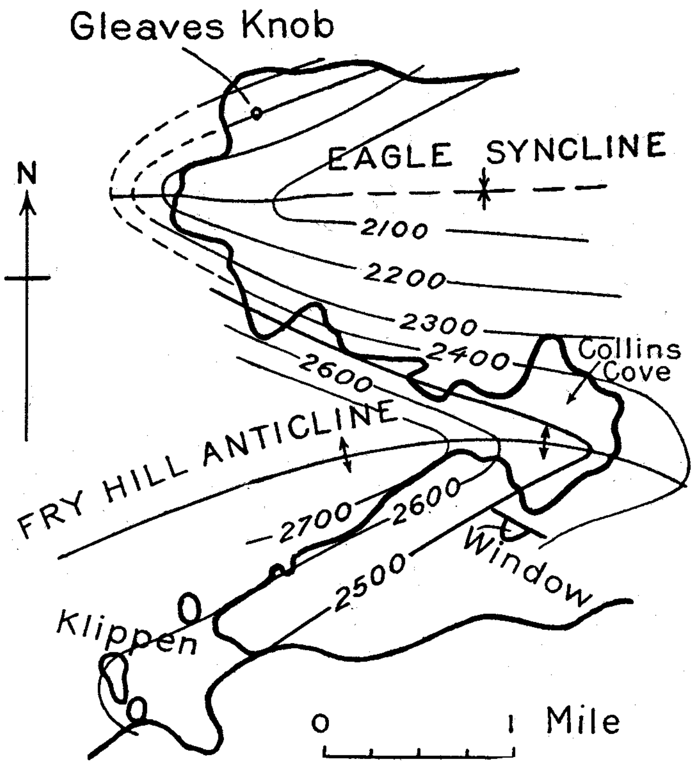

FIGURE 46.—Sketch map showing contoured surface of Gleaves Knob thrust fault south of Gleaves Knob.

[73]Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, p. 101 and Pl. 15B, 1935.

Northeast of Chiswell's Hole, the Gleaves Knob fault is difficult to trace because, in most places the Ledger dolomite is thrust over the similar saccharoidal member of the Shady dolomite and because, the rocks on the upland are concealed by terrace gravel. Disturbed bedding, strong northeast-striking cleavage, brecciation of the dolomite, and ferruginous chert, observed at several places along a northeast-trending zone, apparently mark the fault.

A zone of greatly brecciated and highly mineralized Ledger dolomite, parallel to and one-fourth to one-half mile south of Gleaves Knob thrust fault, in the vicinity of Austinville, probably represents a minor parallel strike fault. The large abandoned open cuts of the Bertha Mining Company at Austinville are located along this break. The mine shaft to the east of the open cuts intersects the large ore body at a depth of 235 feet.[74] At the surface, the Ledger dolomite, penetrated by a shaft that dips about 35° SE., and the mineralized brecciated zone is approximately parallel to the bedding of the dolomite. In the main adit of the mine, which extends south from the river and intersects the shaft at the 235-foot level, other smaller ore bodies were found in brecciated zones parallel to and stratigraphically below the large ore body, and therefore are nearer the sole of the Gleaves Knob overthrust. Both the strike faults and cross faults in the mine are regarded by Brown[75] as the result of compression. He reports that the richest and largest bodies of ore occur at the intersection of these two types of faults. His map shows that the main strike fault is cut and offset by the cross faults.

The Erwin quartzite in Gleaves Knob, at the north edge of the Gleaves Knob fault block, lies 3½ miles north of the southernmost exposure of the overthrust block at the head of Cold Run, west of Devils Den. The roots of the Gleaves Knob overthrust are not known because they are overridden by the Poplar Camp-Holston Mountain overthrust block. The anticline, that brought up the quartzite which now forms Gleaves Knob, must have been at least 3 miles south of the Fry Hill anticline before thrusting took place. It is estimated, therefore, that the fault block has moved northward at least 5 miles.

FRIES OVERTHRUST BLOCK

General Description.—The Fries overthrust block (Fig. 24) lies southeast of the Fries overthrust which crosses the Gossan Lead district

[74]Currier, L. W., Idem, page 100.

[75]Brown, W. H., Quantitative Study of Ore Zoning, Austinville Mine, Wythe County, Virginia: Econ. Geology, Volume 30, Number 4, pages 425-433, Figure 1, 1935.

in a northeasterly direction from the North Carolina line, 1 mile east of Penitentiary Hill, to a point southeast of Dry Pond Mountain at the eastern edge of the district. From the southern edge of the district northeastward to Fries, the Fries block is a belt about one mile wide made up of mylonitized granitic rocks of the injection complex and bands of quartzose mylonite. Northeast of Fries the block narrows rapidly to the vicinity of Crooked Creek. Farther northeastward in the area between that creek and Shorts Creek, the Fries block is discontinuous but is exposed on Poor Branch as a narrow lens of mylonitized granite. East of Shorts Creek, the Fries block is a belt 5½ miles long and not more than one mile wide, which passes through Sylvatus and extends to the eastern edge of the district. This block is composed of the granitic rocks of the injection complex which are sheared to an augen gneiss and to a granite mylonite on the border of the Fries thrust block. The Fries overthrust block consists of narrow and discontinuous bands because it is overridden on the southeast by the Gossan Lead overthrust, which in large part covers the Fries block in the area between Crooked and Shorts creeks.

The character of the mylonites along the Fries overthrust has been previously described in this report. These rocks are mylonitized granite, augen gneiss, and injection gneiss. Southwest of Chestnut Creek, the mylonite belt contains zones of quartzose mylonite (Pl. 1), which may represent infolds of quartzite of the Unicoi formation. The mylonite along the Fries overthrust is well exposed where it is crossed by Brush Creek near its mouth, south of Independence, and at Peach Bottom and Johns creeks and northeastward at several places on New River. Quartzose mylonite forms a cliff on New River south of the mouth of Elk Creek. Granite mylonite is exposed on State Highway 94 north of Riverside and north of Fries (Pl. 25B). It forms the cliff east of the dam on New River at the Washington Mills (Pl. 9A). It is exposed in the cuts of the Norfolk and Western Railway along Chestnut Creek at Stoneman Hill. Granite mylonite along the Fries overthrust occurs east of U. S. Route 52 in Round Knob, along Little Reed Island Creek, and on State Highway 100 north of Sylvatus.

The foliation planes of the mylonite near the fault dip 20° to 25° SE., parallel to the fault plane. In quartzite mylonite these planes are smooth, straight, and parallel, as is shown in an outcrop just north of Riverside and in a cut on State Highway 94 west of Fries (Pl. 26A). The granite mylonite in places has a boudinage structure due to pinching and swelling of granitic bodies as is shown north of Fries (Pl. 25B). Near the border of the Fries overthrust, on the south side of New River southeast of Riverside, slaty rocks enclosing quartzose lenticles are developed in beds of differential hardness. Similar rocks along the Bowers Ferry overthrust were previously described in this report as lumpy shiny slates. The laminated mylonite locally shows close overturned folds. Close folding in mylonitized injection gneisses occurs along Johns Creek, 1 mile southwest of Todd Ford and southwestward. (Pl. 55A). It is well exposed in cuts on Peach Bottom Creek at the mouth of Beaverdam Creek (Pl. 55B). The folds pitch gently southwest in conformity to the southwest pitch of the folds in the Gossan Lead block. The massive granitic rocks were first ground out into banded mylonite, which responded to further deformation by folding.

The Fries overthrust has overridden the pre-Cambrian injection complex in the Elk Creek anticline and has cut off the southeast limb of that fold, (Fig. 34). Northeast of the mouth of Elk Creek a small belt of the Unicoi formation is preserved on the southeast limb of the anticline. Farther north, higher beds of the Unicoi at the plunging end of the anticline, are present north of the Fries thrust fault. Northeast of Toby Knob, at New River 2 miles north of Fries, the Fries overthrust lies south of a narrow block of Cambrian quartzite which is composed chiefly of arkose in which southeast-dipping cleavage has destroyed the bedding. The rock is thought to be the lower member of the Unicoi in which discontinuous beds of argillite and basalt of the middle member are enclosed in tight synclines. As indicated in Figure 47, this slice of Unicoi may represent the lower beds on the southeast limb of the syncline lying between two uplifts of pre-Cambrian rocks. The Fries overthrust follows the south side of this narrow slice to the eastern edge of the district. In an exposure of State Highway 100, three-fourths mile north of Sylvatus, granite mylonite at the fault, dipping 30° S., overrides quartzite of the Unicoi formation.

The Bowers Ferry overthrust, which branches from the Fries overthrust near Toby Knob, extends northeastward from the main fault and then parallels it and follows the north side of the narrow slice of Unicoi formation just described. It joins the Fries overthrust again just east of the Gossan Lead district (Fig. 24). North of Toby Knob, the Bowers Ferry overthrust cuts off the middle and upper members of the Unicoi formation in the Fries Junction syncline and overlaps the Falls overthrust (Pl. 1). Along the Bowers Ferry overthrust there is a cataclastic quartzite interlayered with black shiny slate. The cleavage in the Unicoi at the fault dips gently southward. A narrow band of white to pink marble crops out on U.S. Route 52, at the point where Shorts Creek crosses the

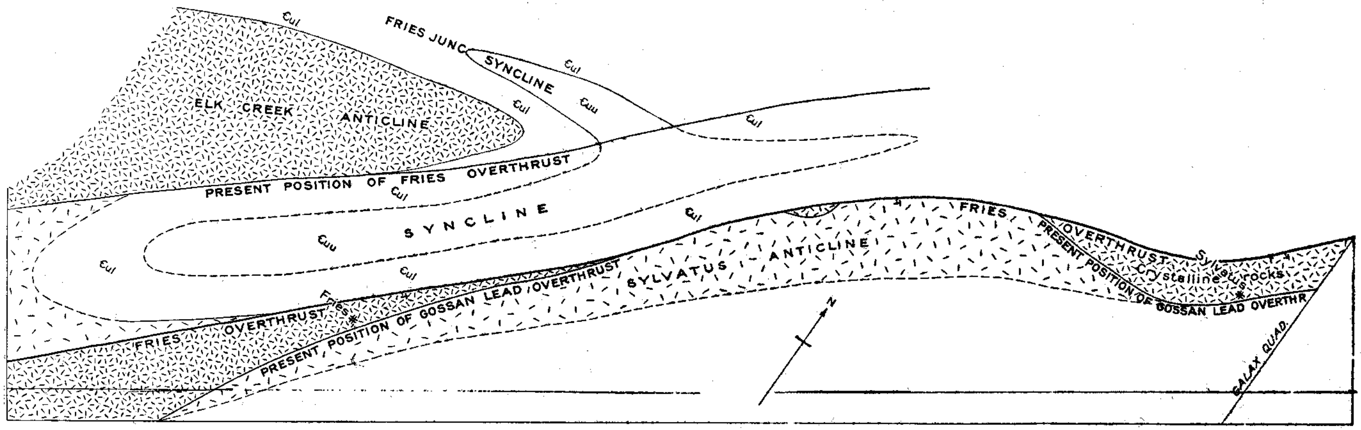

Figure 47.—Theoretical restoration of Elk Creek and Sylvatus anticlines. Єuu, Unicoi formation with upper quartzites; Єul, Unicoi formation with lower arkose, conglomerate, and quartzite.

Bowers Ferry overthrust, and extends one-eighth mile eastward. The marble is surrounded by a mylonite slate and a mylonitized basalt of the Unicoi formation. This marble is probably a thin slice of Lower Cambrian dolomite which was dragged up along the fault plane. North of the marble and along the Bowers Ferry overthrust, there is a wide zone of slate with thin quartzose lenses in which the cleavage dips 30° S. This rock is cut by shear planes diagonal to the cleavage and breaks into lenticular blocks bounded by the two parting planes. The rock has a shiny lumpy surface (Pl. 53B). A rock with a similar structure occurs along the Gossan Lead overthrust. It is described in more detail in the chapter on that overthrust. At a point one mile east of U. S. Route 52, the Bowers Ferry overthrust overrides the Byllesby block, and eastward to the edge of the district, the Bowers Ferry thrust block rests on the Poplar Camp-Holston Mountain block (Fig. 24). In a cut on State Highway 100, 1¼ miles north of Sylvatus, where the highway follows Little Reed Island Creek, the Bowers Ferry overthrust is well exposed. The fault plane dips 20° S. and is marked by a manganese bearing clay and breccia. The dip of the bedding in the overthrust pebbly quartzite of the Unicoi formation and in the overridden rust-colored Erwin quartzite is nearly parallel to the dip of the fault plane.

The Fries overthrust occurred later than the Poplar Camp-Holston Mountain overthrust. It trends diagonally across the structures in the Poplar Camp-Holston Mountain thrust block north of it. The Fries block has moved much farther over that block in the northeastern part than it did in the southwestern part for there the Elk Creek anticline furnished a barrier to its northwestward movement. In the southwestern part of the district, south of the Elk Creek anticline, the Fries overthrust lies 15 miles southeast of the Poplar Camp-Holston Mountain overthrust.One mile east of the district, the Fries overthrust entirely overrides the Poplar Camp-Holston Mountain block so that, for a distance of three-fourths mile, the grantitic rocks of the Fries block are overthrust on the Shady dolomite and Rome formation in the Pulaski block (Fig. 24). These relations may be seen near the bridge over Big Reed Island Creek on the former route of State Highway 100, northeast of Sylvatus.

It has been stated that the Fries overthrust is later than the Poplar Camp-Holston Mountain overthrust. In Figure 47 an attempt is made to restore the structure of the Poplar Camp block before the Fries overthrust took place and before the Fries block was overridden from the southeast by the Gossan Lead overthrust. At that time another anticline made up of early pre-Cambrian rocks, called the Sylvatus anticline, apparently lay southeast of the Elk Creek fold. The two anticlines were separated by a syncline which encloses Lower Cambrian rocks. These rocks are now obscured by the Fries overthrust.

The effect of the Fries overthrust on the Elk Creek anticline.—In the Elk Creek anticline northwest of the Fries overthrust, the rocks of the injection complex are mylonitized in numerous parallel zones arranged *en enchelon* to each other. The amount of movement in the mylonitized zones appears to be small. In many places in these zones the primary pre-Cambrian structures of the injection complex have been destroyed, and a southeast-dipping foliation is now the dominant structure.

A series of shear zones striking N. 45° E. lies south of Chestnut Flats. Others trending N. 50° E. lie northwest of Point Lookout Mountain. The mylonitization along these faults has produced zones of weakness in the granitic rocks and many stream valleys and gaps in the mountains are located along these faults. Mylonite exposed in a gap of Buck Mountain one mile east of Saddle Creek extends northeastward through Hollow Rock Hollow. Longs Gap, which is used by U. S. Highway 21, is also a zone of mylonitization. The strike of the foliation and the zones of mylonitization are parallel to the Fries overthrust block.

In the vicinity of Round Mountain, east of Comers Rock village, several curving faults that trend in a general northeast direction merge into an east-west fault on the south crest of the mountain. The rocks are sheared parallel to the faults, showing that they were under compression when faulted and that the faults are thrust faults. The east-west fault into which the curved overthrusts merge, therefore, is a shear or tear fault having a westward movement on its south side. Some of the thrust faults end at the south in another east-west shear zone, which is accompanied by large quartz veins.

GOSSAN LEAD BLOCK

General statement.—The Gossan Lead block is located in the southeastern portion of the district and south-east of the Gossan Lead thrust fault (Pl. 1). The rocks, composed chiefly of Lynchburg gneiss with thin beds of infolded limestone and mafic and ultramafic sills, are closely folded. The axial planes of the folds are overturned to the northeast. Their crests are sheared out (Pl. 35) in many places. In the southeastern part of this block, the fold axes dip steeply and the formations have a curving strike. The folds pitch less steeply in the central and northwestern parts of the block and the formations have a linear trend. Further details as to the location of the major folds and the main zones of movement in the block are shown in Figure 48.

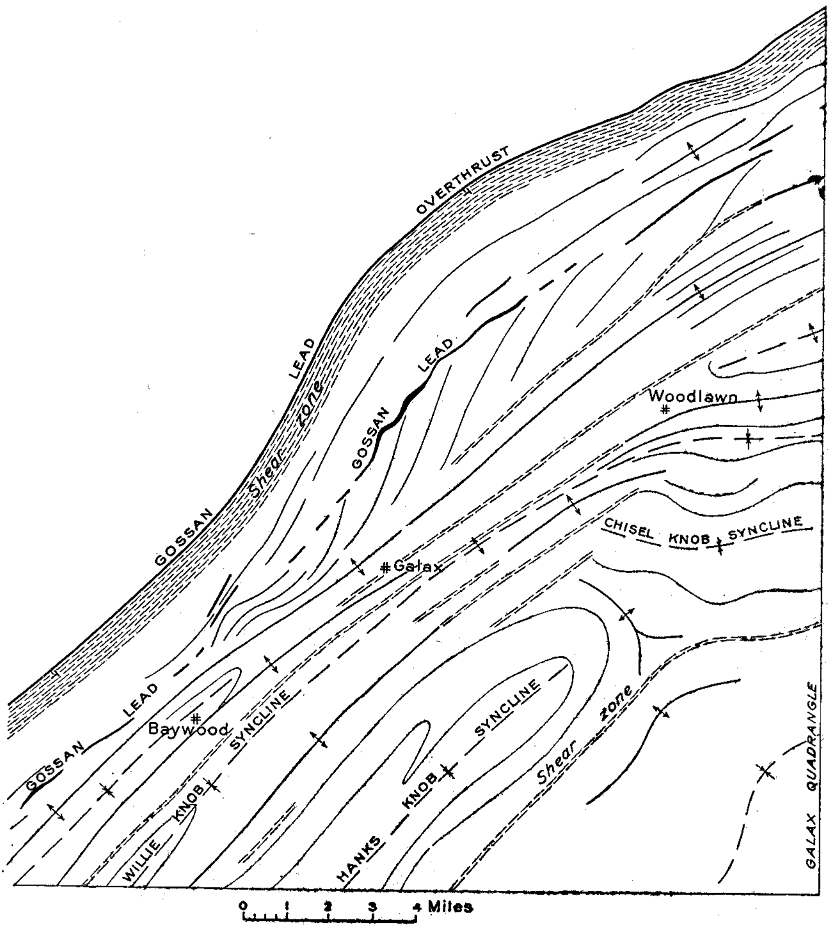

FIGURE 48.—Structural map of Gossan Lead fault block.

The Gossan Lead overthrust, which forms the northeastern boundary of the Gossan Lead block, enters the district one mile east of Sylvatus. It extends from this point southwestward across the district to Bethany Church on the North Carolina line. This fault divided the district into two approximately equal parts. From Crooked Creek southwestward the fault parallels the Fries fault. The strike of the northeastern portion of the fault is S. 70° W. Between Shorts Creek and New River the strike changes to S. 35° W. and further southwestward the fault resumes its S. 70° W. trend. The fault is bordered throughout by a belt of mylonitized slaty and quartzose rocks that have a gently southeast-dipping foliation.

Character of structure in the block.—The southeastern part of the Gossan Lead block is characterized by a steep-axis structure in which most of the fold axes dip to the southwest and south. All of the larger folds extends south and east beyond the the Gossan Lead district. The folds with steep-axis structure are evident only where the crests of the folds are preserved. The Hanks Knob fold (Fig. 48) the largest of these pitching folds, lies southeast of the Elk Creek anticline and south of Galax. The arch of the fold is near Hanks Knob, and the distance between the limbs of the fold increases to the southwest. The middle part of the fold is composed of alternating curving bands of mafic and ultramafic rocks and Lynchburg gneiss. On the northwest limb of the fold, from the North Carolina line, south of Delhart, northeastward, the rocks strike N. 50° E. and dip 80° SE. Just south of Galax the trend changes to N. 80° E., curves around the nose of the fold at Pipers Gap village, and there bends south and then S. 45° W., continuing through The Glades to the State line near Edmonds. At the northeast end of the fold the rocks are minutely crenulated into close folds whose axes, on the north face of Hanks Knob, dip 60° in a direction S. 30 W. To the southeast the folds pitch more steeply southwestward. The dips on the southeast limb of the fold are 60° SE.

The composite character of the Hanks Knob fold is inferred from the structures on the northwest side of the fold. The marble, which is infolded in the Lynchburg gneiss on the northwest limb, appears to be in a minor syncline. The bands of hornblende gneiss, that are northwest of the marble, cannot be traced continuously around the northeast side of the minor fold to connect with bands of hornblende gneiss that lie to the southeast. This discontinuity may be due to the shearing out of these layers on a minor anticline. The fact that the marble strikes more northerly than do the other rocks on the northwest limb of the fold may be due to a local squeezing of the marble to the northwestward along a shear zone.

The Chisel Knob fold lies northeast of Hanks Knob, near the eastern edge of the Gossan Lead district. The main axis of the fold trends nearly west. The northwestern closing end of the fold is cut off by northeast-trending shear zones in the area between Walker and Poplar Knobs. The middle of the fold is formed by Lynchburg gneiss which has a curving trend; the strike is N. 75° E. in the western part of the fold and

N. 70° E. in the eastern part. The axial planes of the close folds are overturned to the northwest. The curving strike reflects the pitch of the folds, the axes of which dip southward. Curving parallel bands of hornblende gneiss form the north and south limbs of the fold.

The Lambsburg fold is in the southeastern part of the district, southeast of the Hanks Knob fold and south of the Chisel Knob fold. In this fold the rocks are closely folded and overturned to the northwest and the arches of the folds are largely sheared out (Pl. 54C). The Lambsburg fold is formed of Lynchburg gneiss with thin infolded layers of hornblende schist and marble. The trend of the spurs of the Blue Ridge escarpment in the vicinity of Lambsburg, including Sugar Loaf just east of the district (Pl. 6B), follows the direction of the fold axes, which dip gently southwest. In that vicinity the Lynchburg gneiss is broken by tension joints at right angles to the inclination of the pitch.

In the area southeast of the Hanks Knob fold, the fold axes of the Lambsburg fold trend N. 40° E., and south of the Chisel Knob fold the trend is N. 70° E. The axial planes of the folds in the northwestern part of this area dip 60° SE. To the southeast, in the vicinity of Blue Ridge School, Lambsburg, and Sams Knob, the axial planes dip about 30° SE. This region of gentle dips seems to mark the center of the fold. Where the center of the fold crosses U. S. Route 52, about 3 miles south of Fancy Gap, the dip is never more than 10° S.

North of the Chisel Knob fold and northward to the vicinity of Gossan Lead ore body the formations strike parallel to those on the north limb of the Chisel Knob fold, but eastward they diverge in a fan-like structure. In this area north of the Chisel Knob fold the fold axes are horizontal, or dip gently southwest, and the axial planes are overturned to the northwest. Such folds may be seen in exposures on U. S. Route 52 southeast of Cranberry, and on Crooked Creek northwest of Woodlawn. The most prominent structure in the northwestern part of the Gossan Lead block is a layering with linear trend parallel to the Gossan Lead overthrust.

In the Gossan Lead district the sequence of beds of the Lynchburg gneiss could not be determined because of the repetition of beds by close folding and the shearing out of the crests of folds. The mafic rocks give no clue to the sequence because they occur as intrusives in the gneiss and are present at different horizons in different parts of the area. It is not possible therefore to determine, on stratigraphic grounds alone, which folds are anticlinal and which are synclinal.

In regions of less complicated pitching folds, the order of the stratigraphic sequence may be found by measuring upward in the direction of the pitch. In closely compressed folds, such as occur in the Gossan Lead block, this method cannot be used. The Hanks Knob fold might appear to be a syncline (Fig. 48) because of the south-southwest dip of the minor fold axes, but the fold axes in all of the pitching folds just described dip southwest or south. Southwest of the Gossan Lead district, in North Carolina, a biotite-muscovite granite is intruded into the rocks of the Hanks Knob fold. In several places in North Carolina, where folds are not overturned and their character can be recognized, granite intrusions occur in anticlines. This suggests that the Hanks Knob fold may be an anticlinal structure. According to this interpretation, the Lambsburg fold may be an anticline and the Chisel Knob fold a syncline.

Shear zones in the block.—A belt characterized by foliated chlorite-garnet schist lies on the northwest flank of the Lambsburg fold. The folds of the schist are sheared out and the dominant structure is a southeast-dipping foliation which is closely spaced in the schist. The displacement, which occurred during the shearing out of the fold crests, although small on any single plane, was considerable when taken as a whole.

The closure of the Chisel Knob fold has been cut off by two shear zones, which extend southwestward into the northwest limb of the Hanks Knob fold. These shear zones are marked by quartz veins. They are parallel and trend N. 45° E. The fold axes of minor folds in the Lynchburg gneiss of the Chisel Knob fold are parallel to the shear zones, and the axial planes of the folds are overturned northwestward towards the shear zones. The folds south of Woodlawn are broken and cut across by veins of quartz. A zone of shearing, injected by veins of quartz containing pyrite and other minerals, extends from Hillsville southwestward through Galax. The rocks here have a linear trend parallel to the shear zone. Northeast of Woodlawn, the foliation dips steeply southeast, while near Galax, it dips 30° SE.

The Gossan Lead ore body follows zones of shearing parallel to the Gossan Lead overthrust. The shear zones, in which the ore body occurs, cut across the structures.

The northwest border of the Gossan Lead block is formed by mylonitized, slaty and quartzose layers with wavy partings that dip gently southeastward. Pyrite and quartz are abundant in the rocks in this thrust zone. The sills of mafic and ultramafic rocks in the Lynchburg gneiss northwest of the Gossan Lead ore body are quite thin, much sheared, and discontinuous along the strike. The mylonitized rocks are well exposed on Little Reed Island Creek, on Shorts Creek along U. S. Route 52, along the Norfolk and Western Railway on Chestnut Creek, and in the bends of New River southwest of Fries.

The Lynchburg gneiss in the Gossan Lead thrust zone has been converted by mylonitization to a shiny slate-like phyllonite that contains layers of biotite, muscovite and magnetite. The phyllonite contains also lenticles of quartzite that lie diagonal to the main slip plane. The intervening micaceous layers curve around the quartzose layers (Pl. 56A). The term "lumpy and shiny" is descriptive of these rocks. They break into small lenticular blocks because of their curved parting planes. Such a structure is regarded as a product of shearing slip in beds of differential hardness[76], and may result in a folded structure in which the folds were formed by slipping along and not by flexure slip in which the layers not only slide one over the other but also bend. In the shearing movement, the quartzose layers have moved as a whole, and the curved displacement in the intervening softer layers has produced the lenticular structure. The sheared rocks on the northwest border of the Gossan Lead overthrust block resemble those described on the edge of the Bowers Ferry block shown in Plate 53B, and in places on the Fries overthrust block.

AGE AND INTERPRETATION OF THE MAJOR STRUCTURES IN THE GOSSAN LEAD DISTRICT

The structures in the Gossan Lead district are only a part of larger structures of the general region. The Poplar Camp-Holston Hountain overthrust is a part of an overthrust that extends from Roanoke, Virginia, southwestward into Tennessee. The Poplar Camp-Holston Mountain block was carried northwestward over the rocks of the Pulaski block and later the block was gently folded. In the area southwest of this district in Virginia and Tennessee, the folding of the western part of the Holston Mountain thrust block resulted in the Shady Valley syncline and an anticline to the southeast. Erosion has cut through the thrust block at this anticline and has exposed the underlying rocks of the Great Valley in a window that extends from Taylor Valley, Washington Country, Virginia, southwestward into Tennessee. The writers[77] have described briefly the Holston Mountain overthrust, which they had previously worked out, and in Plate 26 of their paper showed the folded and eroded

[76]Knopf, E. B., Petrotectonics: Am. Jour. Sci., 5th Ser., Number 150, Vol. 25, pp. 433-470, 1933.

[77]Butts, Charles, Stose, G. W., and Jonas, A. I., Southern Appalachian region: 16th International Geol. Congr. Guidebook 3, pp. 7, 86; Pl. 26, 1932.

character of the overthrust. In later papers the writers[78] showed diagrammatically the extent of the Holston Mountain overthrust in Virginia and described part of its extent in Tennessee. They also named the window in the overthrust mass the Taylor Valley window from Taylor Valley which is located at the northern end of the window in Washington County, Virginia. In a still later paper[79] the writers described in more detail the Holston Mountain overthrust and Taylor Valley window in Tennessee and the relation of the overthrust to other major structural features.

It has been stated in the present report that the Fries and Gossan Lead overthrusts are later than the Holston Mountain overthrust. The northwest edge of the Fries block is only 8 miles south of Draper Mountain, which is part of the Saltville fault block exposed in a deep embayment in the Pulaski overthrust[80] and includes rocks ranging in age from the late Ordovician to Mississippian.

It is evident that the Poplar Camp-Holston Mountain, Fries, and Gossan Lead overthrusts are structural features produced by orogenic movements directed from the southeast which deformed rocks as young as Mississippian on the north border of the Gossan Lead district. Elsewhere, related orogenic movements affected Pennsylvanian and Permian rocks. Therefore these faults appear to be of late Paleozoic age. The younger Paleozoic rocks exposed in Draper Mountain beneath the Pulaski overthrust block were deposited in the Appalachian geosyncline southeast of their present position, and have been moved northwestward by folding and by overthrusting. The thrust sheets of the Gossan Lead district also have been pushed northwestward over the geosyncline. The core of the Poplar Camp-Holston Mountain overthrust is composed of the pre-Cambrian injection complex which forms the basement on which later Pre-Cambrian and Paleozoic rocks of the Appalachian orogenic belt were deposited. The complex has been pushed upward as well as northwestward over the underlying rocks.

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[78]Stose, G. W., and Jonas, A. I., A southeastern limestone facies of Lower Cambrian dolomite in Wythe and Carroll counties, Virginia: Virginia Geol. Survey Bull. 51A, p. 23, 1939. Age relation of the pre-Cambrian rocks in the Catoctin Mountain-Blue Ridge and Mount Rogers anticlinoria in Virginia: Am. Jour. Sci. 5th ser., vol. 237, p. 578, Fig. 2, 1939.

[79]Stose, G. W., and Stose, Anna J., The Chilhowee group and Ocoee series in the southern Appalachians: Am. Jour. Sci., 5th Series, Vol. 242, pts. I and II, pp. 382-385, Fig. 2B, 1944.

[80]Butts, Charles, Geology of the Appalachian Valley in Virginia: Virginia Geologic Survey Bull. 52, p. 449, 1940. Cooper, B. N., Geology of Draper Mountain area, Virginia: Virginia Geol. Survey Bull. 55, pp. 56-58, 1939.

The overthrusts in the Gossan Lead district differ from the overthrusts in the western part of the Great Valley in that they are independent of the folding in the rocks and are not derived from broken and overthrust anticlines. The Poplar Camp-Holston Mountain overthrust had only a veneer of Lower Cambrian quartzites overlying the granitic basement rocks. This overthrust evidently originated in the crystalline basement and did not result from a broken fold in overlying competent sedimentary rocks. In the forward movement of the thrust plate, the sedimentary rocks, overlying the crystalline basement, were folded and broken by minor faults, most of which did not result from broken anticlines. Along some of these minor faults, younger beds were thrust over older, as is well shown on U. S. Route 21, south of Dry Run Gap, where the upper member of the Unicoi formation and overlying Hampton shale, enclosed in the Falls syncline, are thrust on the Falls overthrust over lower beds of the Unicoi (Fig. 14). The internal structure of some of the thrust blocks is discordant to the bounding overthrust, so conspicuously shown south of Sindion Point and on the west side of Dry Pond Mountain. The flat Gleaves Knob thrust plane, as shown south of Gleaves Knob, clearly is not the product of a broken anticline within the block.

The Elk Creek anticline, in the northwestern part of the Poplar Camp-Holston Mountain overthrust block, is formed for the most part of massive, intrusive rocks that are part of the crystalline basement. The Poplar Camp-Holston Mountain overthrust evidently originated in these basement rocks. They are forced upward and northward on this fault and the thin cover of Cambrian sedimentary beds was folded with the basement rocks. The injection complex in the body of the anticline responded to compression by shearing and mylonitization of the rocks along minor breaks. During the late Paleozoic deformation, the rocks of the injection complex were folded only where mylonitization had previously produced a layered structure.

Resistant homogeneous material, subjected to compression, yields by shearing along two diagonal planes included at approximately 45° to the direction of pressure. Experiments in compression have produced rupture on shear planes inclined at angles of 45° to 70° with the direction of pressure, the angle depending on the resistance of the material compressed. The pre-Cambrian rocks, of the injection complex, may be considered homogeneous in that their component parts are not in parallel bands but are irregularly and unsystematically arranged. Therefore, these rocks, when compressed, did not fold but broke along diagonal shear planes, which formed triangular blocks or wedges. Movement took place along these planes chiefly in the direction of least resistance, which was

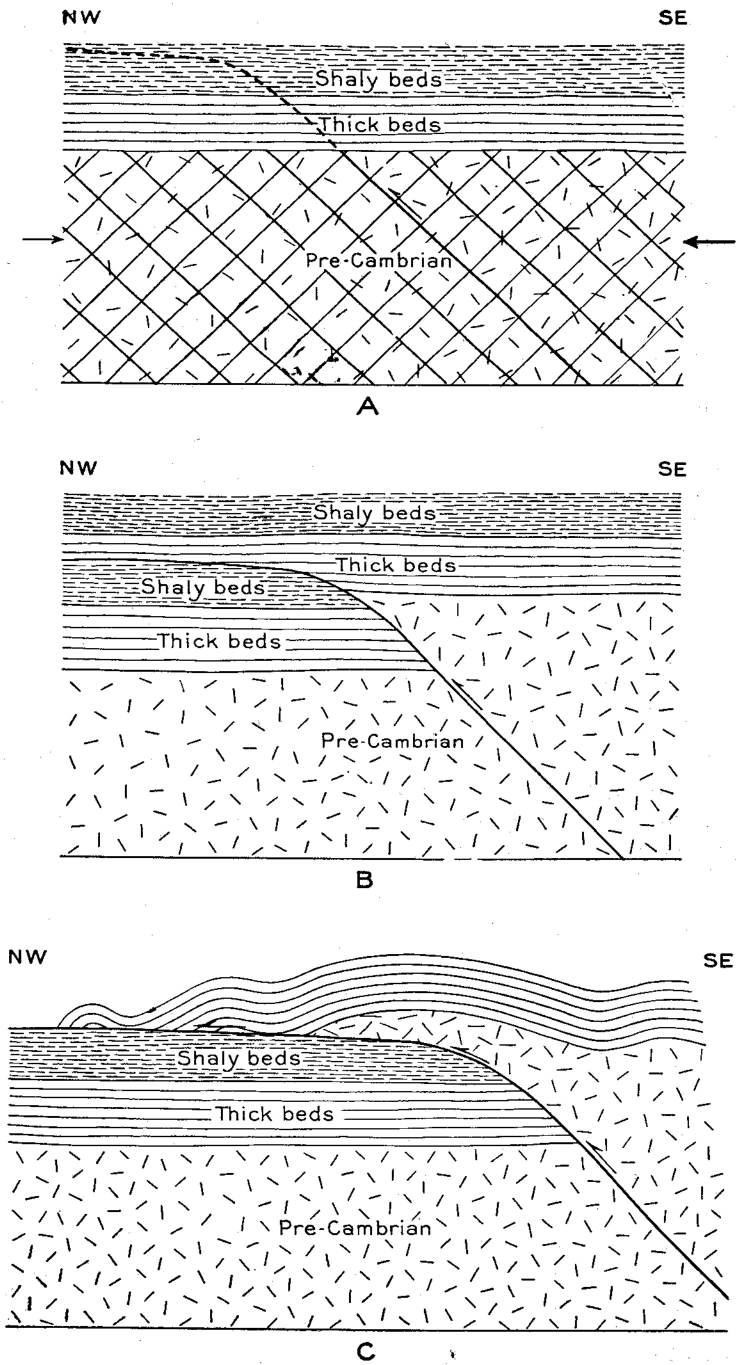

FIGURE 49.—Diagrammatic sections showing theoretical development of overthrusts.

upward, if the load was not too great, and in a horizontal direction away from the source of the dominant pressure. The movement along shear planes, in the crystalline basement rocks of the Appalachians, therefore, would be upward and to the northwest, because the orogenic movements were directed from the southeast. Folds would be produced in the over lying sedimentary rocks at the points of rupture in the basement rocks, but they would be incidental to and would not control, the overthrusting. The shear planes in the cystalline rocks and in the more resistant overlying sedimentary rocks would dip southeastward about 45°. The resulting faults, where they penetrated thick, flat-lying, soft shaly formations in the sedimentary series, would be deflected along the bedding to a lower angle (Fig. 49). That thrust faults followed flat-lying weak beds in the sedimentary series is evident from the fact that some of the larger overthrusts, such as the Poplar Camp-Holston Mountain, Byllesby, and Brush Creek, lie almost within the soft Hampton shale. Likewise the Gleaves Knob overthrust, as far north as Gleaves Knob, is within the Hampton shale.

The Fries overthrust originated also in the crystalline basement rocks. It broke diagonally across the syncline of sedimentary rocks on the south side of the Elk Creek anticline, and into the crystalline rocks of the Sylvatus anticline, which now occur in narrow wedge-shaped masses along the overthrust near Sylvatus and southwestward. The thrusting of the Fries block not only greatly narrows the exposure of the northeastern part of the Poplar Camp-Holston Mountain block but causes the rocks on its northwest border to break into a series of parallel narrow thrust slices along the Bowers Ferry and Byllesby overthrusts.

In an experimental, mechanical, working model for the study of folding and thrusting in sedimentary rocks, Willis[81] has shown that homogeneous rocks beneath uniformly layered rocks when compressed, tend to break along shear planes at angles of about 45° with the direction of pressure, forming trianguluar wedge-shaped blocks (Fig. 50, copied from Plate 93, Figs. G to K, Willis). These shear planes originate in the homogeneous material and pass upward into the overlying bedded layers, where they form irregularly broken folds.

It is concluded therefore: that the Poplar Camp-Holston Mountain and Fries overthrusts, and the minor breaks within the larger fault blocks in the Gossan Lead district, resulted from the adjustment of wedge-shaped blocks of the pre-Cambrian injection complex which were produced by shearing of these older rocks by compression; that some of

[81]Willis, Bailey, The mechanics of Appalachian structure: U. S. Geol. Survey, 13th Ann. Rept., Pt. 2, pp. 217-274, 1893.

the wedge-shaped blocks were forced upward and northwestward by the dominant compressive force; that the shear faults between blocks passed into gently dipping weaker beds of the overlying Cambrian quartzose sedimentary series and formed flat-lying bedding faults (Fig. 49); that these sedimentary rocks were folded during this faulting, but these folds did not control the location of the thrust faults; and, that these thrust faults were not produced by the breaking of tightly compressed anticlines in the sedimentary rocks but by thrusting of blocks of the underlying pre-Cambrian injection complex.

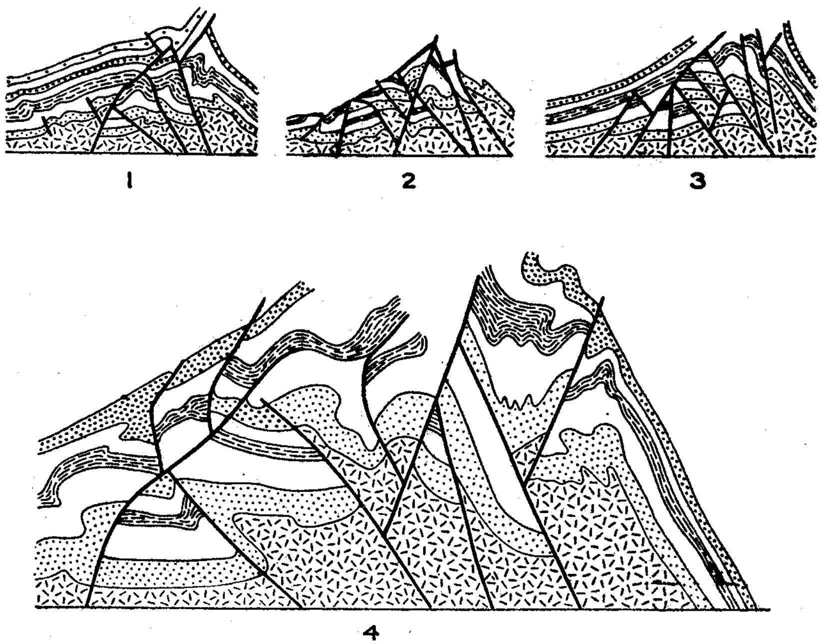

FIGURE 50.—Sketches of layers deformed by horizontal compression.

ECONOMIC GEOLOGY

General Statement.—The minerals and rocks of economic value or possible economic value in the Gossan Lead district are shown on Plate 61. They include barite, limonite, kyanite, magnetite, manganese oxides, copper minerals (chalcocite and chalcopyrite), pyrite, pyrrhotite, rutile, ilmenite, staurolite, spessartite, zinc and lead minerals, soapstone, limestone and building stone.

The main ore bodies are found in or near the Gossan Lead; in the zone of the Fries overthrust southwest of Fries, Grayson County; and in the northern and northwestern part of the district in the vicinity of Austinville, Ivanhoe and Bertha.

The Gossan Lead ore body occurs in the Lynchburg gneiss, where sulphide ores are now being mined at Iron Ridge near Chestnut Yard Station, Carroll County, for use in the manufacture of sulphuric acid. The Gossan Lead orebody is associated with quartz veins containing pyrite, rutile, and ilmenite, which have penetrated the rocks to some distance from the main ore body. Veins of massive spessartite occur several miles southeast of the Gossan Lead. Quartz veins with kyanite and rutile are abundant in a belt extending from Woodlawn in Carroll County southwestward through Galax to Baywood in Grayson County. Soapstone has been quarried on a small scale in the southern part of the district.

In the zone of the Fries overthrust magnetite occurs in a granite mylonite. Magnetite, with pyroxene and spessartite, occurs in the Shoal gneiss northwest of the Fries overthrust, and barite is associated with these veins southwest of Riverside. Another area containing barite is located south of Iron Mountain on the north limb of the Elk Creek anticline. Zinc-lead deposits occur in dolomite in the northern and northeastern part of the district. Barite is found in dolomite and limestone near the zinc-lead deposits. Limestone occurs in the lower part of the Shady dolomite.

GOSSAN LEAD

General distribution.—The Gossan Lead consists of several ore veins or bodies, arranged *en echelon,* in a mineralized zone which extends from the Betty Baker Mine, 5½ miles north of Hillsville, southwestward for a distance of 20 miles across Carroll and Grayson counties to New River, southwest of Oldtown. The ore zone continues southwestward to the North Carolina line, although this part is not so well defined.

The Gossan Lead ore body (Fig. 48) that passes through the Betty

Baker mine trends S. 45° W. for 3 miles. Another ore body with the same trend but lying slightly to the northwest crosses Ogles Branch near the east edge of the district and farther southwest crosses two bends of Little Reed Island Creek. From a point, just east of U. S. Route 52 and southeast of Early, a longer ore body (the Dalton) is in strike with that at the Betty Baker mine, and extends S. 45° W. and passes south of Wildwood School. Mines that were once operated on this vein include the Cranberry, Wildcat, Wolfpit, Kirkbride, and Vaughan. Small showings of sulphide ore extend along the strike for 2 miles farther southwestward. Where the vein crosses U. S. Route 52, southeast of Early, there is a mineralized zone that extends for 300 feet along the road. The rocks in the zone are oxidized and streaked by limonite from iron sulphate waters which ooze at all times out of the vein. The vein in Copperas Hill lies three-fourths mile northwest of the strike of the Dalton vein. It crosses Crooked Creek north of Mount Vernon School and has been traced about 1½ miles along the strike. Southwest of Crooked Creek, the Iron Ridge vein, which is in strike with the Betty Baker and Dalton veins, has an uninterrupted outcrop for 4½ miles. It crosses Chestnut Creek at Chestnut Yard and extends southwesterly through Iron Ridge, where the operating mine of the General Chemical Company is located. Small prospects and outcroppings of ore extend southwestward to Oldtown. Southwest of Oldtown, the Gossan Lead crosses U. S. Route 58, where its presence is marked by limonite stain on the rocks on both sides of the New River bridge. Farther southwest, ore in the Gossan Lead was mined to some extent, mainly at the Hampton and the Blevin mines near New River. At the Hampton mine, located on the north side of New River at Hampton Ford, three-fourths mile below the mouth of Little River, an old tunnel which is said to extend 100 feet into the hill, is still visible. To the southwest, near the mouth of Beaverdam Creek, quartz veins at several places contain pyrrhotite, hematite, and ilmenite, and the rock is stained with limonite. The Gossan Lead ore body extends S. 65° W. into North Carolina where it was mined at the Peach Bottom mine[82], located 7 miles southwest of the Virginia line.

General description.—The Gossan Lead is a series of *en echelon* mineral-bearing veins in the Lynchburg gneiss and in associated sills of hornblende gneiss. In general the ore veins are parallel to the strike of the foliation of the country rock. The dip of the veins and of the folia-

[82]Boyd regarded this mine as part of the "Peach Bottom Lode", which is described as lying southeast of the "Northern" or Gossan Lead Lode. This error was due to the poor base maps which were available in 1881.

tion is to the southeast. The sulphides of the vein are chiefly pyrite, pyrrhotite, and chalcopyrite, with lesser amounts of sphalerite and galena. The country rock in the vicinity of the veins contains much disseminated pyrite and pyrrhotite and, where weathered, is coated and impregnated with limonite. The veins have a limonite gossan and their outcrops are marked by detrital blocks of vein quartz and limonite and by numerous old mines and prospect pits. The gossan is 20 to 60 feet thick and has a greater depth on the upland than in ravines. In a longitudinal section along the Gossan Lead, Weed[83] shows the relative thickness of the gossan, the zone of secondary copper ores, 1 to 6 feet thick, which lies like a floor beneath the gossan, and the unaltered sulphides below.

Copper mining.—Due to the demand for copper, mining for that metal began in the Appalachians at Ducktown, Tennessee, in 1847, and in southwestern Virginia soon after that date. One of the first mines opened for copper was the Toncray mine in Floyd County, east of Buffalo Mountain. Boyd[84] refers to Currey's description of the mine, which he stated was the largest copper producer in the region. Smaller mines, also located northeast of the Gossan Lead district, include the Gardner and Goad mines east of Hillsville and the Early mine southeast of that town. From 1850 to 1859 copper was mined by several companies at many places along the main Gossan Lead vein from the Betty Baker mine at the northeast to the Hampton mine near the North Carolina line at the southwest. The Dalton Mining Company operated in the northeastern part of the vein. The Wythe Lead and Zinc Company operated in the Copperas Hill area, and the Wistar Copper Mining Company mined copper at the "Great Outburst" near Iron Ridge. The secondary copper ore was reported to be 30 feet thick and 12 feet wide in places. Watson reported[85] that in 1854-5 there were eight operating mines on the Gossan Lead; that in the first six months of 1855, they produced 1,545,363 pounds of copper ore that averaged 25 per cent copper; and that the metal sold for 26 cents a pound.

The secondary, or supergene, copper ores were deposited by descending sulphate waters derived from the weathering of the sulphide veins. The richest source of copper was chalcocite, which was called black ore or "smut ore" by the miners. At some places chalcocite occurred with vein quartz. Associated copper minerals are malachite, chrysocolla,

[83]Weed, W. H., Copper Deposits of the Appalachian States: U. S. Geol. Survey Bull. 455, Fig. 29, 1911.

[84]Boyd, C. R., Resources of South-west Virginia, 3d ed., pp. 257-259, New York, John Wiley & Sons, 1881.

[85]Watson, T. L., Idem., p. 511.

cuprite, and a small amount of native copper. Chalcocite has altered in places to covellite, which appears as a bright-blue film on the other minerals. The relations of chalcocite to the other ore minerals are shown by Ross[86]. Emmons and Laney[87] described the gossan, the secondary copper ore, its method of enrichment, and the relation of chalcocitization to erosion at Ducktown and elsewhere.

The black copper ore was treated at two copper smelters, one at Betty Baker and the other at Cranberry Plains, on the old Wytheville turnpike which is now a part of U. S. Route 52. Cranberry Plains, located just east of the Cranberry mine (Pl. 61), was the center of a considerable settlement during the period of copper mining, but only the old shafts and ore dump now remain. The smelted ore was shipped by rail to Max Meadows and from there was hauled by wagon over the rough mountain roads. The country at that time was densely forested. Boyd stated that when he visited the region in 1881, timber, in the northern half of Carroll and Grayson counties, had been cut and made into charcoal to supply the iron and lead smelters in Wythe County, but that towards the southern side of the counties the forests were vast and almost unbroken. In spite of the difficulties of marketing the ore, mining was profitable because of the high price of copper.

Iron mining.—The second stage of mining of the Gossan Lead was largely after 1880 when the gossan was mined for iron. The Virginia Coal and Coke Co. operated at Betty Baker, and the Pulaski Mining Company at Iron Ridge. In 1890 the building of the Reed Island Branch of the Norfolk and Western Railway to Sylvatus with a spur to the Betty Baker mine and another branch along Chestnut Creek to Chestnut Yard, gave an impetus to mining and provided good shipping facilities for the ore.

Before and after the Norfolk and Western Railway was extended into the Gossan Lead district, the iron ore was smelted locally in many charcoal forges. Watson stated that the smelted ore was not satisfactory for wrought iron but was used successfully for castings. The water-blast for furnaces and the trip-hammer of the forges were both operated by water power, and forges therefore were located on streams near falls or rapids. The water-blast furnished air for the bellows and the iron was forged under the trip-hammer. The charcoal used in these forges was produced

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[86]Ross, C. S., Idem., U. S. Geologic Survey Prof. Paper 179, Pl. 42, p. 159, 1935.

[87]Emmons, W. H., and Laney, F. B., Geology and ore deposits of the Ducktown mining district, Tennessee: U. S. Geol. Survey Prof. Paper 139, pp. 71-89, 1926.

by burning wood. The burning took two days to a week, and 700 pounds of charcoal was produced from a pit. Evidence of old charcoal pits may be seen in many places in the woods and fields where the soil, after ploughing, is black with charcoal fragments .In the early mining days, a forge was located at Collins Mill, on Little River near the North Carolina line at what is now Rutherford Mill (Pl. 50A), and ore from the Hampton and Blevin mines was smelted there. Another forge was located at Blair on Chestnut Creek, a mile north of Cliffview. The foundations of the forge and of the old dam are still preserved. Ore from the Leonard mine was used in this forge. Burnett Forge, later called Dobson Forge, was located on Crooked Creek just above its mouth.

Present mining.—The Gossan Lead is being mined at present for sulphide ore, chiefly pyrrhotite, at the Iron Ridge mine, just southeast of Chestnut Creek and Chestnut Yard Station on the Norfolk and Western Railway. This mine is controlled by the Virginia Mining Company, a subsidiary of the General Chemical Company. The sulphide is shipped by rail to Pulaski, Virginia, for the manufacture of sulphuric acid.

At Iron Ridge, mining for sulphide ores was begun by open cuts in the Huey pit and later in the Bumbarger pit. Plate 57A shows the open cut and underground workings in 1928. Present mining is entirely underground. Figure 51 shows a plan of the Bumbarger open cut and its relations to the underground workings. When visited by the writers in

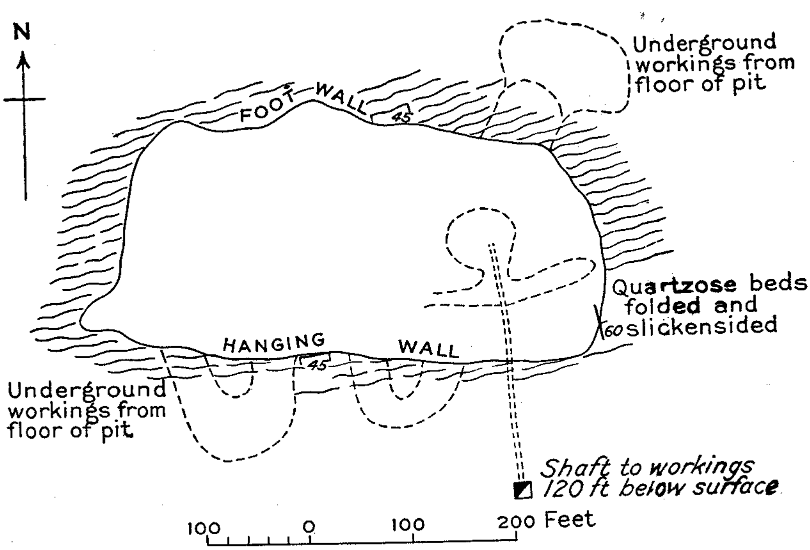

FIGURE 51.—Sketch plan of Bumbarger pit of Iron Ridge Mine.

1938, the open cut, in Lynchburg gneiss, was about 250 feet wide across the strike, and 500 feet long. The foot wall is formed by a fine-grained quartzite of the Lynchburg gneiss which has coarse flakes of biotite and small red garnets.

The hanging wall is a muscovite schist with quartzose layers, interbedded with fine-grained biotite schist. The Lynchburg gneiss is closely folded. At the mine, the axial planes of the folds and the slip cleavage dip 40°-45° SE. The folds pitch gently northeast. The ore veins have replaced the country rock along foliation planes and both the ore veins and the foliation dip 45° SE. The veins contain intercalated and impregnated lenses of schist. The veins are *en echelon* lenses that pinch and swell. They range from 5 to 100 feet in width, with an average width of 20 feet and a maximum width of 100 feet.

The gangue minerals comprise quartz, feldspar, calcite, and the mafic silicates, pale-green actinolite, bronze-colored biotite, and pinkish-red garnet. Actinolite is present in fibrous, radial, or plumose forms intergrown with the ore minerals (Pl. 57B). On the foot wall of the open cut quartzite wraps around irregular masses of the ore body, which contains abundant fanlike sheaves of actinolite, 2 inches long.

Ross reports also the presence of magnetite, rutile, epidote, and specular hematite at Iron Ridge. Biotite is bronzy, reddish brown, and is high in iron. The composition of garnet[88] from the Iron Ridge mine is as follows:

ANALYSIS OF GARNET (SPESSARTITE) FROM IRON RIDGE MINE, CARROLL COUNTY, VIRGINIA

SiO_2	36.59
Al_2O_3	19.63
Fe_2O_3	0.60
FeO	11.77
MnO	19.18
MgO	1.20
CaO	8.82
	97.79

Both its chemical composition and refractive index show that the garnet is the manganese-bearing variety, spessartite. This garnet, a common

[88]Ross, C. S., Idem., U. S. Geol. Survey Prof. Paper 179, p. 63, 1935.

gangue mineral of the ore veins, occurs at the Hampton mine in blocks of glassy quartz, which contains also prisms of clear, yellow staurolite 0.1 mm in length. Gahnite, the green zinc spinel, is reported[89] in the copper-bearing pyrrhotite vein at Ore Knob, North Carolina, 13 miles southwest of the Gossan Lead district, but has not been found with such veins in Virginia. Gahnite occurs also in a quartz vein in North Carolina, 3 miles southwest of Penitentiary Hill, where the gahnite crystals are euhedral and up to half an inch in size. The quartz containing the gahnite was limonite stained, indicating the former presence of sulphides. The plagioclases, oligoclase and albite, occur sparingly as gangue minerals in the Gossan Lead ore bodies. Quartz is present in veins and fine veinlets, largely on the hanging wall of the ore bodies. Much of it is a clear glassy variety. At the Iron Ridge mine and elsewhere in the Gossan Lead, the quartz in the ore veins contains open cavities. Calcite is found at the Iron Ridge mine but is not abundant. Blocks of gneiss of the country rock, which have been enclosed in the ore veins contain coarse actinolite and biotite as blades which have grown as porphryoblastic crystals in the rock. The sulphides are later than all of the other minerals and have replaced them in the gangue and in the country rock adjoining the ore veins (Pl. 58).

Sulphide ores.—At the Iron Ridge mine, according to Ross, pyrrhotite is the predominant sulphide. It has largely replaced pyrite, the earlier formed sulphide. Pyrrhotite has a metallic luster and is sometimes attracted by the magnet while pyrite is never attracted by the magnet. Pyrite has a brassy-yellow color, and is harder than pyrrhotite. The pyrrhotite occurs in granular masses which enclose other minerals. Chalcopyrite forms small disseminated bodies and irregular streaks in the pyrrhotite. Sphalerite and galena are present as microscopic crystals.

According to Ross, the Gossan Lead from Iron Ridge northeast and as far as the Cranberry mine is similar in character to the vein described at Iron Ridge. At the Betty Baker mine the vein contains no actinolite, nor does it include blocks of gneiss. The gangue contains abundant grains of dolomite, which is not an essential component of the Gossan vein to the southwest. Pyrite is more abundant than at Iron Ridge. Pyrrhotite, sphalerite, and chalcopyrite are also present.

Ross[90] describes the ore deposits at the Peach Bottom mine, Alleghany County, North Carolina, as a compound vein with a zone of silver-

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[89] Ross, C. S., Idem., U. S. Geol. Survey Prof. Paper 179, p. 28, 1935.
[90] Ross, C. S., Idem., pp. 85-87, 1935.

bearing galena, 6 to 9 inches wide, on the north wall and plagioclase on the south wall. It contains lenses of calcite and barite in which there are disseminated sulphides. The sulphides also have replaced the country rock in lenses. Pyrite is the earliest formed and most abundant sulphide. It was followed by the introduction of bornite, chalcopyrite, sphalerite, and silver-bearing galena. This vein differs from the main part of the Gossan Lead in Virginia in its abundance of pyrite, calcite, and barite, and in the absence of pyrrhotite and the mafic minerals, actinolite and hornblende. It resembles the ore at the Betty Baker mine, 37 miles to the northeast, where again the minerals include chiefly calcite, some barite and galena, and more pyrite than pyrrhotite.

Origin of ore veins.—In discussing the origin of the ore veins of the Gossan Lead, Ross[91] states that many of the minerals of the gangue and ore are known to form only at high temperature and under pressure, and that some of the high-temperature silicates were altered during a late hydrothermal stage. The writers conclude that the hydrothermal solutions entered the country rock along foliation planes and migrated a long distance from their source. They were introduced after the major part of the deformation of the district was completed. Evidence of movement later than emplacement of the veins was observed at some places. Cross faults with small displacement and slickensided surfaces have been reported at the Betty Baker mine. At the Goad and Gardner mines, which lie east of Reed Island Creek and south of U. S. Route 221, there are slickensided balls of chalcopyrite in a fissile actinolite schist. Similar balls in schist were reported at Ogles Branch, 2 miles southwest of the Betty Baker mine.

Boyd[92] described veins of native copper that were opened on the James Early property, 2½ miles southeast of Hillsville, where, he says, the veins ran diagonally across the strike from Little Reed Island Creek to Woodlawn. The veins at the Early mine are in a hornblende gneiss which is closely folded and in which the axes of the folds dip steeply. Veins contain quartz, native copper, feldspar, and epidote. They follow the foliation planes of the gneiss and conform to the local structure and do not cut across it, as is stated by Boyd. The sulphide ores in the Gossan Lead ore body have replaced mica schist and hornblende gneiss along zones of weakness that are parallel to the Gossan Lead overthrust. The ore body at Iron Ridge, which contains the largest amount of ore yet

[91]Ross, C. S., Idem., pp. 80-81, 1935.
[92]Boyd, C. R., Mineral wealth of southwestern Virginia: Am. Inst. Min. Eng. Trans., Vol. 8, p. 342, 1880.

found in the Gossan Lead veins, occurs where the vein and the Gossan Lead overthrust bend southward (Fig. 48 and Pl. 61).

SPESSARTITE VEINS

General description and distribution.—The manganese mineral in these veins is the manganese silicate, spessartite. The spessartite veins lie in two belts. In the southeastern belt the veins are in the Lynchburg gneiss and associated narrow bands of hornblende gneiss. In the northwestern belt the veins occur in shear zones (Pl. 61). These veins have been described briefly in a previous paper[93].

Southeastern belt.—The Lynchburg gneiss and associated hornblende gneiss contains veins of massive spessartite in two areas; one in Grayson County, 4 miles southwest of Galax, and the other in Carroll County, 6 miles east of Galax.

In the area southwest of Galax, the longest vein of massive spessartite is exposed on a low terrace northwest of Beaver Creek, and extends from a valley southeast of Hampton Knob 3 miles in a S. 60° W., direction to the Dalhart-Rector School road. At both ends the spessartite vein passes into barren glassy quartz. Near Little River 1½ miles southwest of the southern end of the Beaver Creek vein, two other spessartite veins have been traced for short distances. The veins of spessartite rarely crop out and can be traced only by old mines, prospect pits, dumps, and float of glassy quartz and massive spessartite stained and coated black with hydrous manganese oxides.

Little can be seen at the old mines and prospects, but exposures in openings made in 1941 were helpful in determining the relation of the ore to the country rock, the mineral composition of the veins, and the amount of manganese available. The veins lie, for the most part, at the contact of Lynchburg gneiss and hornblende gneiss and dip southeast with the country rock. The vein northwest of Beaver Creek is exposed on a low terrace whose surface is 2,500-2,600 feet in altitude, about 50 feet above and to the northwest of a road along the creek. The vein dips 80° SE., with the country rock. In 1941 the Virginia Manganese Corporation of Richmond, Virginia, took an option on the property of Fontaine Higgins, and dug shafts, near the site of an old mine. The deepest shaft is 40 feet. The mica schist on the hanging wall is weathered and shows slickensides coated with hydrous manganese oxides. Small knots of manganese oxides replace the schist for a distance of 1 to 2 feet from the

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[93]Jonas, A. I., Manganese-bearing veins in southwestern Virginia: Econ. Geology Vol. 37, no. 5 pp. 408-414, 1942.

main vein. Near the surface, the fine-grained hornblende gneiss that forms the foot wall is weathered and barren of ore, but near the bottom of the shaft the fresh hornblende gneiss contains unoxidized grains and thin stringers of spessartite. The vein in the shaft has a maximum width of 4 feet and pinches to 3 feet. It is composed of fine-grained, dense, dark-red spessartite (Pl. 56B) which breaks along straight partings parallel to the walls and on cross fractures which are filled with quartz coated with hydrous manganese oxides. The massive spessartite contains irregular nodular masses of glassy quartz, and is crosscut by veins of white and smoky quartz containing euhedral crystals of light-pink spessartite, rarely exceeding 0.5 mm. in diameter. These veins contain also light green fibrous hornblende and scanty grains of pale-green fluorapatite. The closely spaced partings of the massive spessartite are coated with thin films of hydrous manganese oxides to the bottom of the 40-foot shaft, so that every block of garnet rock has a thin black coating. The red color of the garnet can be seen only on a fresh fracture. Near the surface the oxidation of spessartite is greater, and float of quartz contains a still greater amount of manganese oxide.

Half a mile southwest of the prospect of the Virginia Manganese Corporation and beyond a small valley, manganese was prospected in 1941 to a depth of 20 feet in two pits 100 feet apart. These pits wre dug by the Binkley Coal Company of Chicago, under the direction of Clark Jennings of Baywood, Virginia. The mineral composition and structural relations of the vein here are like those described on the Higgins property. The vein visible in the pits is lenticular and discontinuous, with a maximum width of 4 feet. The spessartite has not been deeply weathered.

Near the spessartite vein northwest of Beaver Creek, vein quartz containing black tourmaline crystals occurs as float, and a short distance to the southeast quartz veins 4 to 6 inches wide that contain black tourmaline crystals crop out in a road cut. The quartz veins are in mica schist and strike with it, but dip southeastward at a lower angle than the schist. The quartz and tourmaline are coated and infiltrated with hydrous manganese oxides. The tourmaline has been analyzed and found to contain no manganese, so that the secondary manganese minerals are probably derived from the weathering of associated spessartite or other primary manganese-bearing minerals not now visible. The amount of these manganese minerals in the quartz veins in the road cut is too small to be of commercial value. Tourmaline also occurs in a quartz vein exposed in the cut on State Highway 89 just south of Galax. It was observed also on the East Fork of Chestnut Creek east of Hickory Knob and at the north foot of Rich Mountain. At neither of these places does the vein contain manganese minerals.

In the veins southwest of Dalhart, the Binkley Coal Company has a tunnel 20 feet long, which follows the strike of the rocks, S. 55° W. It is 30 feet above the road. It shows veins of spessartite 2 to 4 inches wide, which parallel the foliation of the mica schist and dip 80° SE., and muscovite-pegmatite dikelets 1 inch wide, which contain tourmaline. On top of the hill southwest of the tunnel the company has opened shallow prospect pits at intervals along the vein for a distance of nearly 1,000 feet. The pits uncovered several parallel stringers of spessartite, 2 to 18 inches wide. The veins exposed in the tunnel and pits are in a belt of mica schist that lies northwest of a layer of hornblende gneiss, which is apparently the layer that forms the foot wall of the vein on the Higgins property; if so, these spessartite veins are *en echelon*. Search, southwest of the Rector School-Dalhart road, failed to locate any spessartite or quartz veins along the strike of the Beaver Creek vein.

In the hill southeast of Rutherford Mill, 1½ miles southwest of the end of the vein near Beaver Creek, there is a small abandoned prospect where manganese was reported to have been found. On the Otto Phipps property, in a big bend of Little River southwest of Rutherford Mill, the Binkley Coal Company opened a pit in 1941. It is located on the hilltop southeast of Cold Spring School at an altitude of 2,600 feet. It is in the Lynchburg gneiss and strikes N. 55° E. The pit was 6 feet deep and showed a lenticular vein of spessartite with a maximum width of 3 feet. Fresh massive spessartite with only a thin film of hydrous oxide on joint fractures extends from the bottom of the pit to the surface. The spessartite here has the same mineral association as that at the Higgins property—that is, quartz and fibrous green hornblende. Thin veins of quartz cut the massive garnet vein.

Six miles east of Galax, spessartite veins cross Crooked Creek north of Chisel Knob (Pl. 61). These veins lie 7 miles northeast of the Beaver Creek veins. In the intervening area, the only evidence of manganese seen by the writers was a thin quartz vein stained black with hydrous manganese oxides. The most northerly veins in the belt north of Chisel Knob can be traced by blocks of quartz and spessartite coated with hydrous manganese oxides from a sharp bend in the East Fork of Crooked Creek northwestward for 2 miles to a valley on the east flank of Walker Knob. Other shorter veins, which show only quartz and hydrous manganese oxides, occur three-fourths mile to the south between Elkhorn Creek and Hurricane Fork of Crooked Creek. The veins north of Chisel

Knob follow the strike of the country rock, which is here N. 70° W. Along the northern vein-zone narrow veins of spessartite, quartz, and epidote in hornblende gneiss are exposed on a farm lane 1 mile north of Chisel Knob, east of Crooked Creek. The hornblende gneiss is closely folded. The folds pitch 45° SW. To the southeast, this vein-zone crosses the property of Mr. Larue to East Fork, where it can be traced by float of quartz and spessartite stained black by hydrous manganese oxides. A small prospect was opened in 1937 on the William Hayes farm, north of a sharp bend in the East Fork of Crooked Creek just above its mouth, and marks the southeast end of the northern vein. West of Crooked Creek, float of a similar character occurs on the property of A. J. Fadis. The float, and presumably the veins from which it was derived, end half a mile northwest of Crooked Creek.

Two and a half miles south of the Virginia line and 7 miles southwest of the Higgins prospect, manganese-bearing veins occur in Alleghany County, North Carolina, somewhat northwest of the strike of the Beaver Creek veins in Virginia. On Crouse Knob at an altitude of 3,000 feet on the southeast side of Bald Knob, these veins were explored by a shaft which had caved in when visited in 1938. The mineralogic features of these veins have been described by Ross and Kerr[94]. They report a vein 5 to 7 feet wide, with a strike of N. 50°E., and a dip of 50° SE, that occurs along the contact of hornblende gneiss and Lynchburg gneiss. The chief manganese mineral is spessartite, with rhodonite (a manganese silicate) being next in abundance. Rhodochrosite (manganese carbonate) occurs in the rhodonite. Tephroite (manganese olivine) and alleghanyite (manganese silicate with water and flourine) are in veins in the rhodonite. Galaxite (a black manganese spinel) occurs as black shiny grains intergrown with alleghanyite. This vein is distinctly banded. Spessartite forms massive lenses 2 feet in width, whereas rhodonite forms one lens 4 inches wide. Ross and Kerr state that oxides of manganese are abundant to a depth of 10 feet and none was found below a depth of 40 feet. In 1941 the Binkley Coal Company started to reopen the mine in the belief that manganese carbonates and oxides formed a large part of the vein, but abandoned it when they found the minerals were silicates.

Northwestern belt.—Secondary hydrous manganese oxides in quartz veins occur in places along the Fries overthrust and in shear zones northwest of the overthrust. Spessartite associated with magnetite are believed

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[94]Ross, C. S., and Kerr, P. F., The manganese minerals of a vein near Bald Knob, North Carolina: Am. Mineralogist, Vol. 17, No. 1, pp. 1-18, 1932.

to be of a different origin and are described under a later heading, "Magnetite and associated minerals."

The Bud Elliott prospect, on a hill on the north side of the east branch of Brush Creek three-fourth mile southwest of Bethel Church, was opened for manganese because fragments of rock containing hydrous manganese oxides are sparingly distributed in the soil nearby. A trench 20 feet deep extends northwestward into the hill across the strike of the rocks, which dip about 30° SE. The exposed rock is granite mylonite locally replaced by brown ferruginous chert, with drusy quartz lining small cavities. Many of the quartz grains are coated with black hydrous manganese oxides. The latter fill small cavities in the rock. Tourmaline associated with quartz occurs in small pockets in the replaced rock. No spessartite was observed at this prospect. Southwestward along the strike of the vein, a white, sericite-quartz mylonite, dipping steeply southeastward, is exposed on U. S. Route 21, half a mile south of Brush Creek Church, and in the hill to the northeast. It appears to be a much sheared quartz vein that contains no manganese minerals.

A parallel vein to the northwest is exposed at the bend in the road along Beaverdam Creek, one-eighth mile north of the E. H. Wingate farm. Here, a quartz vein with hydrous manganese oxides cuts granite gneiss that is veined with green epidote. Half a mile northeast of Penitentiary Ford a quartz vein with hydrous manganese oxides is exposed in a shallow road cut. The vein is 10 feet thick and is composed of glassy quartz grains and pyrite. It is broken by many shear planes coated with silky white sericite. Hydrous manganese oxides occur in cavities of the rock, which was probably made porous by the weathering of a manganese silicate.

Weathering.—Weathering in most crystalline rocks takes place slowly and is deepest on land surfaces that have stood at a constant level for a long period of time. Spessartite is especially resistant to weathering. In the veins examined, weathering of the silicate to hydrous manganese oxides has taken place from the surface downward along closely spaced partings, which are chiefly parallel to the schistosity of the country rock. The amount of hydrous manganese oxides decreases with depth, and is very scanty at a depth of 40 feet, which is the lower limit of exploration in the Gossan Lead district. Blocks that appear to be made up of hydrous manganese oxides have cores of unaltered dark-red garnet, which can be recognized only on a freshly broken fracture. The hydrous oxides in most cases form only a thin film on the unaltered silicate.

The terrace surface along Beaver Creek, where the largest vein of massive spessartite in the region is exposed, was formed when the land stood at a constant level for a long period of time and the rocks at its surface were subjected to prolonged weathering; hence there are larger quantities of hydrous manganese oxides derived from spessartite in the vein and in the rock fragments on the surface. The terrace is not continuous along the vein but has been dissected by cross drainage that flows southeast into Beaver Creek. In these cross valleys, cut 50 to 60 feet below the terrace level, little manganese oxide occurs and the mineral in the exposed vein is largely spessartite.

The veins north of Chisel Knob lie on the drainage slope of Crooked Creek. The garnet here is but little weathered because erosion has removed the rocks on the old terrace surface in which weathering of the manganese garnet probably took place before the present erosion cycle began.

Hydrous manganese oxides have been prospected and mined in the mineralized belts near Galax and Independence, but only a small amount of ore has been obtained. The manganese deposits are small and shallow because they occur in the Blue Ridge plateau where the rocks are not deeply weathered, and spessartite, from which the ore was derived, is even less weathered than the country rock. The residual secondary manganese minerals are limited to erosional remnants of the plateau and terrace surfaces. Furthermore, the manganese silicate from which the secondary minerals were derived occurs as lenses and not as continuous bodies.

Twelve miles southeast of Galax, in Surry County, North Carolina, 3 miles south of the Virginia line, a vein of spessartite with associated secondary manganese minerals[95] was mined by the Tar Heel Manganese Company. It is reported that about 385 tons of high-grade manganese ore were shipped from this mine in 1917 and 1918. The large quantity of hydrous oxide ore in this deposit is due to its location in the Piedmont lowland where the rocks at the surface are more deeply weathered than are those on the Blue Ridge Plateau because they lie 1,500 feet lower and nearer sea level, where erosion is less active.

Origin.—The manganese garnet, spessartite, occurs in lens-shaped veins and is associated with other high-temperature minerals and vein quartz. The garnet is not associated with limestone or with a particular horizon of the Lynchburg gneiss that might have originally contained sedimentary grains of manganese minerals. It is believed, therefore, that

[95]Jonas, A. I., Manganese-bearing veins in southwestern Virginia: Econ. Geology, vol. 37, p. 412, 1942.

the garnet was not formed by metamorphism of manganiferous sediments or by concentration from such sediments, but by hydrothermal replacement of the rocks in which it occurs.

MAGNETITE AND ASSOCIATED MINERALS

General description and distribution.—Magnetite deposits occur in two parallel zones, one just south of the Fries overthrust and the other northwest of it (Pl. 61). Those south of the thrust fault occur in granite mylonite along a belt half a mile wide extending from a point south of Fries southwestward to the North Carolina line just west of the New River bridge on U. S. Route 21. The deposits were worked for iron in the 1880's and earlier. The most northeasterly mine was the Whitaker, located on the bluff of New River just south of the Fries dam. The mine dump of the Whitaker mine shows massive magnetite with hornblende, augite, and a little quartz. The Funk mine was 1½ miles to the southwest, and two other magnetite mines were farther southwest along the strike, southwest of the bend of New River. The northern one of these was on the Williams property, where a quartzose mylonite, with disseminated magnetite, is exposed in a shallow pit. Ore from these mines was sent to the Blair Furnace near Cliffview on Chestnut Creek.

The ore dump at two old openings on the Edwards farm, 2 miles southwest of Riverside, show massive magnetite in an epidote-quartz rock associated with small spessartite crystals. The ore is veined with asbestos, and is cut by later quartz veins carrying pyrite crystals. Two miles to the southwest, half a mile southeast of the Moore barite prospect (Pl. 61), magnetite occurs in schistose granite gneiss. Four miles to the southwest and three-fourths mile northeast of Peach Bottom School, magnetite was reported on the Kirk property, but the writers found none. Here limonite occurs as rusty spots in a band of actinolite schist about 4 feet thick, and cubes of limonite, derived from pyrite crystals, are scattered in the soil. Three old mines were located near U. S. Route 21, just north of the New River bridge. Two of the mines were on the L. C. Wingate farm east of the highway. The ore is magnetite with glassy quartz and fine actinolite needles. The ore body strikes N. 80° E, and dips 60° S., parallel to the foliation of the country rock. Hornblende schist forms the foot wall, on the north side, and schistose granite gneiss the hanging wall. A tunnel extended through the hill at the mine nearest the highway, and the mine was therefore known as the Tunnel mine. Another mine exposing magnetite, along the strike to the southwest, was opened on a hill west of the highway.

In the zone northwest of the Fries overthrust, veins composed of a granular mixture of magnetite and hedenbergite crop out in parallel belts in an area 2 miles wide which extends from a point north of Rectors Store southwestward to New River near Penitentiary Ford. In places the veins contain spessartite, quartz, hornblende, epidote, and pyrite. These veins occur in the Shoal gneiss, associated granite augen gneiss, and amphibolite of the injection complex. The deposits are lenses that lie along the course of the veins and are parallel to the structure of the country rocks. Veins of this type, in similar rocks extend southwest in Alleghany and Ashe counties, North Carolina, as far as Lansing. During the time that magnetite was mined in this belt, the land was divided into large tracts, one of the largest being the Fulton property, said to have contained 3,000 acres. The Fulton property included the area that extends from Independence northeastward to a point near Flat Rock School and Rectors Store, and southward on Peach Bottom Creek to the Lige Wingate farm on Beaverdam Creek. The Bourne tract lay northeast of Rectors Store and east of the Fulton property. The Billings properties lay southwest of Brush Creek. The ore from the mines on these properties was smelted in nearby furnaces. A furnace on the Fulton tract was located at the falls of Peach Bottom Creek, 1¾ miles northeast of Independence. The Wingate furnace was on Peach Bottom Creek, one-fourth mile south of the present crossing of U. S. Route 58. The Pine Hope furnace was on New River 3 miles southeast of Independence.

Magnetite mines in the northwest zone were operated on the Bourne tract northeast of Rectors Store and on the Fulton tract to the southwest. The ore on the old dumps is magnetite in smoky quartz. To the southwest along the strike, five or six parallel ore veins were formerly mined south of U. S. Route 58 (Pl. 61). The veins are not continuous but ore has been found at several places along the strike of each of them. Toward the northeast, near Peach Bottom Creek, the veins strike N. 80° E. Southwestward, near U. S. Route 21, the strike changes to N. 50° E. These veins are in the Shoal gneiss and lie parallel to the foliation. The most southeasterly vein crosses the old Wingate property, where a magnetite mine was opened 2 miles southeast of Independence in a hill northeast of Beaverdam Creek, on the farm now owned by E. H. Wingate (Pl. 61). The vein dips 60° SE. Hornblende gneiss forms the foot wall and fine-grained granite gneiss the hanging wall. The vein is composed of crystalline magnetite and a coarsely crystalline, green pyroxene of the diopside-hedenbergite series and bands of granular spessartite. Along the strike, northeast of the Wingate workings and east of Peach Bottom Creek, magnetite grains are disseminated in the Shoal gneiss on the Hendricks farm.

At the Hendricks farm magnetite is associated with granular spessartite. Small amounts of quartz, chlorite, and actinolite, and massive light-gray epidote occur in the veins. The epidote is the low iron variety, clinozoisite. Because of its light-gray color and high specific gravity it has been mistaken for barite. Veins of quartz containing pyrite cut the magnetite veins and the country rock, and are younger than the magnetite. A spessartite vein which crops out southwest of the old mine on the road along Beaverdam Creek, near the E. H. Wingate house, can be traced from this point for a mile southwestward. It lies between hornblende gneiss and fine-grained injection gneiss.

Magnetite occurs on the Boyer farm, 2 miles southwest of Independence and south of the road up Brush Creek (Pl. 61). The vein is a coarse-grained, rust-colored rock composed largely of green hedenbergite, spessartite, and epidote, with scanty quartz, magnetite, and red-brown biotite. Blocks of a dense, cream-colored epidote associated with green fibrous hornblende, and pink pegmatite, strew the surface. The vein is at the contact of hornblende gneiss with granite injection gneiss. A chemical analysis of the hedenbergite from the Boyer vein, made by the U. S. Geological Survey, is as follows:

ANALYSIS OF HEDENBERGITE FROM BOYER FARM ON BRUSH CREEK, GRAYSON COUNTY, VIRGINIA

(J. G. FAIRCHILD, *analyst*)

SiO_2	49.26
FeO	19.65
MnO	3.56
MgO	2.11
CaO	21.88
Al_2O_3	0.74
Fe_2O_3	2.17
H_2O	0.66
	100.03

The most northwesterly vein of this zone crops out on the southeast side of Wolf Hill, southeast of Independence, where a vein composed of granular spessartite and epidote is associated with pink pegmatite. A vein, that crosses U. S. Route 21 half a mile south of Beaverdam Creek, is apparently on the strike of the Wolf Hill vein. In two fresh cuts on the road, which it crosses twice at a sharp curve, the vein is only 2 feet wide, strikes N. 50° E., and dips 75° SE. It is composed of quartz with 4- to 6-inch layers of fine-grained red spessartite and kaolinized feldspar, and also spessartite grains with quartz and actinolite. The garnet has largely weathered to hydrous manganese oxides. It is evident here that the spessartite has replaced the country rock along the contact between the Shoal gneiss on the north and hornblende schist on the south. The quartz appears to be later than the granular spessartite. The writers did not find magnetite in this northwestly vein.

Southwest of the Boyer farm magnetite was mined on the Billings tract in a hill just south of Brush Creek, where parallel lines of old pits are still visible. Blocks of quartz stained with limonite and containing yellow brecciated chert are found on the dumps.

Origin.—Magnetite and hedenbergite, with varying amounts of spessartite and epidote, occur in veins in the injection complex. At most of the outcrops the ore veins are poorly exposed. The relations of the vein to the country rock are best observed at the E. H. Wingate prospect and on U. S. Route 21 south of Beaverdam Creek. Where observed, the veins occur at the contact of sheared hornblende diorite with fine-grained biotite injection gneiss (Shoal gneiss). The vein replaced the country rock along the gneissic structure and is characterized by minerals that crystallize at high temperature. The mineral association and the localization of the veins at the contact of metadiorite with granite gneiss of pre-Cambrian age, make the magnetite-hedenbergite veins of this district similar to the magnetite deposits at Cranberry, Mitchell County, North Carolina. The Cranberry vein has been described in several reports[96].

At the Cranberry mine the magnetite veins, shown in the open cuts and in drill cores from the mine, occur at a constant horizon at the contact of fine-grained hornblende gneiss with fine-grained biotite-granite injection gneisses mapped by Keith as Cranberry granite. A pink microcline pegmatite with blue quartz in dikes up to 20 feet in width, which cross cut the magnetite vein and country rock at steep angles, has penetrated the wall rock along the gneissic banding. These relations indicate that the pink pegmatite was intruded later than the introduction of the

[96]Bayley, W. S., The magnetite iron ores of East Tennessee and Western North Carolina: North Carolina Geol. and Econ. Survey Bull. 32, pp. 37-81, 1923; The magnentic ores of North Carolina and their origin: Econ. Geology, Vol. 16, pp. 142-152, 1921. Ross, C. S., Origin of the copper deposits of the Ducktown type in the Southern Appalachian region: U. S. Geol. Survey Prof. Paper 179., pp. 107-112, 1935.

magnetite veins. Bayley[97] stated that the magnetite and pyroxene are part of the pegmatitic intrusion, which was followed by later intrusion of pyroxene and magnetite and finally by magnetite. The pink pegmatite in the Cranberry mine resembles the pink microcline pegmatite facies of the Carsonville granite which is the latest phase of intrusion in the early pre-Cambrian injection complex in the Gossan Lead district. The magnetite veins in that district, therefore, are regarded by the writers as of Early pre-Cambrian age.

It is possible that the magnetite deposits that occur just south of Fries, in the mylonite zone along the Fries overthrust, may be of later age than those farther to the southwest. Where the ore is exposed on the Williams property, it occurs as magnetite crystals disseminated in quartzose mylonite, and seems to have replaced the mylonite, which was formed during late Paleozoic deformation, and hence the magnetite may be of late Paleozoic age. At the other prospects in the zone of the Fries overthrust, namely the Whitaker, Funk, and Edwards, the ore specimens seen in the dump are similar to the magnetite to which pre-Cambrian age is ascribed.

KYANITE

General description and distribution.—Kyanite occurs in the Gossan Lead district chiefly in a narrow belt extending from Woodlawn southwestward through Galax to Baywood (Pl. 61). Kyanite occurs in quartz veins which commonly contain crystals of rutile and ilmenite. The kyanite-bearing quartz veins cut garnet-staurolite-mica schist of the Lynchburg gneiss, and are in general parallel to the foliation of the schist. They pinch and swell along the strike and rarely exceed 10 feet in width. Kyanite prospects have been opened on the Pierce, Phipps, and Nuchol properties west of Galax, but deposits of commercial value have not yet been proved.

Kyanite is a blue to grayish-blue aluminum silicate mineral which has two cleavages (Pl. 59B) and two hardnesses, one hardness of 4.5 parallel to the length of the crystal and the other of 7 perpendicular to the length. In this district kyanite occurs as wide-bladed crystals and massive crystalline aggregates in veins of quartz or pegmatite. Some masses of kyanite blades are as much as 7 inches long and 4 inches wide. Plate 59B shows such an aggregate, found 1 mile northeast of Baywood, in which the blades are irregularly arranged. At the Nuchol prospect, southwest of Galax (Pl. 61) the massive kyanite has crystal blades

[97]Bayley, W. S., Idem, pp. 50, 60, 62.

crowded together but divergent in their grouping. The longer dimension is at right angles to the wall of the vein. Such a block of massive kyanite from the Nuchol prospect has been previously illustrated[98]. This prospect was opened in 1928 by E. B. Crabill. The kyanite penetrates the quartz vein from a zone near its contact with the mica schist. The Phipps and Pierce prospects are on the hill just west of Galax. Kyanite also occurs in pegmatites exposed in a cut on U. S. Route 58, half a mile east of the New River bridge. Here feldspar composes 10 per cent of the vein, although it is absent in most of the kyanite-bearing veins.

Origin.—The writers are of the opinion that kyanite in this district may be of hydrothermal origin. The fact that kyanite in this district occurs in quartz veins is indicative of this mode of origin. The association of rutile and ilmenite with kyanite in quartz veins is further confirmatory evidence for such an origin. It is possible that kyanite may have been formed in part from the leaching of alumina (Al_2O_3) from the mica schist of the wall rock by hot vapors brought up with the pegmatitic material. The kyanite-bearing veins near Galax are believed to be related to the ore-bearing veins of the Gossan Lead district. A more complete discussion of the occurrence and origin of kyanite in Virginia is given by Jonas[99].

At the time that report was written, mining at Baker Mountain, Prince Edward County, Virginia, was confined to a shallow pit in which the relation of the kyanite-bearing quartzite to the adjoining rock was not evident. In the above report the writer suggested that the kyanite was formed by regional metamorphism of beds originally rich in alumina. By subsequent development the Baker Mountain mine has been deepened and now it may be seen that the kyanite-bearing quartzite was intruded by pegmatite. The kyanite-bearing quartzite here contains much pyrite and fine black needles of rutile; also the bright-green chrome-bearing mica, fuchsite, which is found also in kyanite-bearing quartzite at Madisonville, 6 miles west of Baker Mountain. Kyanite and pyrite occur in small amounts also in the muscovite pegmatite at Baker Mountain. Because of the association of kyanite with pyrite, rutile, and fuchsite, its concentration at certain places in the quartzite, and its association with pegmatite the writers believe that the kyanite in Baker Mountain and the adjoining area is of hydrothermal origin.

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[98]Jonas, A. I., Geology of the Kyanite belt of Virginia: Virginia Geol. Survey Bull. 38, Pl. 7, 1932.

[99]Jonas, A. I., Geology of the Kyanite belt of Virginia: Virginia Geol. Survey Bull. 38, pp. 12-16, Pl. 7, 1932.

Uses.—In recent years kyanite, as well as other refractory minerals such as sillimanite and andalusite, has been used for ceramics and refractories. The economic aspects of kyanite have been discussed by Watkins[100].

RUTILE AND ILMENITE

General description and distribution.—Rutile and ilmenite are minerals from which much of the commercial titanium is obtained. Rutile is a red to brownish-red mineral composed of titanium dioxide (TiO_2). It has a metallic to adamantine luster, and a pale-brown streak. It occurs in massive form as well as in acicular inclusions. Ilmenite is a black to brownish-red, slightly magnetic mineral with metallic luster, of the composition $FeTiO_3$. It occurs as thin black layers or flat tabular plates in quartz. Most of the rutile and ilmenite in the Gossan lead district occurs in quartz veins, although some is present in veins with kyanite. Neither rutile nor ilmenite, in this district, is of economic value.

Rutile and ilmenite have been found with kyanite on Dr. Robinson's farm at Woodlawn, at the Pierce prospect west of Galax, and on the Gordon farm south of the bridge over New River on U. S. Route 58, west of Galax. An unusually well-formed twinned crystal of rutile (Pl. 59C) was obtained by the late E. B. Crabill from the Pierce prospect. Vein quartz, with radiating crystals of rutile, was found at Five Forks northeast of Woodlawn and at Hanks Knob. Rutile crystals in the soil are abundant at Eona 3 miles east of Woodlawn, east of Cox Mill, 1 mile northeast of Hanks Knob, at Edmonds, on the Jennings farm on Meadow Creek, and half a mile south of Baywood. The rutile is associated with ilmenite. Near Eona and one-fourth mile north of Edmonds, ilmenite occurs in flat tabular plates, over 1 inch in length, some of which have weathered out of the rock and are numerous in the soil near Edmonds. Ilmenite crystals found at Adkins Church, 2 miles north of State Highway 95 occur in pegmatite. Individual plates of ilmenite have been found that measured 2 inches long, an inch wide, and an inch thick.

QUARTZ VEINS

General description and distribution.—Quartz veins are very numerous throughout the area of the Lynchburg gneiss in the vicinity of the Fries overthrust, and in the northern part of the Elk Creek anticline. The large quartz veins are shown on the geologic map (Pl. 1) and on

[100]Watkins, J. H., Economic aspects of kyanite: Virginia Geol. Survey Bull. 38, pp. 39-45, 1932.

Plate 61. They are in general from 2 to 5 feet in width and rarely crop out for more than 1,000 feet along their strike. Masses of vein quartz strew the surface in many places even though no outcrop is visible. Quartz veins are most numerous in zones of shearing, as in the area northeast of Galax, near Woodlawn, and near the Fries overthrust. They accompany the Gossan Lead ore veins and the massive spessartite veins. Usually where quartz veins are thick and numerous, the ore minerals are very lean.

Pyrite, in places weathered to limonite, is commonly present in the vein quartz or represented by angular molds. Kyanite, rutile, and ilmenite occur in many places in quartz veins. A quartz vein north of Pilot Knob (Pl. 61) contains abundant grayish-green crystals of the low iron epidote clinozoisite. Quartz in these veins, is glassy when fresh but limonite-stained and granular when weathered. In most places the veins are parallel to the foliation of the Lynchburg gneiss in strike and dip. In other places the veins cut across the strike of the foliation but dip in the same general direction as does the gneiss. Such cross-cutting quartz veins are exposed on Beaverdam Creek south of Woodlawn and in the area southeast of Walker Knob (Pl. 61). Quartz veins, containing pyrite, mark the Fries overthrust, north of Hilltown, north of Fries, and near Bald Rock northeast of Fries. A quartz vein also marks the Byllesby thrust along Brush Creek, where it occurs in the Unicoi formation and the Hampton shale.

North of Elk Creek village a series of quartz veins, trending east and west, is intersected by another system that strikes N. 10° W. The east-west veins follow a shear zone a mile north of the village at the contact of Comers granite gneiss with Saddle gneiss. A vein in this zone, prominently exposed where it crosses U. S. Route 21, northeast of Elk Creek village, is about 20 feet thick and is much sheared. The shear planes dip southeastward and are coated with sericite. West of U. S. Route 21 the sheared quartz vein makes prominent ledges in a series of hills, and can be traced along the strike for 3 miles. Quartz veins also follow the curving thrust faults south of Round Mountain and near the crest of the mountain quartz veins form prominent white ledges. A quartz vein containing pyrite, which lies 1 mile south of Elk Creek village, was reported by Boyd[101] to contain gold.

Thick quartz veins form the crests of several hills 1 to 1½ miles northwest of Spring Valley. The two most prominent veins trend

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[101]Boyd, C. R., Resources of southwest Virginia: 3d ed., New York, John Wiley & Sons, p. 304, 1881.

almost due north and follow the contact of rhyolite and granite. The eastern vein is 30 feet thick and makes prominent ledges. The rhyolite at the contact is brecciated and cemented with quartz, drusy chert, and jasper. The veins probably follow a fault at the contact of the rhyolite and granite. Two other quartz veins, which follow faults that affect also the Mount Rogers volcanic series, occur south of Comers Rock village.

Quartz is used as a source of silica in many industries. Clear, untwinned quartz crystals are in great demand for radio instruments. Search for quartz which is adapted to both of these uses has been made in the vicinity of Galax, but so far none has been found in sufficient quantity and purity to be commercially developed either for silica or for optical use.

BARITE

General description and distribution.—Barite occurs at several places in two belts in the Gossan Lead district. The southern belt is near the Fries overthrust zone and extends from a point southwest of Riverside to the big bend of New River in the southwest corner of the district (Pl. 61). The northern belt lies west and southwest of Fallville. The barite deposits of this area, the properties of barite, and its uses in industry have been described by Edmundson.[102]

The Moore and Poole prospects are southwest of Riverside on New River. The barite on the Moore farm is located one-fourth mile south of Hole School, and a small pit has been opened on the south side of a small stream flowing west through the property. The vein strikes N. 50° E. and follows the strike of the country rock, which is a granite mylonite with micaceous partings that dip 30° SE. Barite has replaced the rock in a zone 2 feet wide, forming lenses parallel to the foliation of the rock. The barite lenses are three-fourths inch to 5 inches in thickness. They contain calcite eyes as much as 2 inches in length. No barite has been found to the southwest along the strike of this zone.

The Poole prospect is 2 miles north of the Moore prospect, half a mile east of Baxter Ferry. The barite is on the border of the Fries overthrust in Grayson granodiorite gneiss which contains eyes or augen of pink feldspar. The matrix of the granodiorite gneiss is composed of quartz, epidote, green muscovite, and saussuritized plagioclase. As stated by Edmundson, barite was prospected here prior to the War between

[102]Edmundson, R. S., Barite deposits of Virginia: Virginia Geol. Survey Bull. 53, pp. 4-8, 49-50, 1938.

the States. It was prospected to a maximum depth of 100 feet in one of three shafts dug in 1926-1928 for Mr. E. B. Crabill of Galax. A solid vein of barite, 16 inches in width and brecciated bedrock cemented by barite, were reported. When visited by the writers in 1932, the shafts were filled and no breccia was seen on the dump. Lumps of barite, veined by epidote and containing quartz grains, occur in the pink and green augen gneiss. Edmundson[103] shows a hand specimen and photomicrograph of the augen gneiss from this locality with tabular areas of barite, in which epidote in part appears to occur in a saussuritized plagioclase. Throughout the Grayson granodiorite gneiss the plagioclase feldspars show this alteration to epidote, and in many places biotite is altered to chlorite. These metamorphic changes occurred in a relatively deep zone during regional deformation. Barite was introduced after the deformation and alteration of the wall rock. The chlorite and epidote may have been the result of propylitization by solutions accompanying the barite, as is suggested by Edmundson[104], or they may have been present in the granodiroite before it was replaced by barite.

Fluorite occurs in the Grayson granodiorite gneiss and in a course pink pegmatite dike at the Poole prospect east of Baxter Ferry. Elsewhere it occurs as a primary constituent of the Striped Rock granite, and as a primary mineral in the rhyolite on Whitetop Mountain west of the Gossan Lead district. It also coats joints of a diabase dike of later pre-Cambrian age near Fallville and shear planes of granite mylonite west of Longs Gap. Fluorite in the district is of different ages so that it cannot be stated with certainty that the fluorite in the gneiss at the Poole prospect was introduced with the thermal solutions that deposited barite and epidote.

The barite prospect on the Cox farm is in the southwest corner of the Gossan Lead district, south of New River, three-fourths mile west of Ham Ford, on a small stream that flows into New River at that ford. The barite is in mylonitized granite similar to the country rock at the Moore prospect. The rock strikes N. 70° E., and dips steeply southward. When the writers visited this deposit in 1934, no trenches had been dug, but barite blocks 6 to 8 inches in thickness were found on the surface. The barite is associated with vein quartz which crops out on the hill top. Relations of the barite to the country rock could not be observed.

Southwestward along the strike of the vein, barite occurs on the Charles Cox farm in Virginia and on the Phipps property just to the

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[103]Idem., Pls. 5B, and 7B, 1938.
[104]Idem., p. 19-20, 1938.

southwest, in North Carolina. Both of these localities are just west of the Gossan Lead district (Pl. 61). In 1936, five trenches were dug on the Cox farm. Here the barite replaces mica schist in three parallel layers, which have a maximum thickness of 1 foot. The barite deposit strikes nearly due east and dips 50° S., with the enclosing rock. The barite is massive, and appears to be of high grade, but its extent below a depth of 10 feet, has not been proved.

The barite on the Phipps property, where it is partially exposed in a test pit, has replaced the bedrock along the foliation. The bedrock and the character of the veins are similar to those at the Cox prospect.

Barite in the area west of Fallville occurs in pink pegmatite and in Comers granite gneiss. Here the barite has replaced these rocks in brecciated zones along normal faults between those rocks and the Unicoi formation. Five prospects occur within a distance of 2 miles near and just north of State Highway 95 (Pl. 61). Another prospect is located just south of the highway. The largest prospect is the F. M. Vaught pit, located just south of Perkins Knob at the foot of Iron Mountain. It is on an east-west normal fault between Comers granite gneiss and a small outlier of the overlying Unicoi formation. The writers visited the prospect in 1928 while the shaft was being sunk. The shaft had a depth of 50 feet, with a drift to the east, but is now filled. The foot wall is granite injected by pink pegmatite. Barite occurs in a brecciated zone 4 feet thick which dips 60° S., and persists to the bottom of the shaft. Edmondson[105] reported that about 20 tons of barite was removed from this pit. A mile to the east of the F. M. Vaught prospect a small test pit along the same fault was dug on the Porter farm, but no body of barite was found at that point.

Two other barite prospects, the S. F. Vaught and the Porter, are located one-fourth mile to the south on a parallel normal fault in pink granite and pegmatite. The open cuts yielded only a small amount of barite, and are now filled. Numerous blocks of barite have been found on the farm of F. M. Vaught east of State Highway 95 half a mile south of the Porter prospect, on the adjoining farm of George Vaught to the east, and on the C. Rhudy farm south of the highway half a mile east of the F. M. Vaught farm (Pl. 61). At all of these places barite float is abundant, but the width of the veins was not determined.

On the John R. McLane farm, east of Elk Creek village, just west of Turkey Fork and a mile south of State Highway 95, blocks of barite

[105]Idem., p. 47.

strew the surface. The vein lies at the contact of sheared Comers granite gneiss and a porphyritic rhyolite dike. The cleavage in the country rock strikes N. 30° E., and the barite vein has a cleavage in the same direction. At the time of the writers' visit in 1938, no prospecting had been done.

A small amount of barite float occurs on the Martin property, at the forks of two small branches of the headwaters of the East Branch of Turkey Fork, north of High Knob and one-fourth mile east of U. S. Route 21. The barite float seems to have come down the southeast fork. The parent ledge has not been found but probably lies along the near-by Byllesby thrust fault on which the middle member of the Unicoi formation has overridden the Hampton shale to the north.

Currier[106] reports barite as occurring in several of the zinc and lead deposits in the Austinville-Ivanhoe district, where it replaces coarse white crystalline dolomite. Barite is associated also with zinc and lead sulphides and pyrite in brecciated dolomite in prospect pits at Allisonia, 8 miles northeast of Austinville.

All the barite in the Gossan Lead district has replaced the country rock as lenses. In the southern part of the district, barite occurs near the Fries overthrust fault (Fig. 24), where barite solutions penetrated along foliation planes in the sheared igneous rocks. Barite in the northern belt is localized along fault zones. The deposits south of Iron Mountain occur along normal faults which have brecciated the pre-Cambrian igneous rocks and provided planes of easy access for thermal solutions carrying barite. The most northerly occurrence of barite, on the Martin property, is probably along an overthrust in the Lower Cambrian rocks.

Origin.—Barite in this district occurs almost wholly in pre-Cambrian granitic rocks in which there is no local source for the mineral. It is associated with hydrothermal minerals and in the southeastern belt, is adjacent to veins of magnetite and spessartite. The writers believe that barite in this district is of magmatic origin. In this conclusion they agree with Edmundson,[107] who first emphasized this origin for the barite of this region.

LEAD AND ZINC

The lead and zinc deposits of the district have been fully described

[106]Currier, L. W., Zinc and Lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, pp. 78-79, 1935.
[107]Idem., pp. 16-24, 1938.

by Currier.[108] Mining is now restricted to operations by the Bertha Mineral Company at Austinville in Wythe County. Zinc and Lead were formerly also mined by a subsidiary of the New Jersey Zinc Company at Ivanhoe and at Bertha, in the same county. Mining of lead began about 1750, but it was 1838 before lead and zinc ores were mined in quantity.

The ore occurs as sulphides in fracture zones along the Gleaves Knob overthrust and in parallel shear planes at their junction with cross fractures. Secondary rich carbonate ores overlie the sulphides.

AGE AND SOURCE OF VARIOUS ORE DEPOSITS

The Gossan Lead and other ore-bearing veins, described above, as well as the quartz veins in the Gossan Lead district south of Iron Mountain, occur in pre-Cambrian rocks, including rocks of the injection complex, the Lynchburg gneiss and associated hornblende gneiss. In large part the veins follow the foliation of these rocks and occur also along faults and related shear zones; hence the processes of mineral deposition were influenced by the structural control. That the veins were later than the deformation, is evident, from the lack of shearing in them and from the presence of unfilled cavities, which are lined with mineral crystals, a common feature of the Gossan Lead vein. The deposition of ore in the pre-Cambrian rocks therefore occurred just after or during the closing stages of late Paleozoic orogenic movements. The barite in Iron Mountain and the ore deposits in the Lower Cambrian rocks of the Austinville area in the Great Valley occur also along faults of late Paleozoic age. They also are of late Paleozoic or post-Paleozoic age.

Sulphides and other ore solutions of hypogene origin commonly are related to an intrusive body of granite magma. Undeformed granite at Mount Airy and Stone Mountain, North Carolina, has intruded the Lynchburg gneiss in the area just south of the Gossan Lead district and muscovite pegmatite has intruded the gneiss at Rutherford Mill in the district. The exact age of these intrusions is not known. Near Spruce Pine, North Carolina similar granite and pegmatite have intruded the Lynchburg gneiss at the close of the folding of the gneiss. The age of the granite near Spruce Pine has been determined as Ordovician. If the muscovite pegmatite and granite in the south edge of the district and in the adjoining part of North Carolina also are of Ordovician age,

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[108]Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, 122 pp., 1935.

the ore-bearing solutions of the district are not genetically related to these granites.

Because of their high volatile content, ore-bearing solutions may have moved far from their source. In the case of the ore veins in the Gossan Lead district, the source may be granite bodies to the east in the Piedmont region.

LIMONITE AND MANGANESE OXIDES

LIMONITE

General description and distribution.—Limonite is a term used to include hydrous iron oxides of various compositions. The limonite deposits associated with the Gossan Lead sulphide ores has been described under the heading "Gossan Lead." Deposits of limonite also are found in residual clays derived from the weathering of various rocks, particularly the dolomite at the foot of the steep northern slope of Iron Mountain.

These deposits were formerly worked at numerous places across the Gossan Lead district, from a point southwest of Speedwell northeastward to Boom Furnace (Pl. 61). The persistence of limonite in the residual clay near the base of the Shady dolomite indicates that these hydrous iron oxides were derived from the solution of disseminated iron-bearing minerals in the rocks at or near this horizon during weathering, and concentrated by deposition in the residual clays. The lowermost beds of the Shady dolomite are exposed at only a few places in the district because of their solubility and the thick mantle of debris from the quartzose rocks of the adjoining mountains. The uppermost beds of the Erwin quartzite, which are exposed in a few places, especially in the vicinity of Little Wythe Furnace, are calcareous quartzites that contain grains of glauconite. Similar glauconitic beds were observed at the top of the Erwin quartzite in the road cut on the divide west of Cold Ridge, on Cove Branch near Eagle (Fig. 41), and on U. S. Route 21 just north of Henley Hollow (Fig. 22). These beds are believed to be the source of the iron and manganese deposits in the foothills along the southeast side of the Great Valley.

Faults facilitated the circulation of ground water and thus aided in the concentration of the mineral deposits, so that many of the larger deposits are located at or near faults. Several old iron mines south and southwest of Speedwell are in residual limestone clays at or close to the Holston Mountain overthrust and the fault to the east of Sindion Point which passes south of the Speedwell syncline. Near that overthrust, on the top of the hill just northeast of Sindion Point and just west of Dry Run, the Shady dolomite is weathered to a dark-red granular clay soil filled with hard nodular masses of limonite. Ferruginous chert and limonite are concentrated at the Holston Mountain fault to the south. Another group of iron pits is located on the low hills east of Francis Mill Creek in an embayment in the mountains south of Little Wythe Furnace. Here the ore is in the dark-red residual clay of the Shady dolomite. The clay over a large area has been dug away, leaving large deep open pits. Fresh dolomite is exposed in high pinnacles in some of the pits (Pl. 48B). A large mine was located on the front of Little Horse Heaven Mountain 1 mile west of Little Wythe furnace. One mine in this group, south of Shiloh Church on Cold Run, is located at the Poplar Camp overthrust.

South and east of Ivanhoe there were several iron mines in the vicinity of the zinc deposits in that area. On Hematite Mountain, northwest of Jackson Ferry on New River, where much iron ore was formerly mined, the ore was in residual clay on nearly horizontal beds of Shady dolomite. The concentration of ore seems to have been due in part to solutions containing iron, derived from the weathering of ferruginous limestones, which circulated along the adjacent fault to the north. Hydraulic methods were used in some of these mines, and pits 100 feet deep were excavated.

Numerous old iron pits along the north foot of Poplar Camp Mountain are in deposits that were concentrated by waters that circulated along the Poplar Camp overthrust, for they lie in clay residual from the various limestones which are adjacent to the fault and not from the base of the Shady. The pit at Sheeptown is large and yielded much ore. Smaller pits were opened south and southwest of Bethany and at Poplar Camp. South and east of Rackettown the large pits, which were dug in the terrace gravels and wash from the mountains, are located along the Poplar Camp fault. Similar large pits northeast of New Castletown School are found along a branch of this fault.

Several large mines in a belt 3 miles long on the south slope of Fosters Falls Mountain were at or near the contact of the Shady dolomite and Erwin quartzite. Some of the ore, reported to have been in the quartzite, was called "mountain ore," and was high in silica and manganese. Analyses showed 17 per cent silica and 4.5 per cent manganese. A few small iron mines, along the north foot of the mountain, were in the Shady dolomite at its contact with the overthrust Erwin quartzite. The iron pits at the west foot of Dry Pond Mountain are associated with the

Poplar Camp overthrust. Those located west of Little Reed Island Creek and around Boom Furnace, in the Great Valley, are in residual clays of flat-lying Shady dolomite.

A large number of iron mines in the limestone area south of Barren Springs, northwest of Patterson, which are not shown on the geologic map (Pl. 1), were listed and described by Holden.[109] He states that the mines were operated by the Virginia Iron, Coal, and Coke Company and that much of the ore contained 44 per cent iron while some of the ore as much as 56 per cent.

Iron mining in the district reached its height in the middle of the 19th century, when the ores were smelted in numerous local charcoal furnaces. These furnaces include Little Wythe Furnace, five in the vicinity of Cripple Creek, and others at Speedwell, Ivanhoe, Poplar Camp, Fosters Falls, Boom, and Max Meadows.[110] Readily available iron ore in the Gossan Lead district has been largely mined out.

MANGANESE OXIDES

General description and distribution.—Deposits of manganese oxides, which include several secondary manganese minerals, occur in the Great Valley at the west foot of the Blue Ridge, at or near the contact of the Shady dolomite and Erwin quartzite.[111] Such deposits were prospected in the Gossan Lead district in the vicinity of Cattron, 4 miles west of Ivanhoe, but none was found to be of commercial value. The ore from the iron mines south of Cripple Creek and around Speedwell contained some manganese.

The secondary manganese minerals in the Great Valley were derived from disseminated manganese-bearing minerals in the adjacent sedimentary rocks.[112]

The uppermost beds of the Erwin quartzite, which are exposed; in the vicinity of Little Wythe Furnace; in the cut on the Ivanhoe-Galax road west of Cold Ridge; on Cove Branch near Eagle, on the Norfolk & Western Railway half a mile southwest of High Rocks Mill; and on U. S.

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[109]Holden, R. J. Iron, *in* Watson, T. L., Mineral resources of Virginia: Virginia—Jamestown Exposition Commission, Lynchburg, Va., J. P. Bell Co., pp. 451-454, 1907.

[110]Holden, R. J., idem. p. 479. Bruce, Kathleen, Virginia iron manufacture in the slave era: 482 pp., New York, The Century Co., 1931.

[111]Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, pp. 130-139, 1919.

[112]Stose, G. W., Source beds of manganese ore in the Appalachian Valley; Econ. Geology, vol. 37, no. 3, pp. 163-172, 1942.

Route 21, north of Henley Hollow, contain glauconite and phosphate grains. These beds may represent the zone that contains manganese-bearing minerals, for the rocks therein, on weathering, become stained by hydrous oxides of manganese and iron.

SOAPSTONE

General description and distribution.—Soapstone is found in lenses and irregular bodies in the ultramafic igneous rocks associated with the Lynchburg gneiss. These bodies have been quarried on a small scale at several places. Burfoot[113] mentions the occurrence of soapstone in Carroll and Grayson counties. In his description of commercial grades of soapstone, he says that the best grade is steatite, a massive, firm rock with a greenish to bluish color, composed of fine-grained talc flakes. Rock of this grade may contain a small amount of chlorite and scattered grains of magnetite. An increase of these and other minerals impairs the quality of the rock. Soft stone contains a large amount of talc; tough stone contains a large proportion of serpentine, with talc, chlorite, and amphibole.

Soapstone was mined in 1900 near Piney Creek on the Floyd Cox farm, 2 miles southwest of Blue Ridge Mill (Pl. 61). It was reported that a body of pure white soapstone (steatite), 10 feet long, was found in an opening 36 feet deep and 15 feet long. The pit is now filled and the relations of this steatite to the relatively impure soapstone could not be seen. Another opening in soapstone is on the G. W. Sheets property, just east of old State Highway 89 and 1½ miles north of Tolivers School. This area lies one-eight mile north of the main serpentine area of The Glades, and is separated from it by a narrow band of Lynchburg gneiss. The pit was opened for stone for use in fireplaces. Along the same strike to the southwest, on the west side of the highway, there is a small opening in impure soapstone on the Clive Woods farm. The rock strikes S. 40° W., with cleavage that dips 45° SE. It extends southwestward across Glady Creek into the main area of The Glades. The soapstone is pale-greenish gray, saws readily, and breaks into slabs along the schistosity. Much of the rock exposed, however, is pitted and the holes are filled with limonite. Soapstone occurs at many places in The Glades between Blue Ridge Mill and Hanks Knob, but has not been quarried in that area. The rock that crops out at the surface in this area contains many

[113]Burfoot, J. D., Jr., The origin of the talc and soapstone deposits of Virginia: Econ. Geology, Vol. 25, pp. 807-809, (Fig. 1), 1930.

impurities. Soapstone has been prospected on the E. H. Burnette farm west of Jerico, northwest of Woodlawn. The deposit there is narrow and of very limited extent.

A small amount of soapstone has been quarried also on the L. C. White property, 2 miles southeast of Sylvatus, just east of the Gossan Lead district. It is a fine-grained, green, chlorite-tremolite schist and is soft enough to be sawed into slabs.

LIMESTONE

General description and distribution.—In this district limestone is used chiefly as a soil conditioner. Most of the limestone in this district occurs north of the mountains in the southeastern part of the Great Valley. Small areas of limestone within the Blue Ridge Plateau are of value because of the great need of lime for the local soils.

In the part of the Great Valley included in the district, limestone and dolomite, in the Shady dolomite, were quarried at many places for local use on soils and as building stone, and formerly were extensively quarried at Little Wythe Furnace, Wythe County, for use as flux in the old iron furnace. Pure limestone in the Kinzers formation was formerly quarried south of Ivanhoe for use in the National Carbide Company plant, but limestone for this purpose is now obtained from a larger quarry northeast of Ivanhoe. A quarry for rough building stone from the Patterson member of the Shady dolomite was formerly operated in Buckeye Hollow, northeast of Patterson.

Beds of limestone in the crystalline rocks of the mountains have not been extensively quarried. Some limestone was obtained on the Blevin farm, 1½ miles southeast of Dalhart and burned for field lime. The limestone in this belt is impure and contains much mica and quartz, but would be suitable for local use in soils in the form of ground limestone or as burned lime. One reason why this limestone is not used now is that finely crushed dolomite is a byproduct of the lead and zinc industry and is collected in vast silt ponds in the vicinity of the plant (Pl. 59A).

BUILDING STONE

The Lynchburg gneiss is quarried for crushed stone and foundation blocks in the City quarry, half a mile south of Galax east of State Highway 89. During the construction of the Blue Ridge Parkway, a quarry was opened on the south side of Banks Branch, and the stone was used for culverts, bridges, and walls along the Parkway. The extensive use of local stone in Parkway construction in this district and elsewhere has added greatly to the beauty and interest of the Parkway.

The Point Lookout granite has been quarried on U. S. Route 58, half a mile north of Baxter Ferry, north of the same highway 3 miles west of Independence, at The Mole, 2 miles north of Independence, and east of Summerfield School. The rock was used for foundations and for crushed stone in highway construction.

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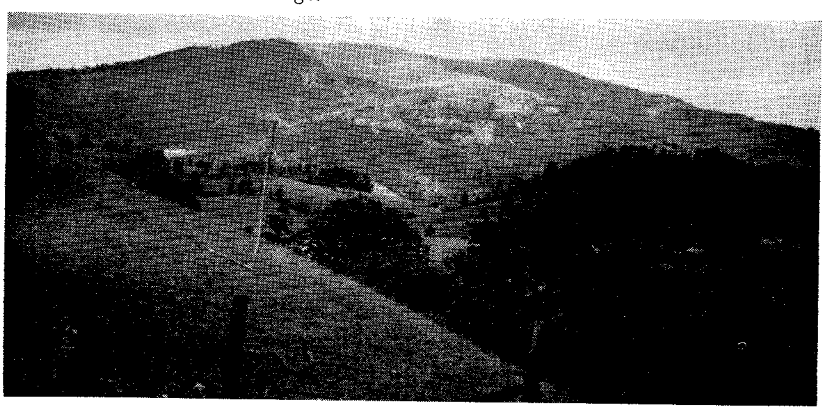
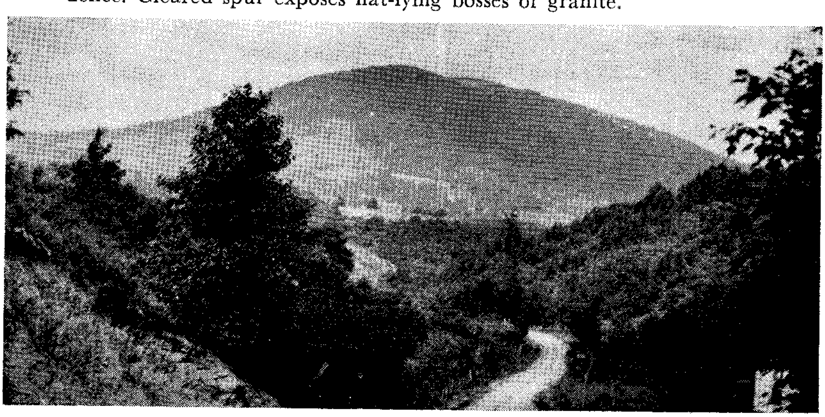


2B. Point Lookout Mountain viewed from U. S. Route 58, west of Independence. Cleared spur exposes flat-lying bosses of granite.



2C. View of Whitetop from the west. Seen from Taylor Valley road east of McQueen Gap, Mount Rogers quadrangle.

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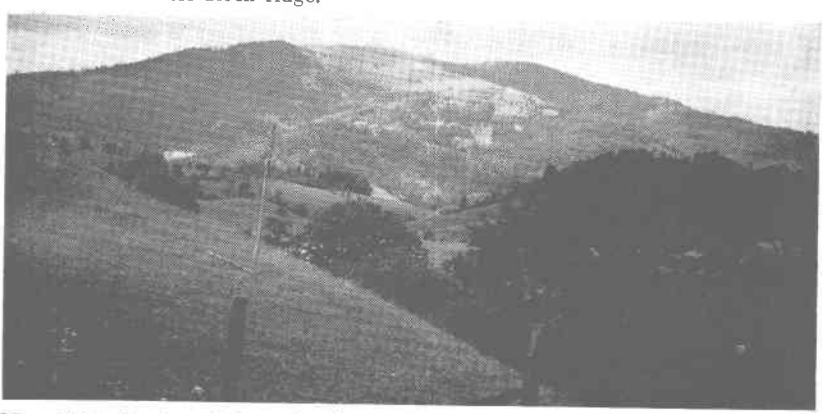

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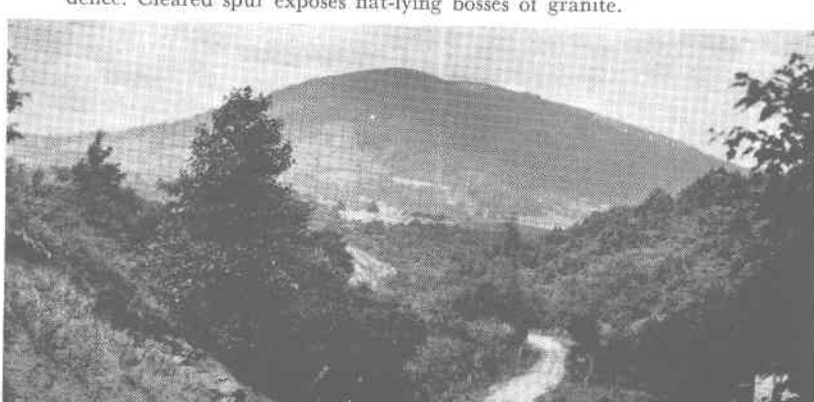

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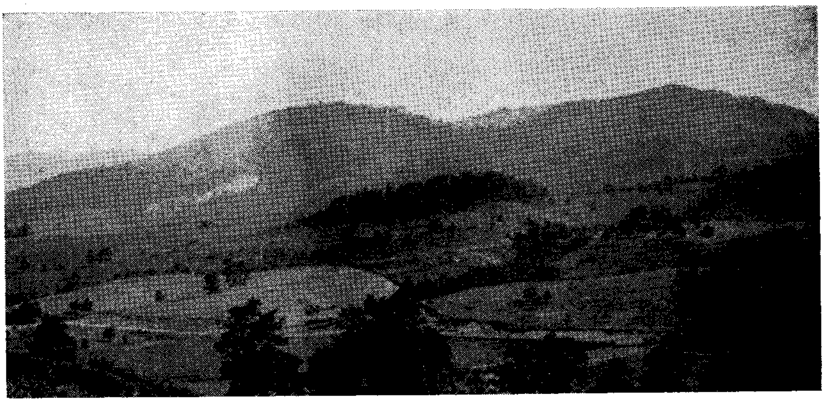
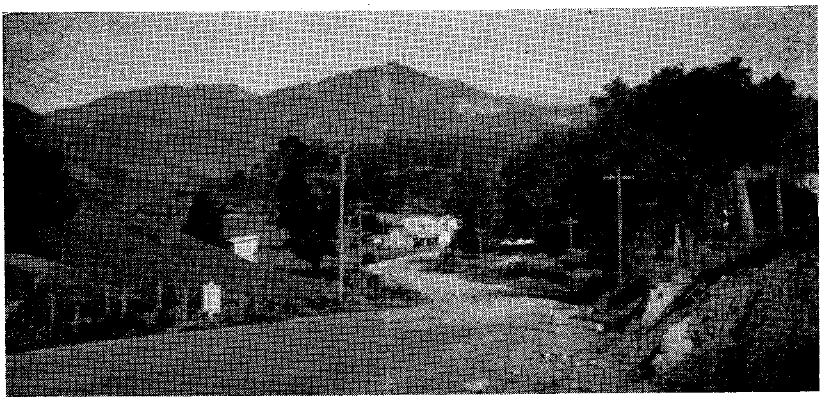
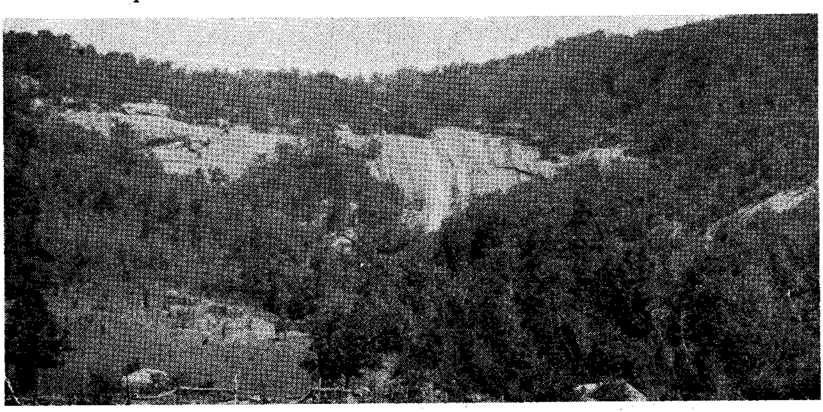


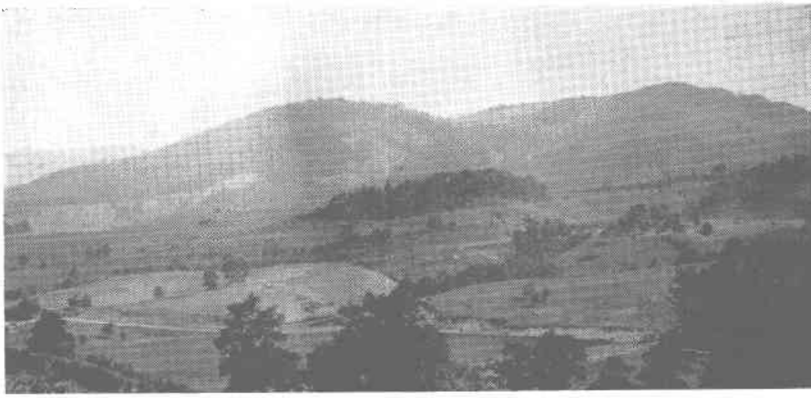
3A. View of Buck Mountain from the south. Seen from a point north of Osborne School.



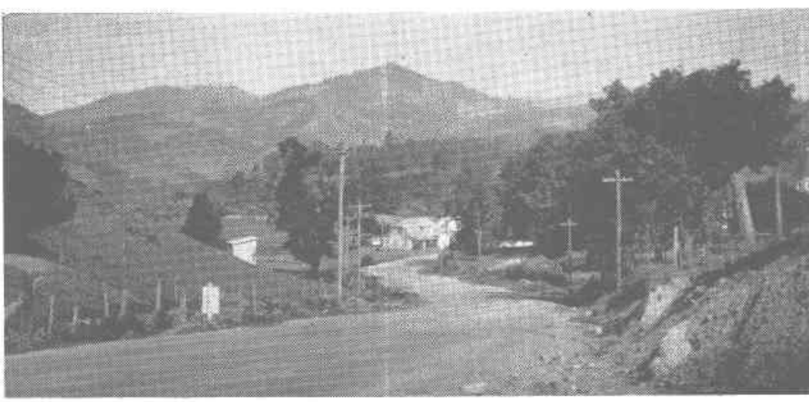
3B. Buck Mountain viewed from the southeast. Seen from U. S. Route 21, north of Independence.



3C. Striped Rock on the southwest slope of Point Lookout Mountain. Rounded granite cliffs, streaked with limonite by running water.



3A. View of Buck Mountain from the south. Seen from a point north of Osborne School.



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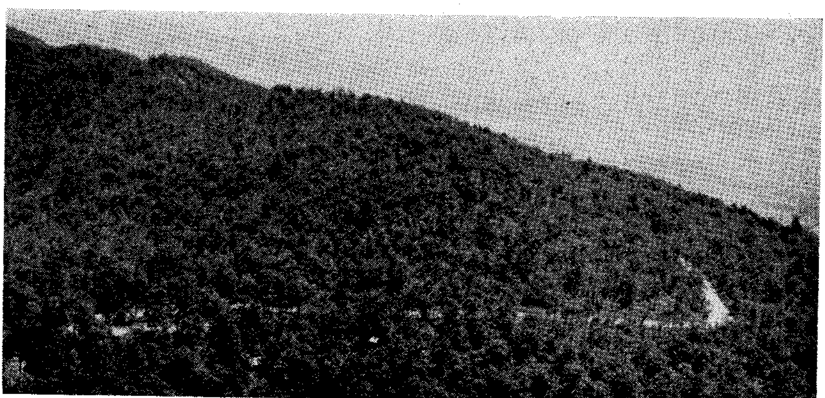
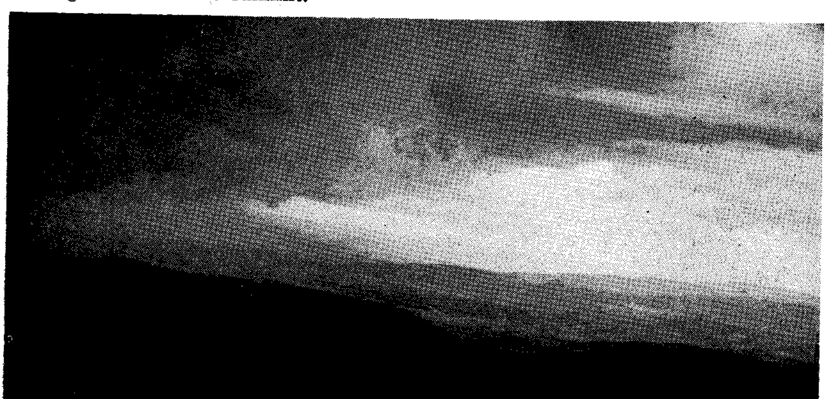
3C. Striped Rock on the southwest slope of Point Lookout Mountain. Rounded granite cliffs, streaked with limonite by running water.

4A. Comers Rock peak seen from the west. Viewed from the Blue Spring Gap road.



4B. Near view of densely wooded top of Iron Mountain, a part of Jefferson National Forest. Looking east from Comers Rock Lookout. Road in foreground leads to summit.

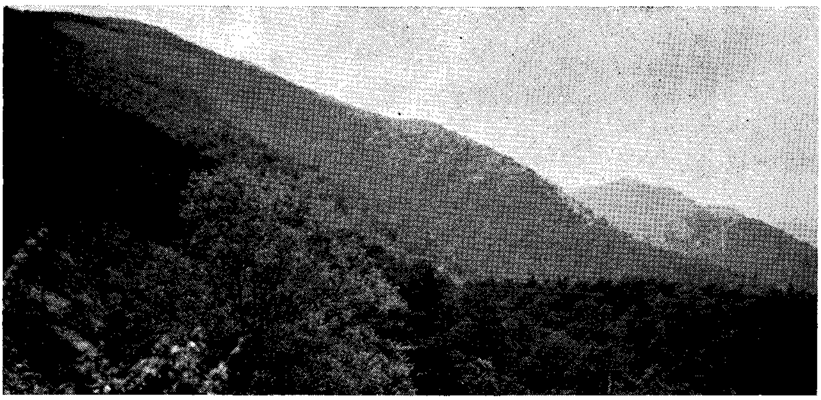


4C. Thunder storm over Iron Mountain. Seen from Comers Rock Lookout. Looking northwest.

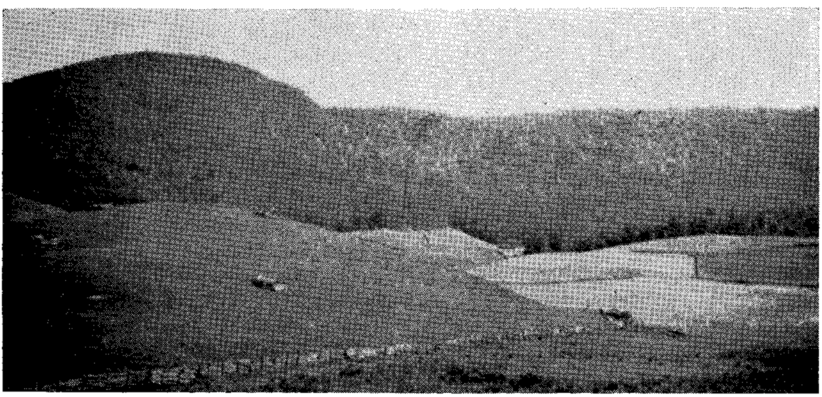
4A. Comers Rock peak seen from the west. Viewed from the Blue Spring Gap road.

4B. Near view of densely wooded top of Iron Mountain, a part of Jefferson National Forest. Looking east from Comers Rock Lookout. Road in foreground leads to summit.

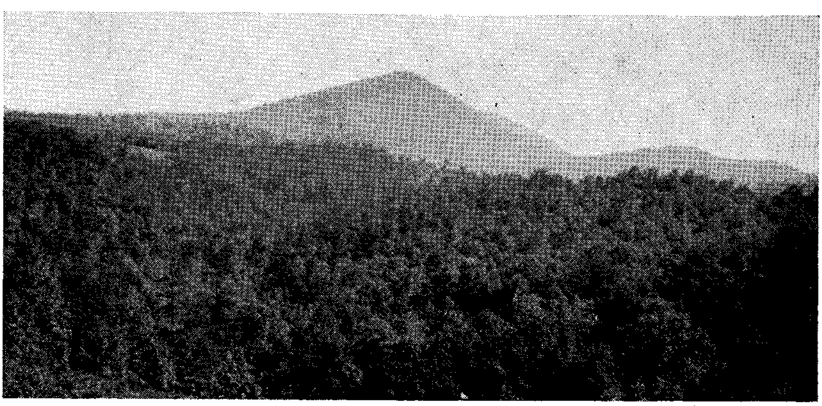
4C. Thunder storm over Iron Mountain. Seen from Comers Rock Lookout. Looking northwest.



5A. The north escarpment of Iron Mountain. View looking west from road over Blue Spring Gap to Camp.



5B. South-facing escarpment of Iron Mountain, culminating in High Knob. Seen from the south.



5C. Farmer Mountain in the Unaka National Forest viewed from the west. Seen from a point north of Brush Creek.

5A. The north escarpment of Iron Mountain. View looking west from road over Blue Spring Gap to Camp.

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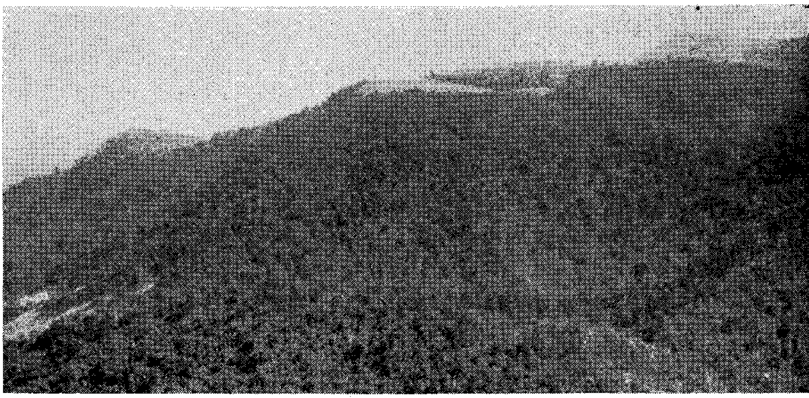
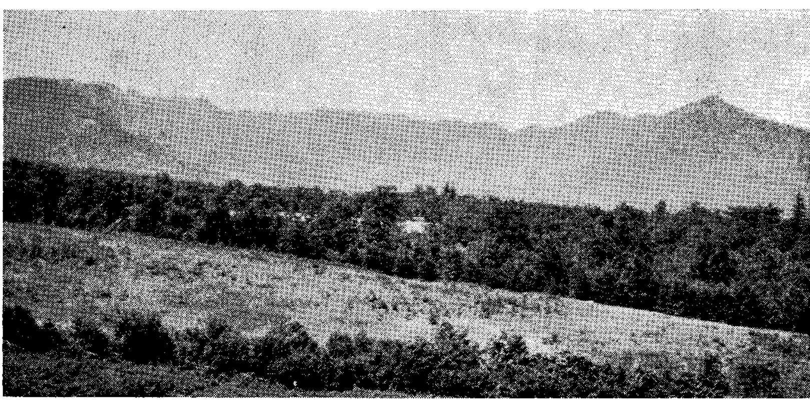
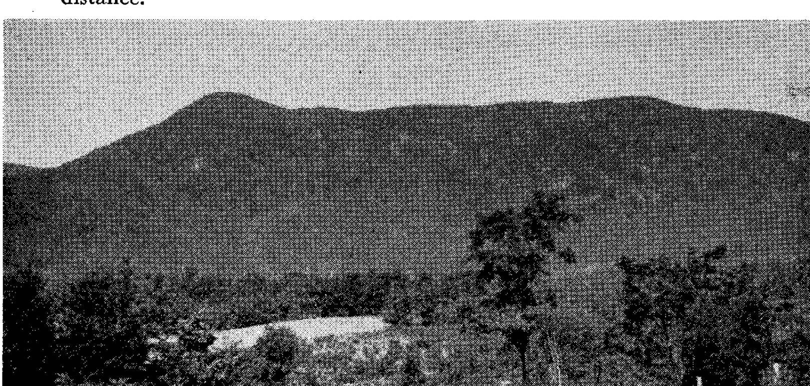


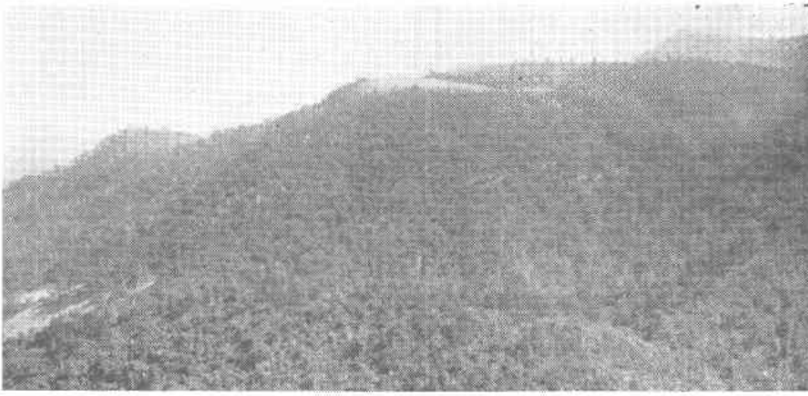
6A. Blue Ridge escarpment. Looking southwest from State Highway 89, south of Low Gap. Saddle Mountain, North Carolina, in right distance.



6B. Blue Ridge escarpment seen from the south. Looking northeast from a point southwest of Lambsburg on the Piedmont lowland. Sugar Loaf peak in right distance.



6C. Fisher Peak on the Appalachian trail. Viewed from the Piedmont lowland. Looking west from a point 2 miles west of Lambsburg.



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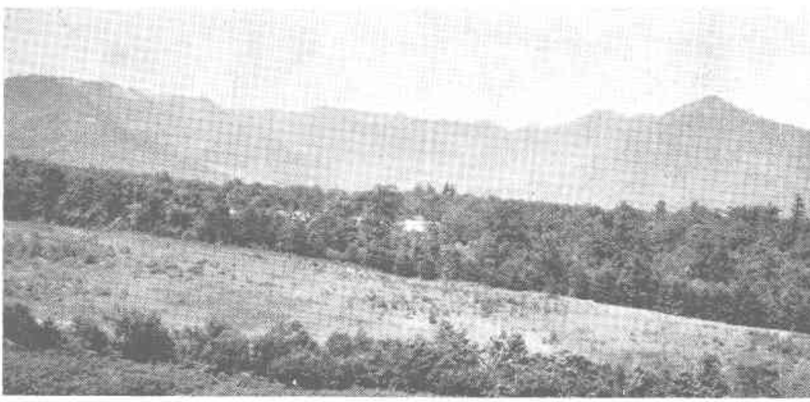

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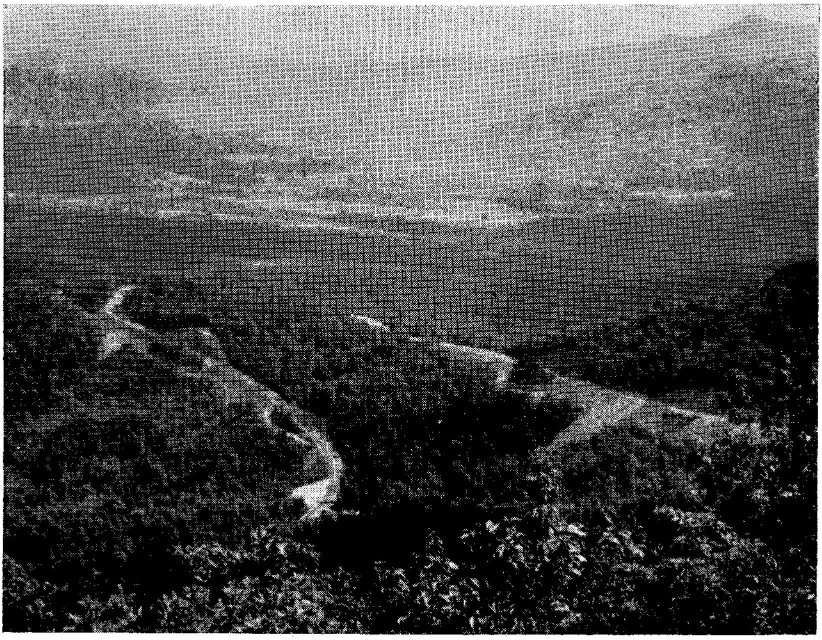
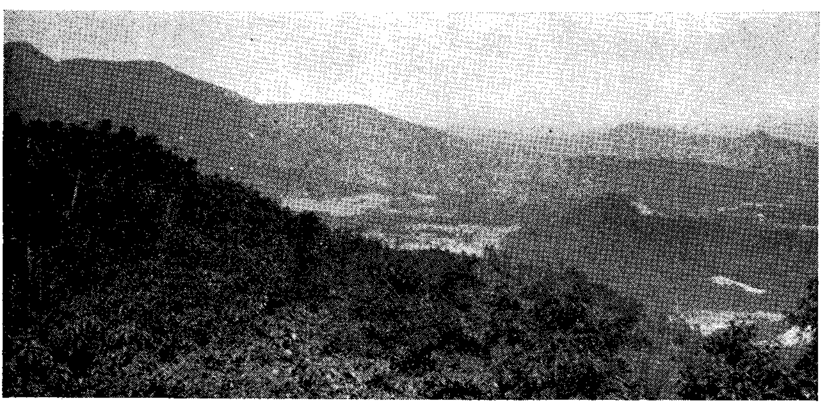


7A. View over Piedmont lowland from Norvale Crags on crest of Blue Ridge escarpment. Shows State Highway 89, descending the escarpment.



7B. Knobs and low ridges in the Piedmont lowland. Looking east from the Blue Ridge Parkway west of Low Gap. South spur of Fishers Peak in left distance.

7A. View over Piedmont lowland from Norvale Crags on crest of Blue Ridge escarpment. Shows State Highway 89, descending the escarpment.

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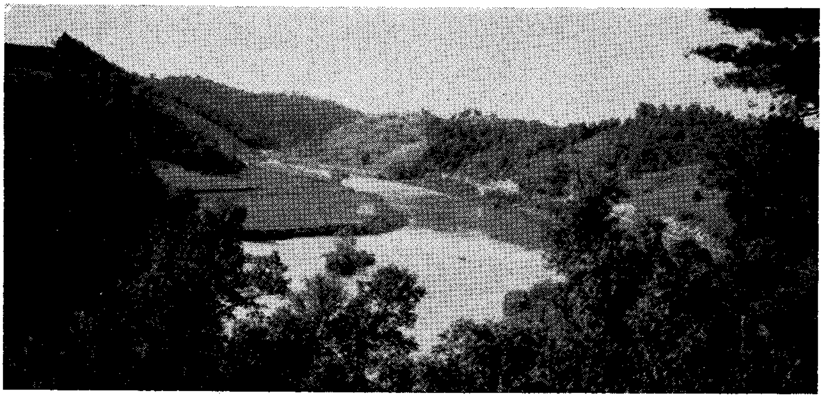
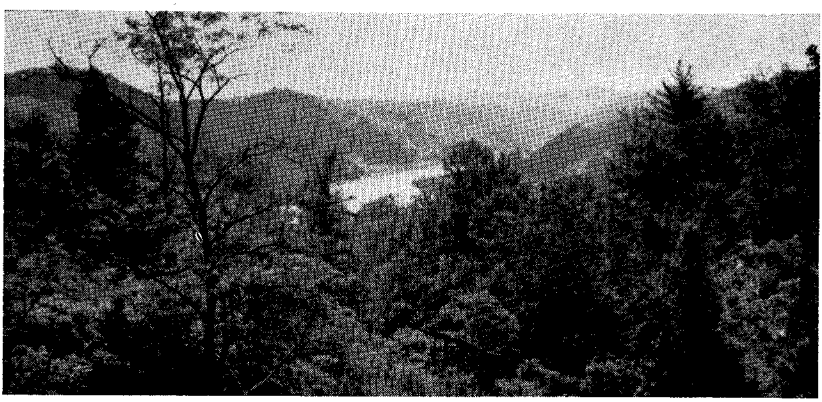
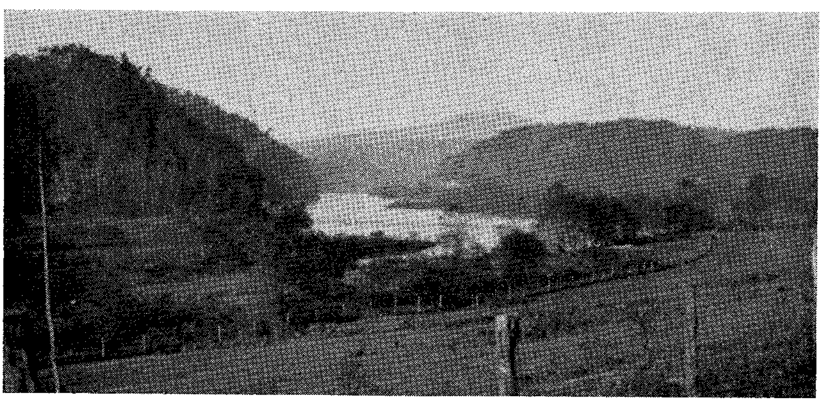


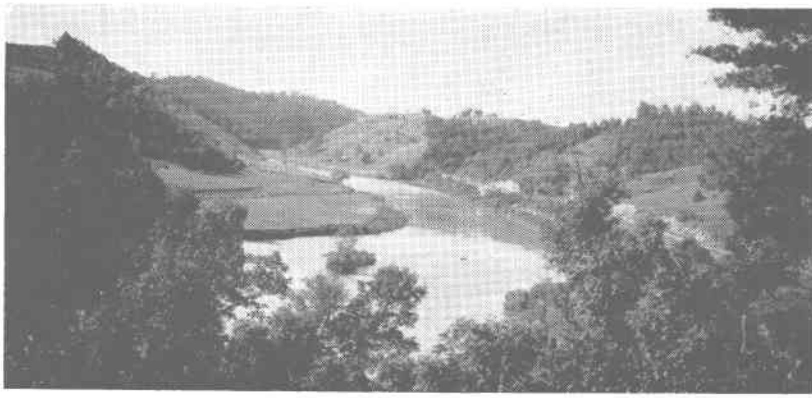
8A. High terraces bordering New River. Looking upstream from near Baxters Ferry.



8B. High terraces bordering New River. Viewed from near Johns Creek School.



8C. New River near Riverside. Looking upstream. Point Lookout Mountain in center distance.



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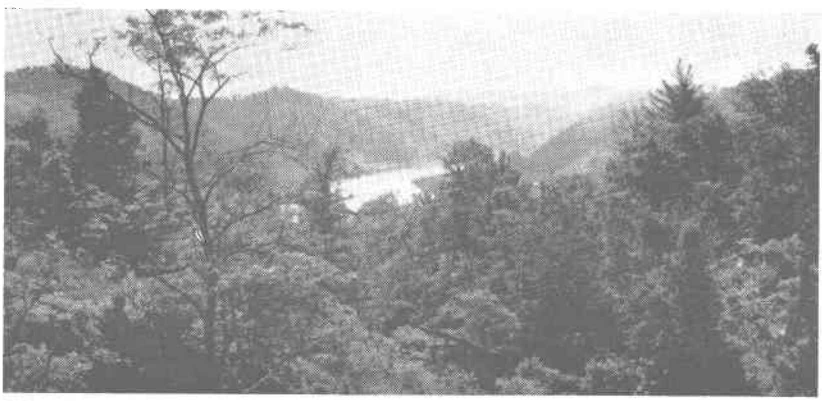

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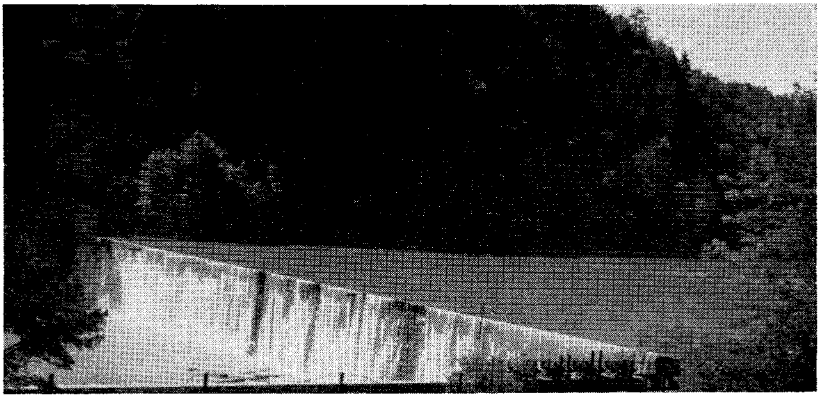
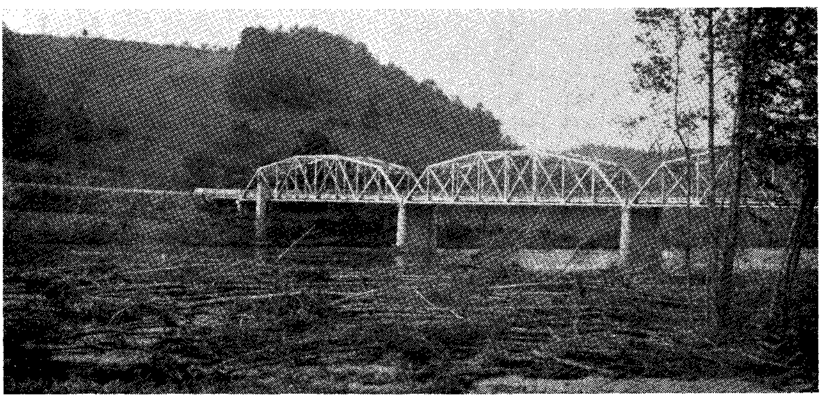
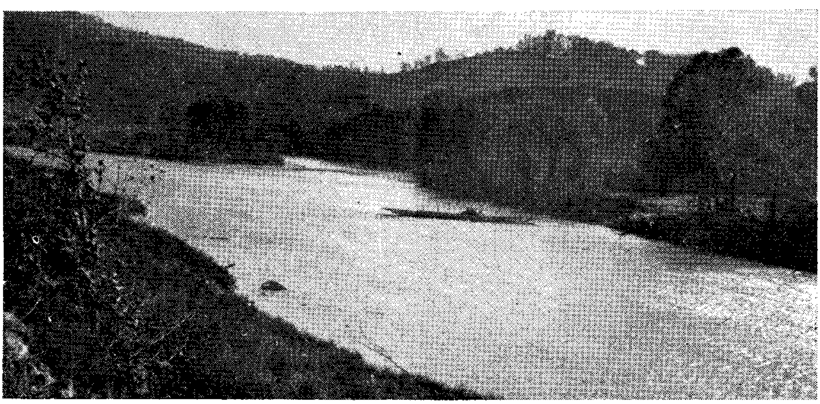


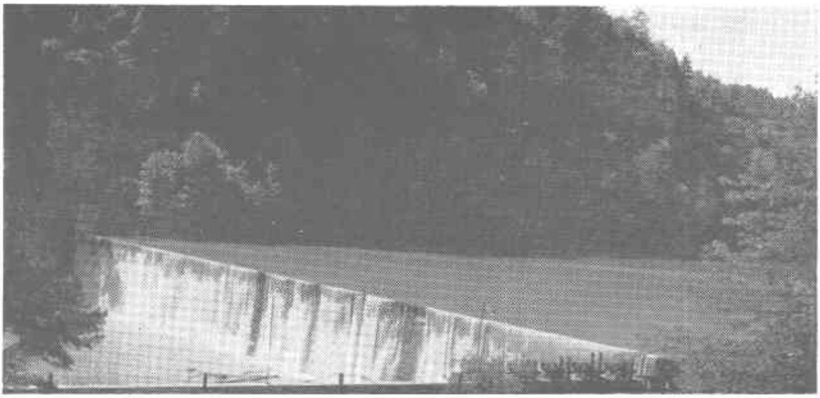
9A. Power dam of Washington Mills Textile Plant on New River at Fries. Cliff of granite mylonite east of river.



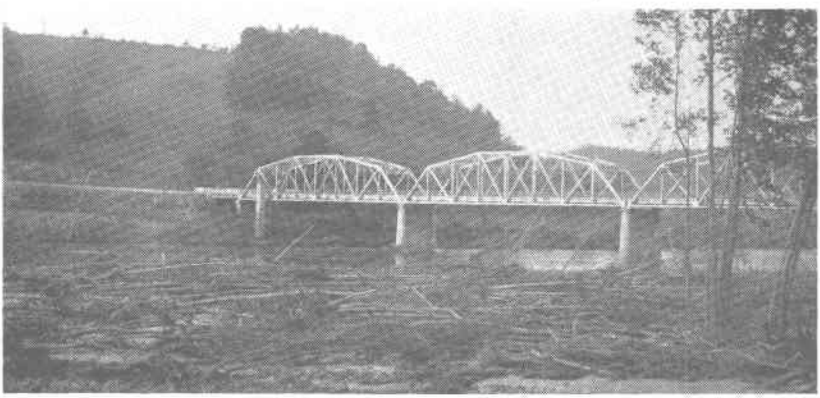
9B. Bridge over New River on U. S. Route 58, west of Galax. Trees felled by flood of August 1940, in foreground.



9C. Ferry boat at Baxters Ferry on New River.



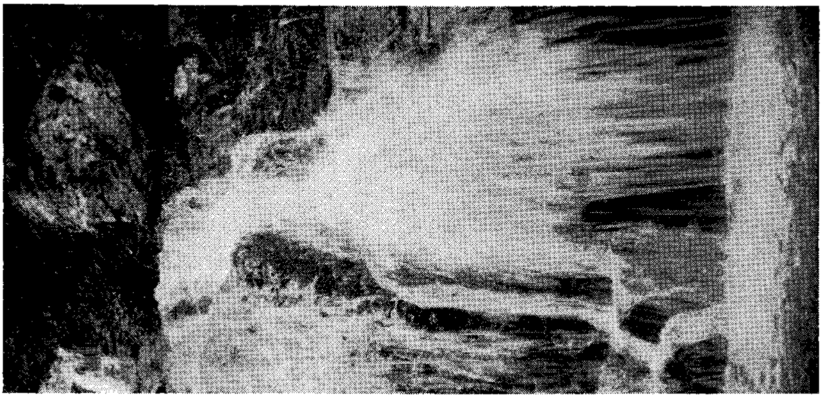
9A. Power dam of Washington Mills Textile Plant on New River at Fries. Cliff of granite mylonite east of river.



9B. Bridge over New River on U. S. Route 58, west of Galax. Trees felled by flood of August 1940, in foreground.

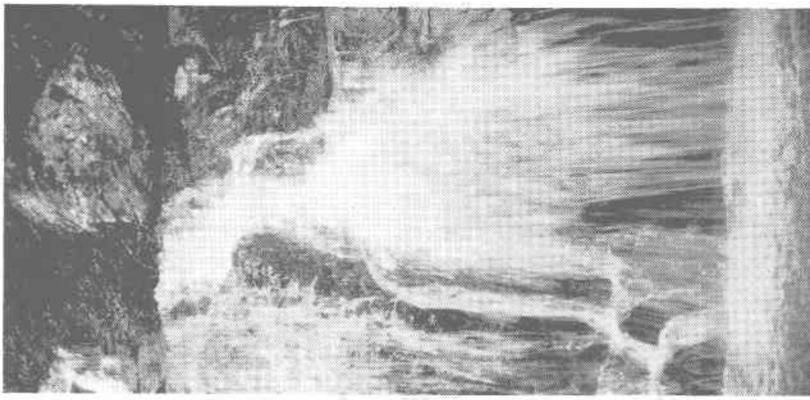
9C. Ferry boat at Baxters Ferry on New River.

10A. Pot holes in vertical wall of gorge of Elk Creek at Clito Mill. Upper pot hole still contains stream pebbles.

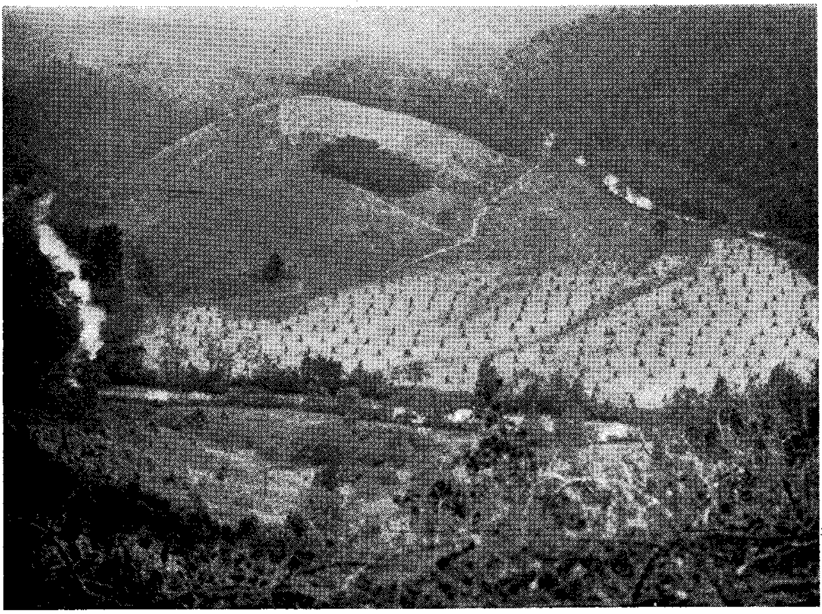


10B. Falls of Jumping Creek, 2 miles south of Elk Creek village just beside U. S. Route 21.

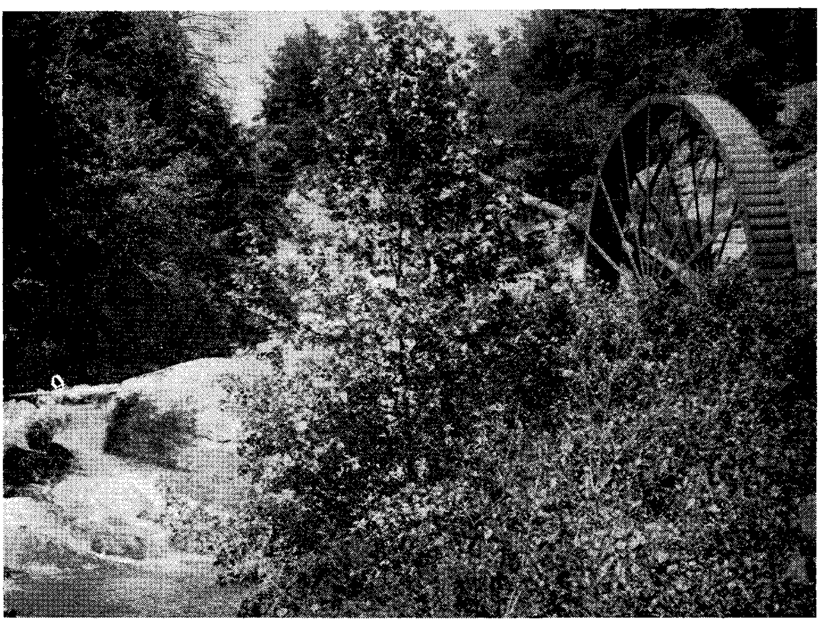
10A. Pot holes in vertical wall of gorge of Elk Creek at Clito Mill. Upper pot hole still contains stream pebbles.



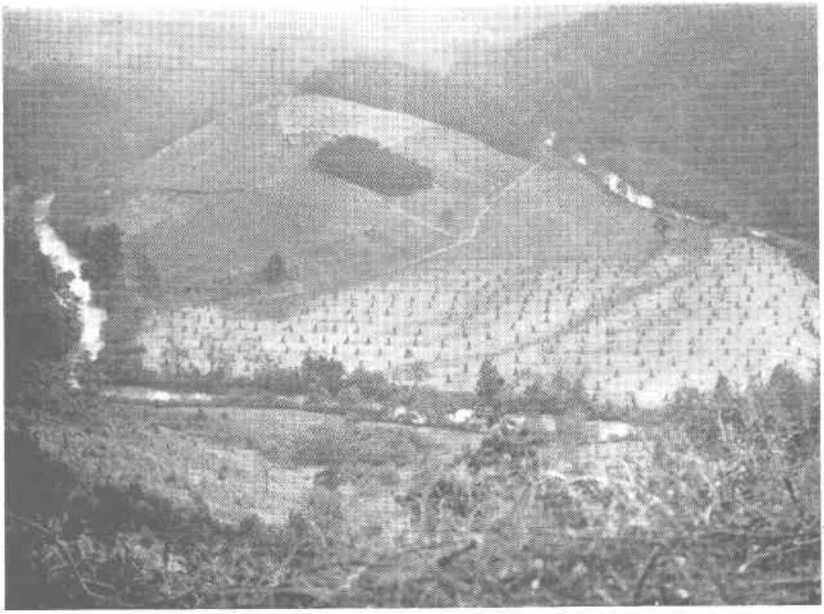
10B. Falls of Jumping Creek, 2 miles south of Elk Creek village just beside U. S. Route 21.



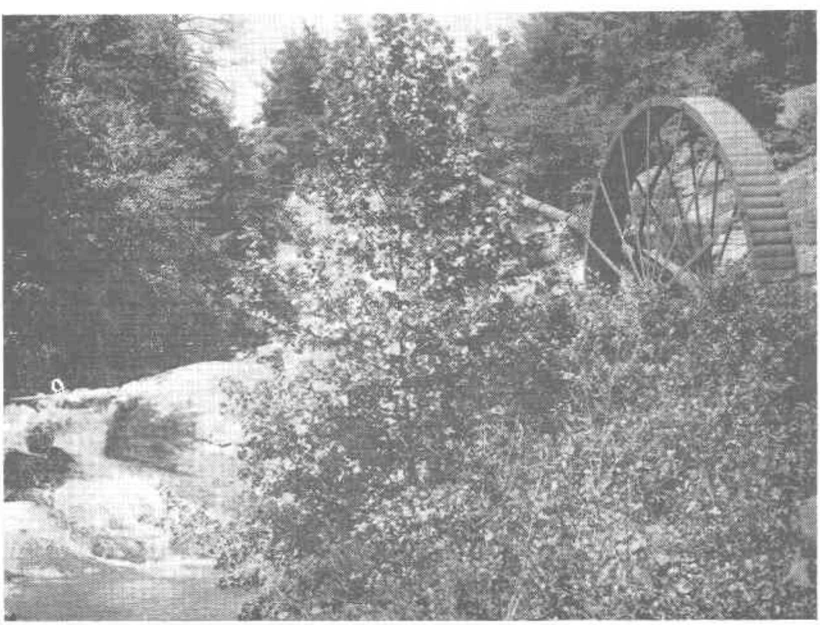
11A. Incised oxbow of Little Reed Island Creek, northwest of Sylvatus.



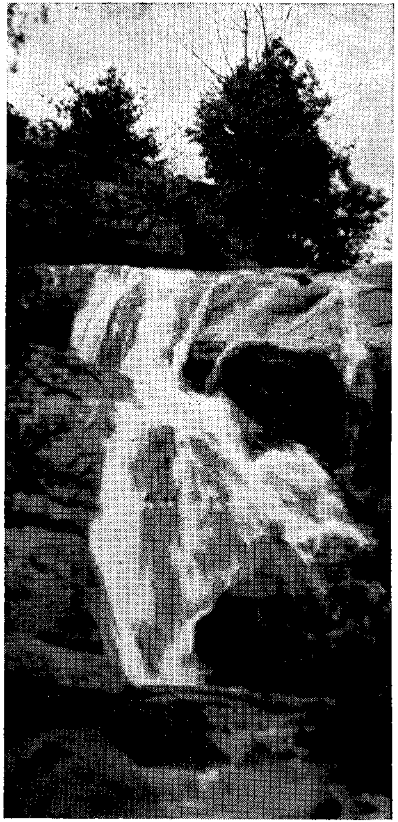
11B. Abandoned water wheel at falls of Peach Bottom Creek, 1 mile northeast of Independence.



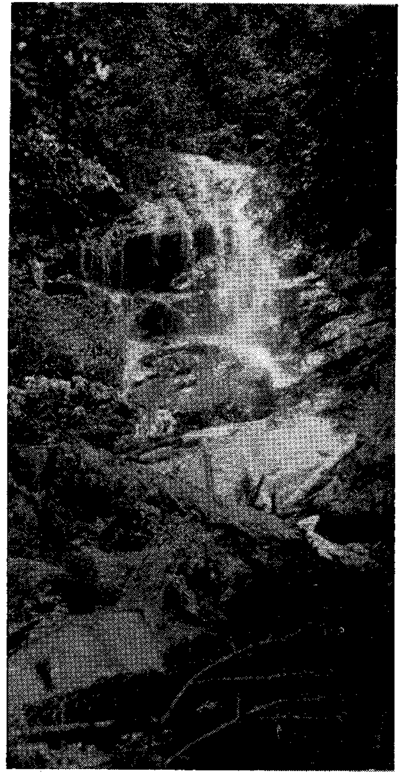
11A. Incised oxbow of Little Reed Island Creek, northwest of Sylvatus.



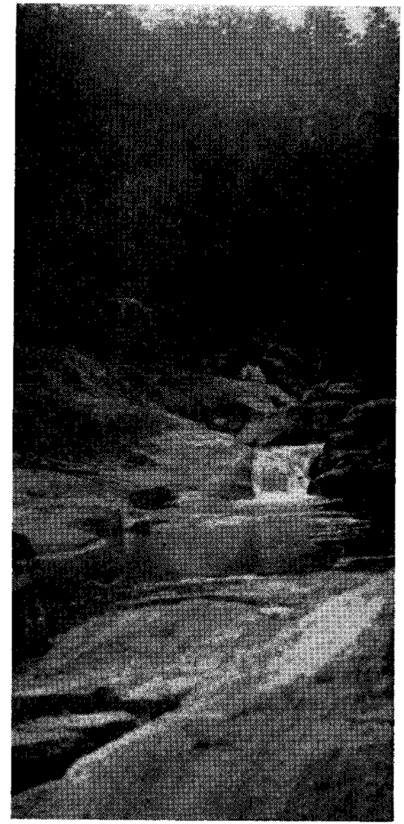
11B. Abandoned water wheel at falls of Peach Bottom Creek, 1 mile northeast of Independence.



12A. Falls of South Branch of Elk Creek near Lundy School, just west of the district. Falls are over Comers granite gneiss.

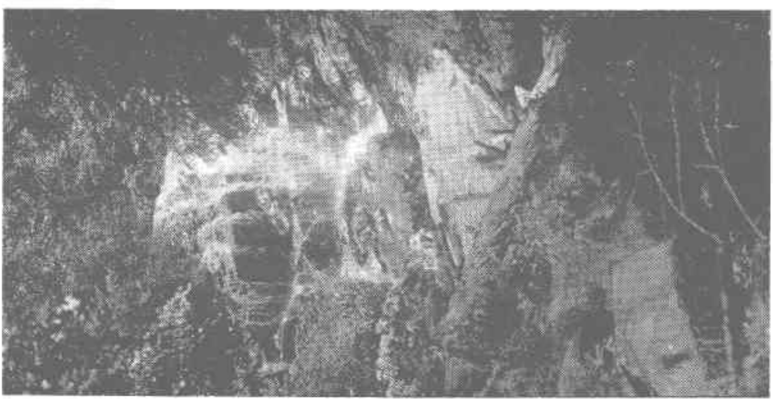


12B. Falls on Falls Branch of Knob Fork, north of Fallville. Falls are over upper quartzite beds of Unicoi formation.

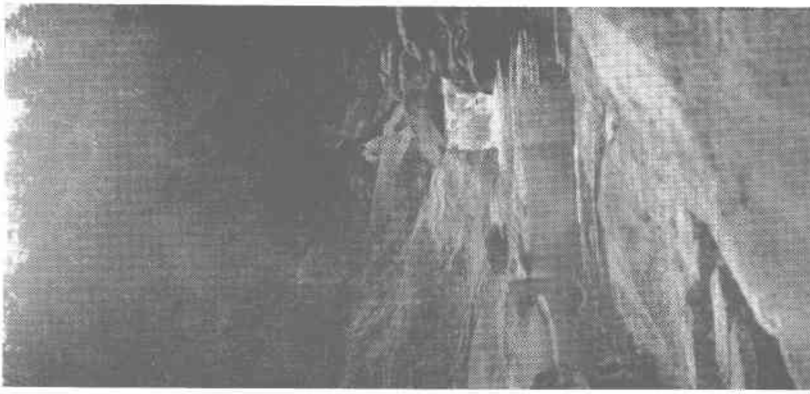


12C. Rocky gorge and falls of Elk Creek at Clito Mill. Gorge is cut in Grayson granodiorite gneiss.

12A. Falls of South Branch of Elk Creek near Lundy School, just west of the district. Falls are over Comers granite gneiss.



12B. Falls on Falls Branch of Knob Fork, north of Fallville. Falls are over upper quartzite beds of Unicoi formation.



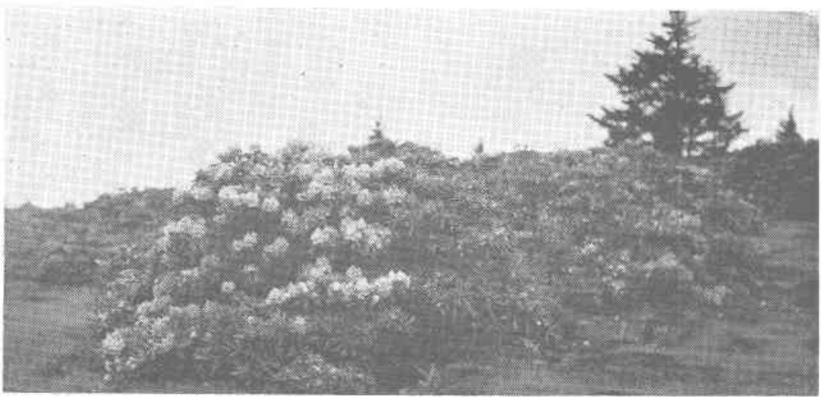
12C. Rocky gorge and falls of Elk Creek at Clito Mill. Gorge is cut in Grayson granodiorite gneiss.

13A. Galax in bloom and ferns, in the Blue Ridge near the Gossan Lead district.

13B. Rhododendron in bloom, in the Blue Ridge near the district.

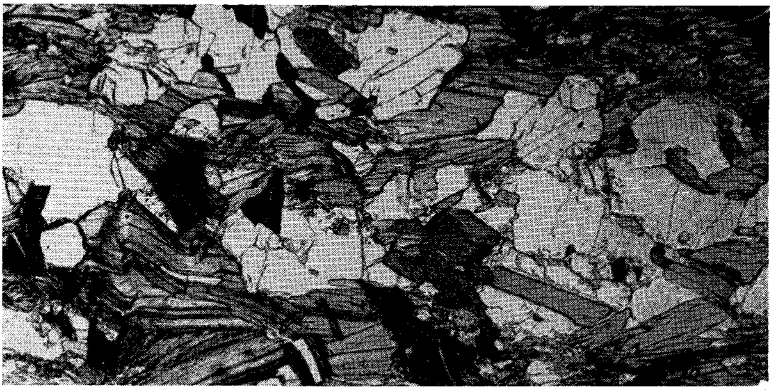
13C. Falls of Poor Branch over basalt flow in Unicoi formation. West of McGee School.

13A. Galax in bloom and ferns, in the Blue Ridge near the Gossan Lead district.

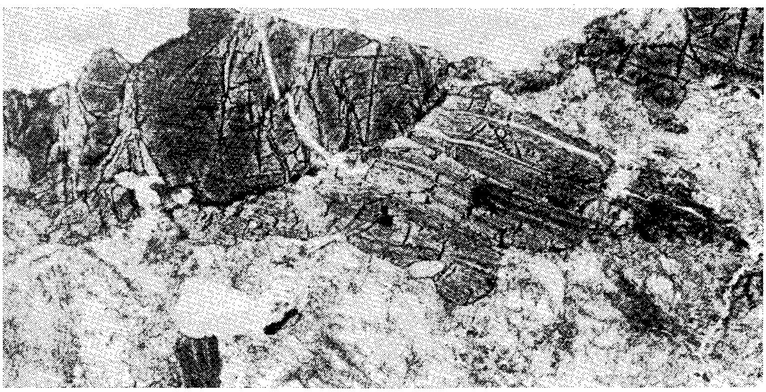


13B. Rhododendron in bloom, in the Blue Ridge near the district.

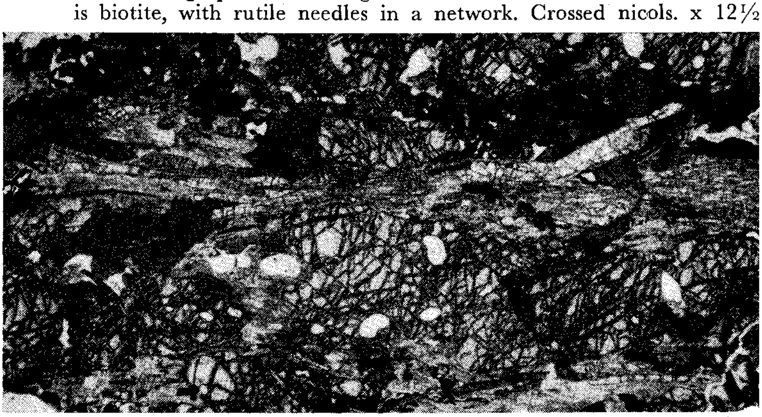
13C. Falls of Poor Branch over basalt flow in Unicoi formation. West of McGee School.



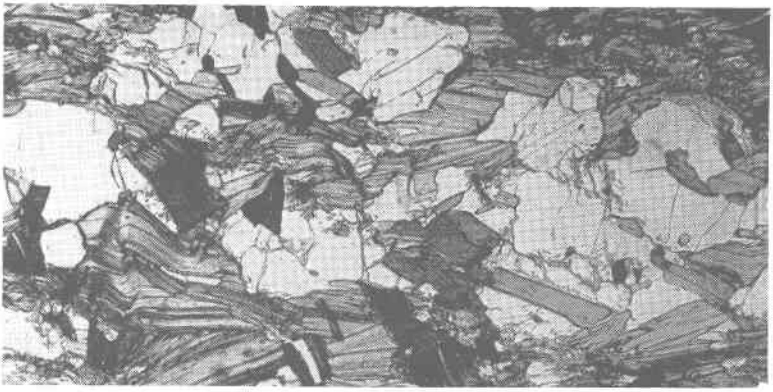
14A. Photomicrograph of Saddle gneiss on Turkey Creek, 3 miles north of Elk Creek village. It contains red-brown biotite blades that are folded. Crossed nicols. x 12½.



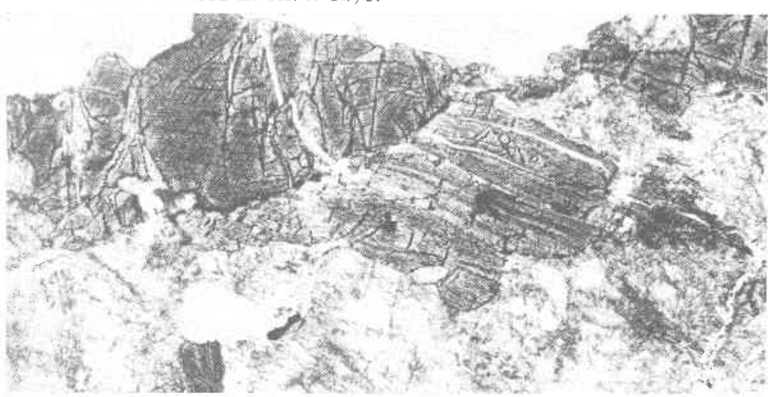
14B. Photomicrograph of Saddle gneiss near Rectors Store. Dark mineral is biotite, with rutile needles in a network. Crossed nicols. x 12½.



14C. Photomicrograph of sillimanite-bearing Saddle gneiss, from 1 mile west of Independence. Sillimanite is in long needles. Garnet shows cracks and quartz inclusions. Biotite is black. One nicol. x 12½.



14A. Photomicrograph of Saddle gneiss on Turkey Creek, 3 miles north of Elk Creek village. It contains red-brown biotite blades that are folded. Crossed nicols. x 12½.



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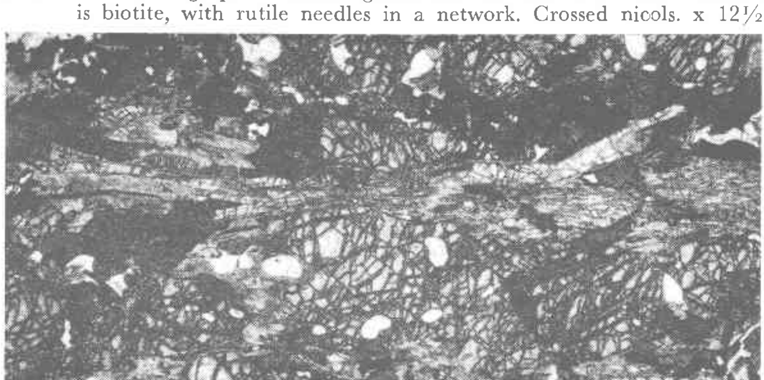

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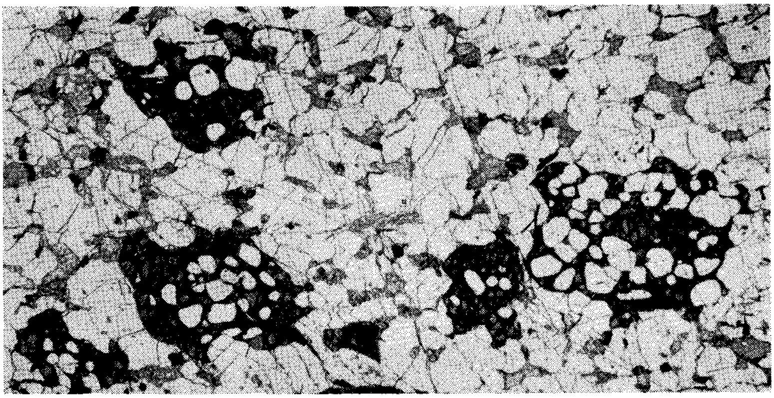
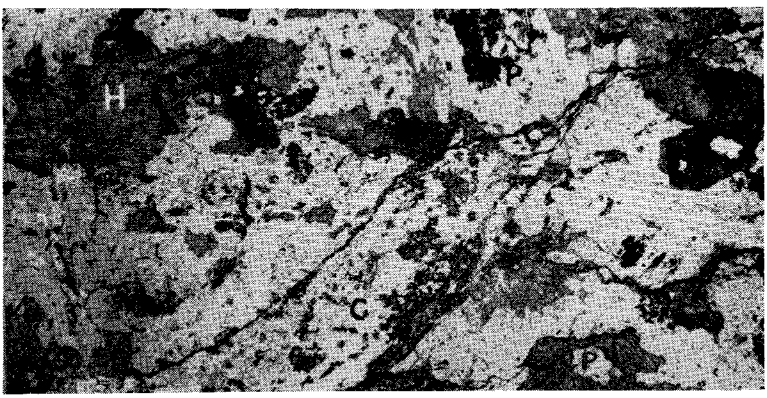
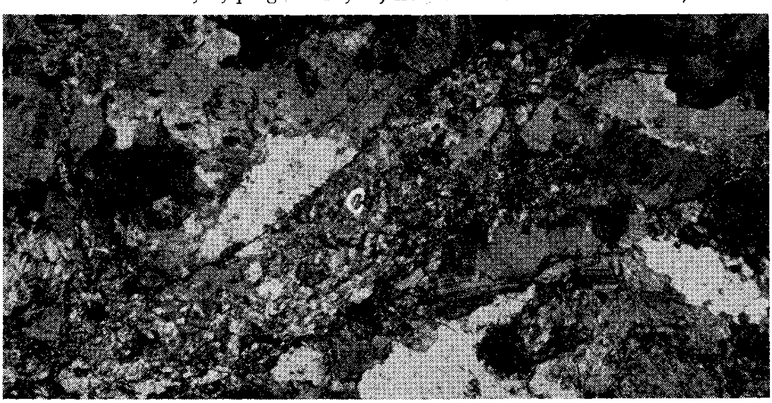


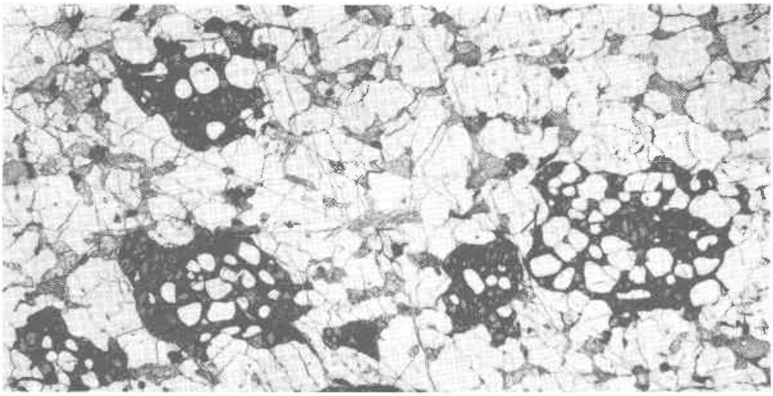
15A. Photomicrograph of quartzite in the Saddle gneiss, from ½ mile east of Eureka School. Composed of quartz (white), feldspar (gray), with skeletal garnets (dark) including quartz (white). One nicol. x 12½.



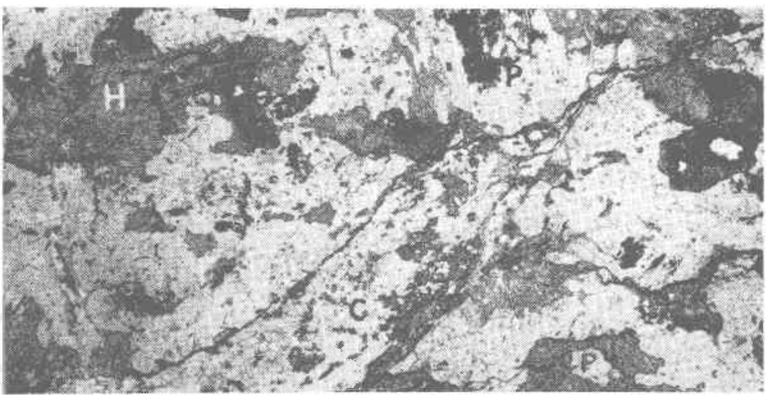
15B. Photomicrograph of Cattron diorite at Big Ridge. C, shear zone crosses rock; P, plagioclase; H, hornblende. One nicol. x 12½.



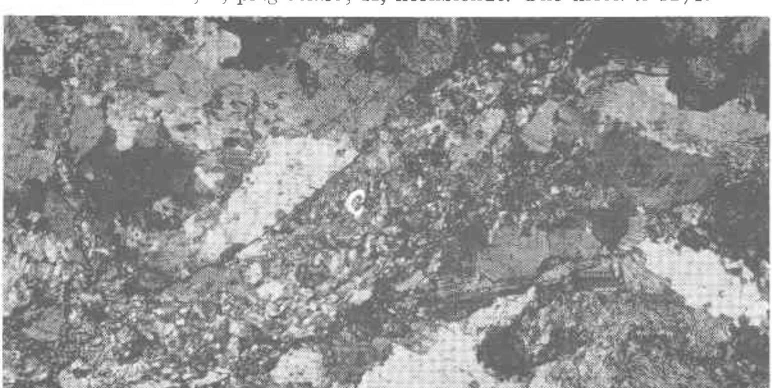
15C. Photomicrograph of same section as 15B with crossed nicols. Cataclasis is shown in shear zone, C. x 12½.



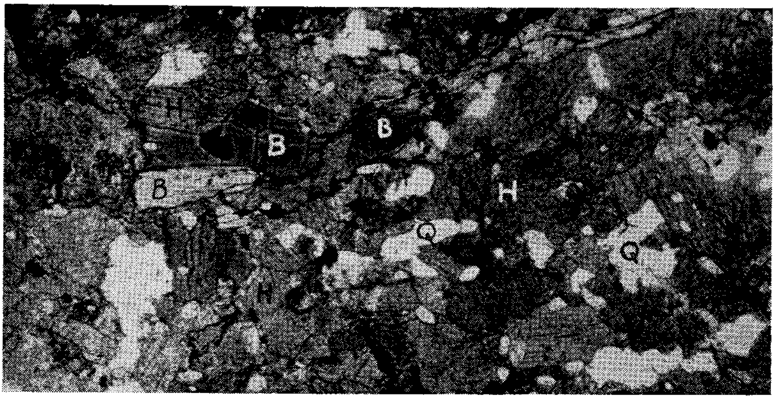
15A. Photomicrograph of quartzite in the Saddle gneiss, from ½ mile east of Eureka School. Composed of quartz (white), feldspar (gray), with skeletal garnets (dark) including quartz (white). One nicol. x 12½.



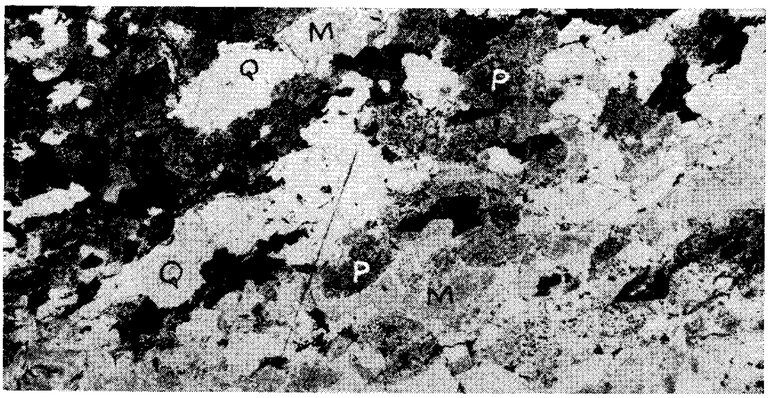
15B. Photomicrograph of Cattron diorite at Big Ridge. C, shear zone crosses rock; P, plagioclase; H, hornblende. One nicol. x 12½.



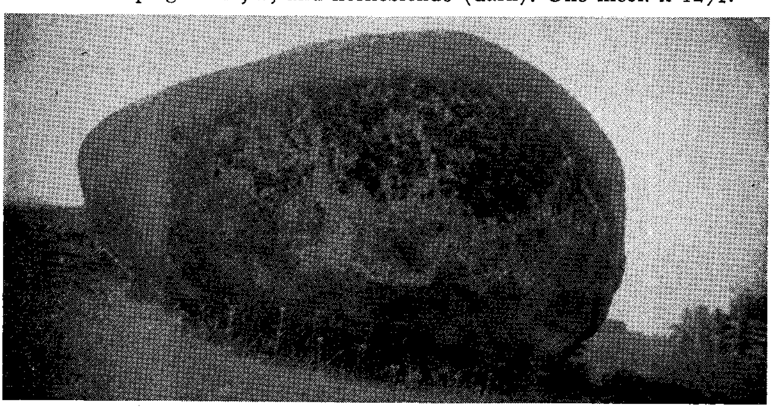
15C. Photomicrograph of same section as 15B with crossed nicols. Cataclasis is shown in shear zone, C. x 12½.



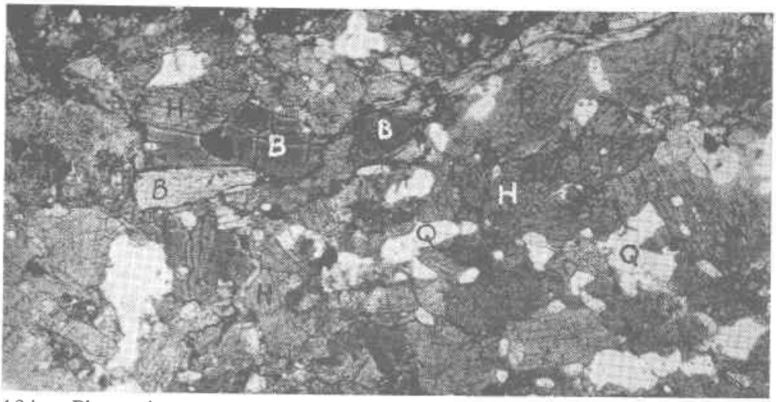
16A. Photomicrograph of Cattron diotite, 1½ miles west of Riverside. Contains biotite, B; hornblende, H; plagioclase, P; and quartz, Q. One nicol. x 12½.



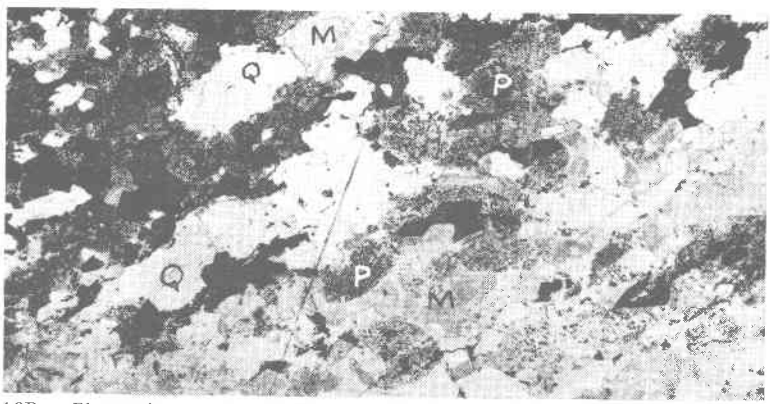
16B. Photomicrograph of Cattron diorite at Salem Church. Contains quartz, Q; and sodic microcline, M, replacing rock composed of altered plagioclase, P, and horneblende (dark). One nicol. x 12½.



16C. Huge rounded residual boulder of Grayson granodiorite gneiss, State Highway 95, 1 mile east of Spring Valley. Rounding produced by exfoliation of homogeneous rock.



16A. Photomicrograph of Cattron diotite, 1½ miles west of Riverside. Contains biotite, B; hornblende, H; plagioclase, P; and quartz, Q. One nicol. x 12½.



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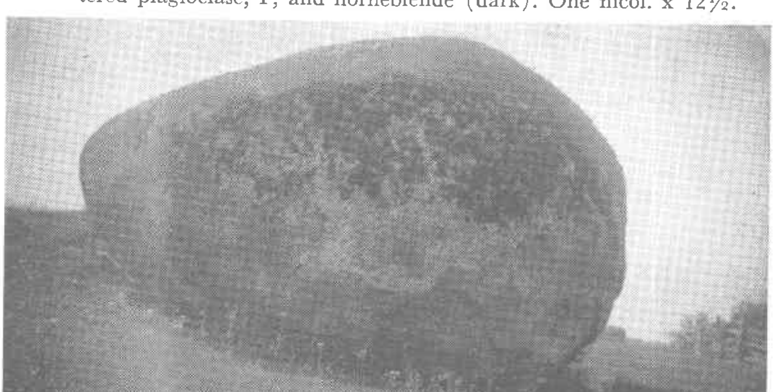
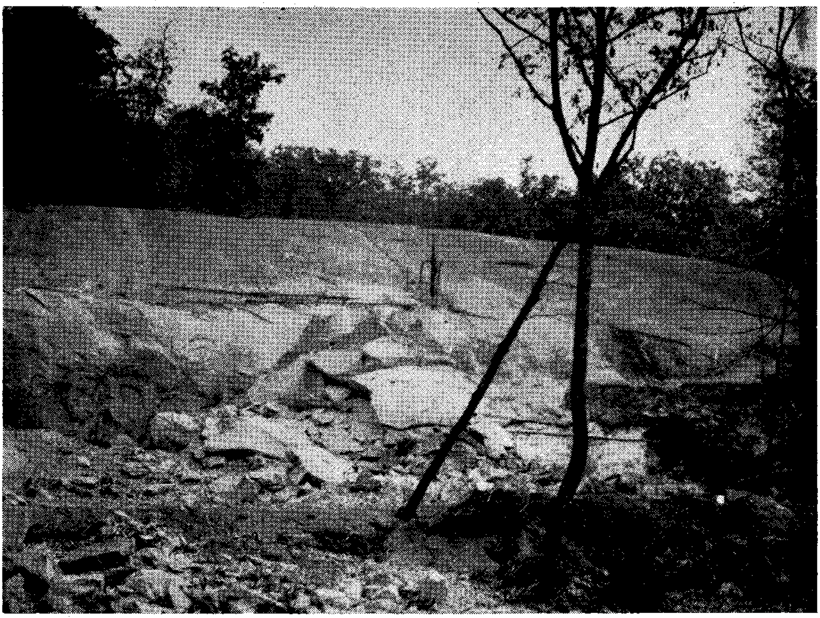


16C. Huge rounded residual boulder of Grayson granodiorite gneiss, State Highway 95, 1 mile east of Spring Valley. Rounding produced by exfoliation of homogeneous rock.



17A. The "Mole," at the southwest foot of Point Lookout Mountain. Rounded granite ledges on a spur of the mountain.

17B. Quarry in Striped Rock granite on north side of the "Mole."

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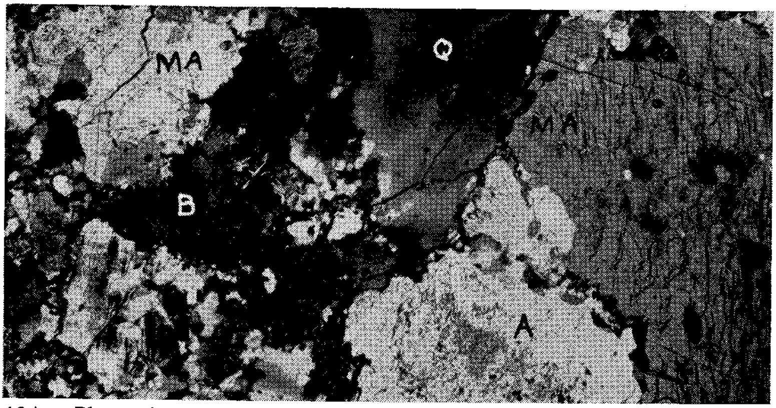
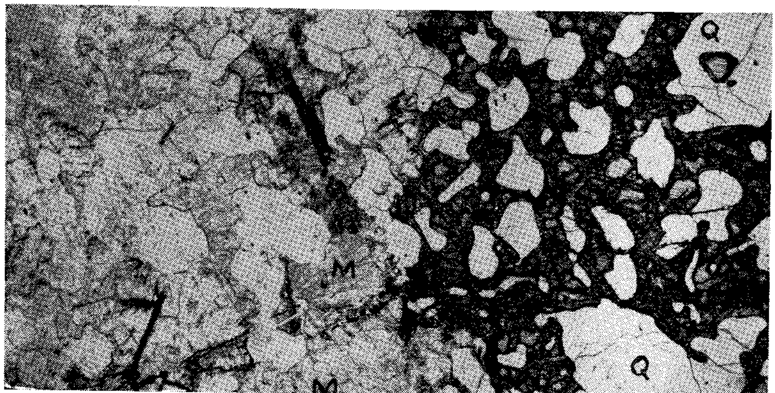
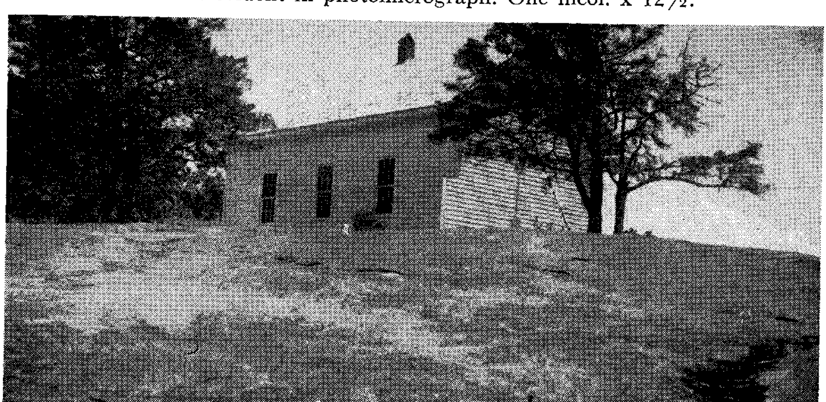
17B. Quarry in Striped Rock granite on north side of the "Mole."



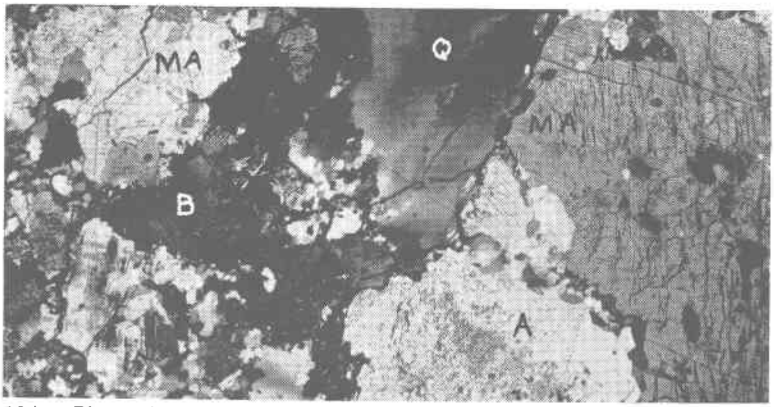
18A. Photomicrograph of Striped Rock granite near Saddle Creek. Microcline, MA, is intergrown with plagioclase, A, which replaces the microcline; quartz, Q, is strained. Dark areas are largely biotite and epidote, B. Crossed nicols. x 12½.



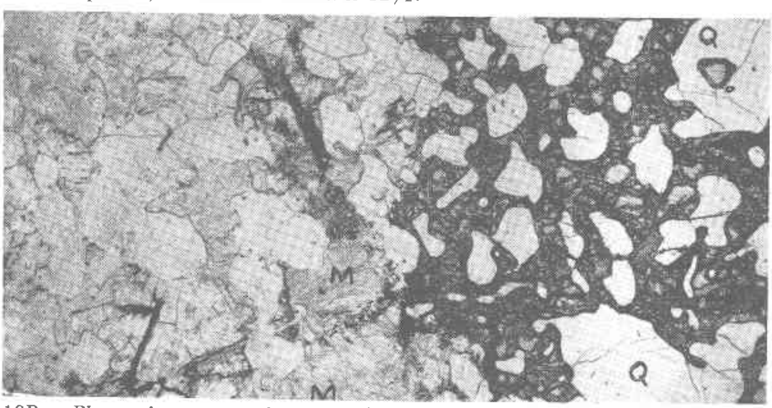
18B. Photomicrograph of aplite, ½ mile west of Striped Rock. Composed of clear quartz and gray microcline, M. Large skeletal garnet (dark) contains quartz, Q. Alteration of garnet to biotite on borders and in cracks not evident in photomicrograph. One nicol. x 12½.



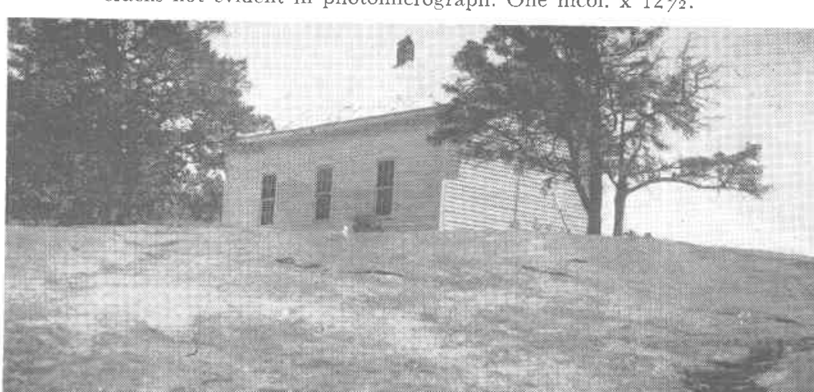
18C. Flat Rock church perched on top of a dome or "pavement" of syenite facies of the Striped Rock granite. Dome produced by curved exfoliation.



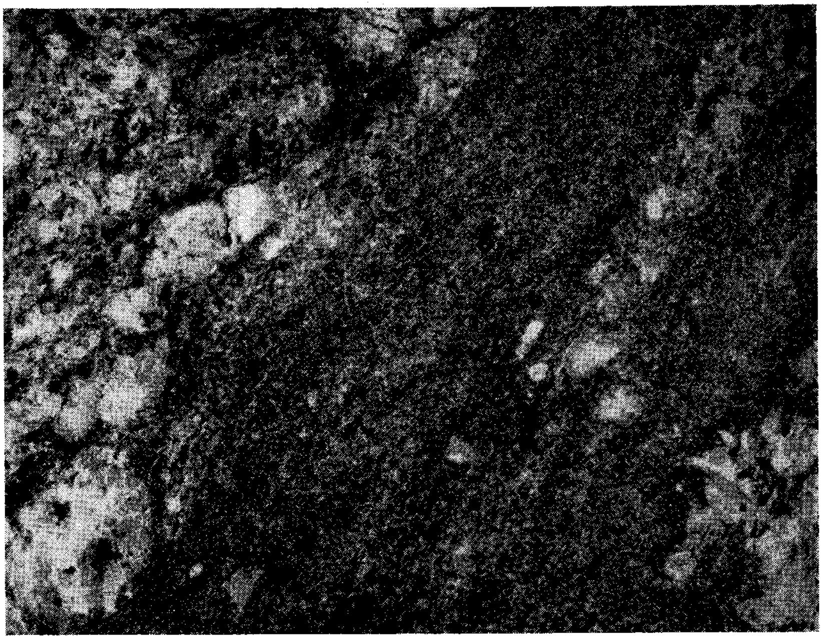
18A. Photomicrograph of Striped Rock granite near Saddle Creek. Microcline, MA, is intergrown with plagioclase, A, which replaces the microcline; quartz, Q, is strained. Dark areas are largely biotite and epidote, B. Crossed nicols. x 12½.



18B. Photomicrograph of aplite, ½ mile west of Striped Rock. Composed of clear quartz and gray microcline, M. Large skeletal garnet (dark) contains quartz, Q. Alteration of garnet to biotite on borders and in cracks not evident in photomicrograph. One nicol. x 12½.

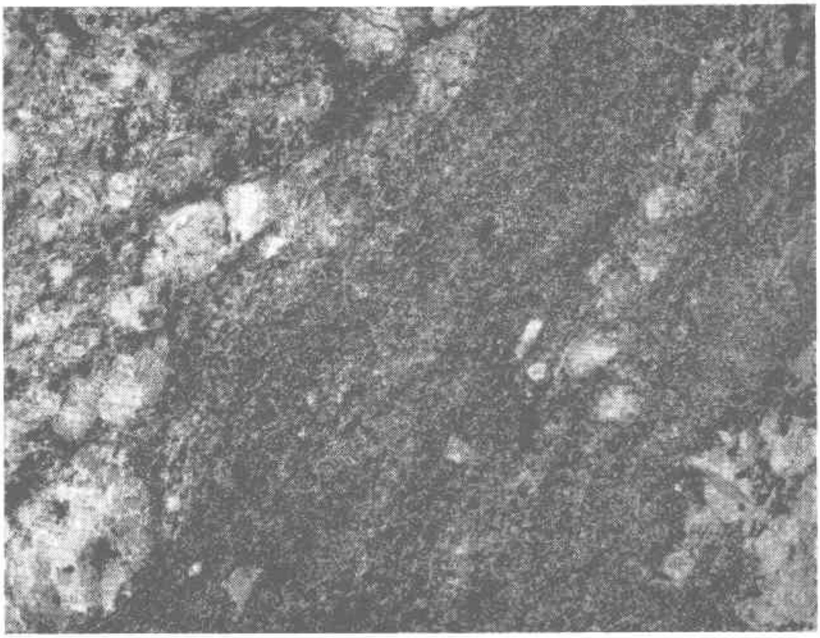


18C. Flat Rock church perched on top of a dome or "pavement" of syenite facies of the Striped Rock granite. Dome produced by curved exfoliation.



19A. Polished specimen of Striped Rock granite from quarry in the "Mole." Shows replacement of biotite gneiss by granite.

19B. Cattron diorite injected and cut by white aplite. Near Salem Church, 2 miles east of Longs Gap.



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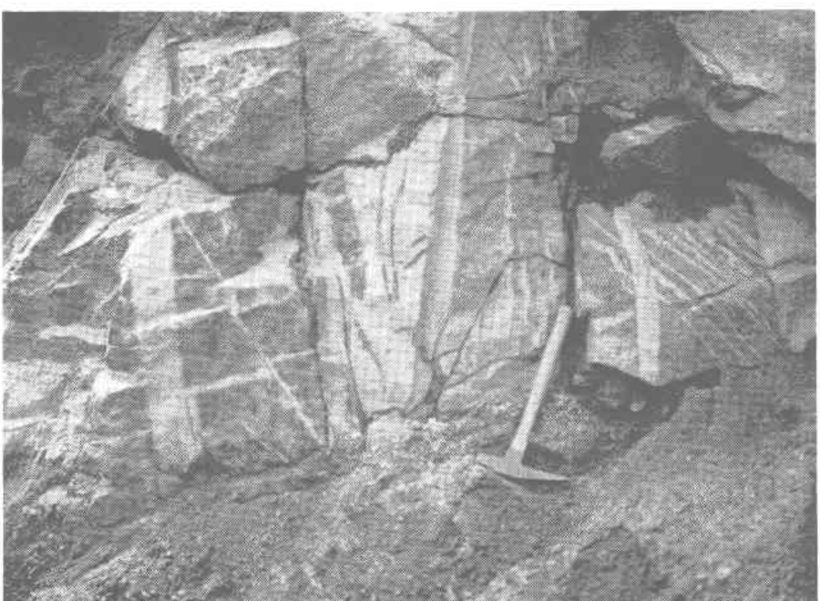

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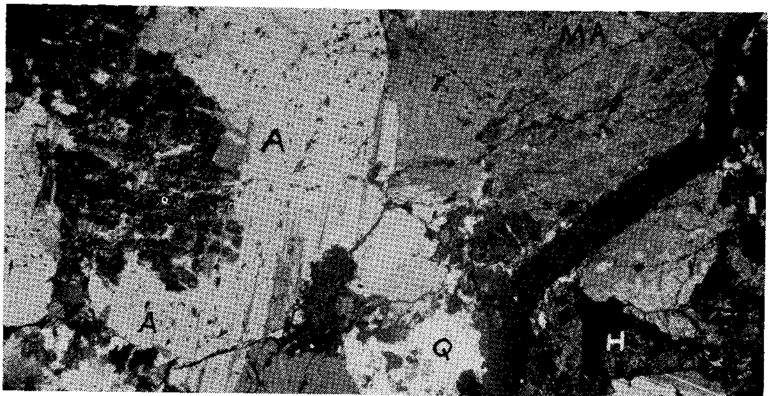
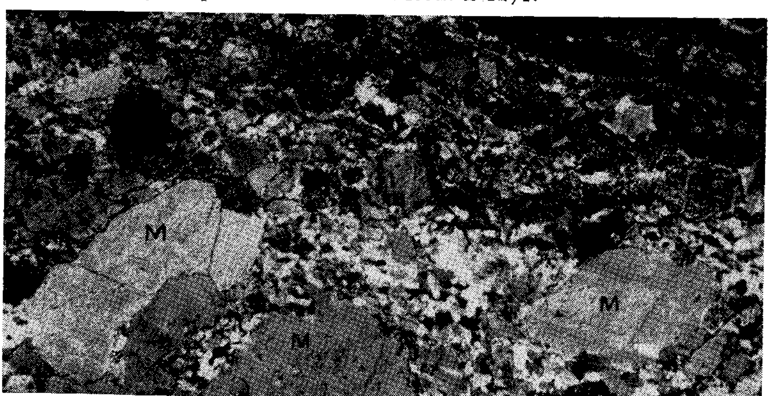
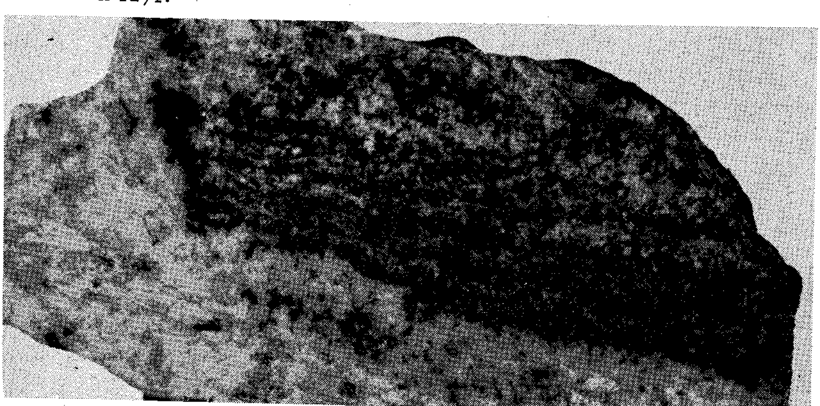


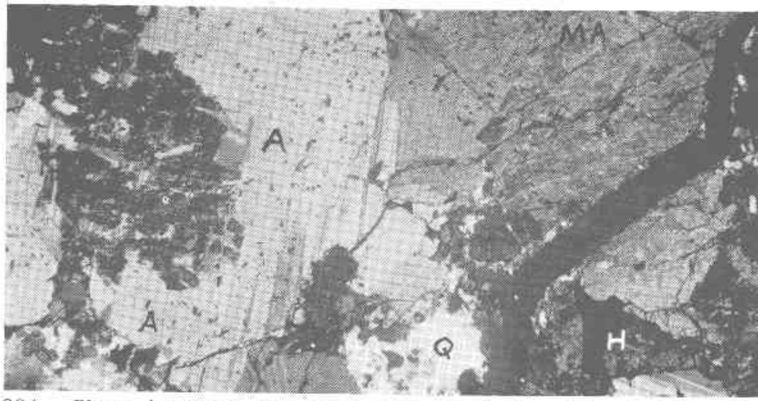
20A. Photomicrograph of syenite at Peach Bottom Church. Microcline intergrown with albite-oligoclase, MA, twinned albite-oligoclase, A, quartz, Q, and dark interstitial areas of biotite, hornblende and epidote H, compose rock. Crossed nicols. x 12½.



20B. Photomicrograph of Beaverdam Creek augen gneiss, from 2 miles southeast of Independence. Microcline, M, in cataclastic ground mass of quartz and plagioclase with biotite bands, black. Crossed nicols. x 12½.



20C. Polished specimen of Cattron diorite injected and replaced by granite. Near Hines Branch Church.



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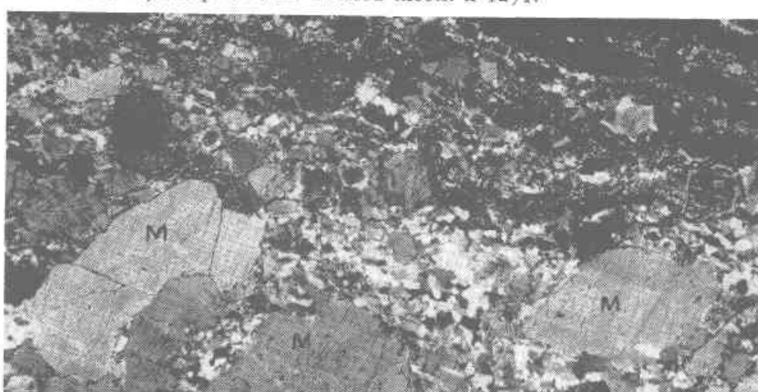

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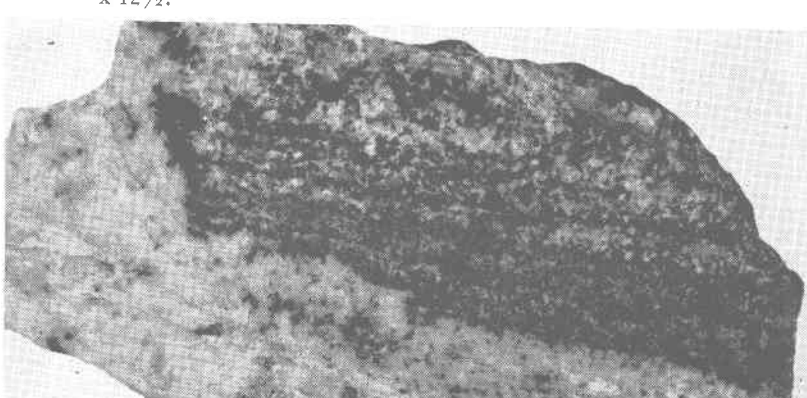

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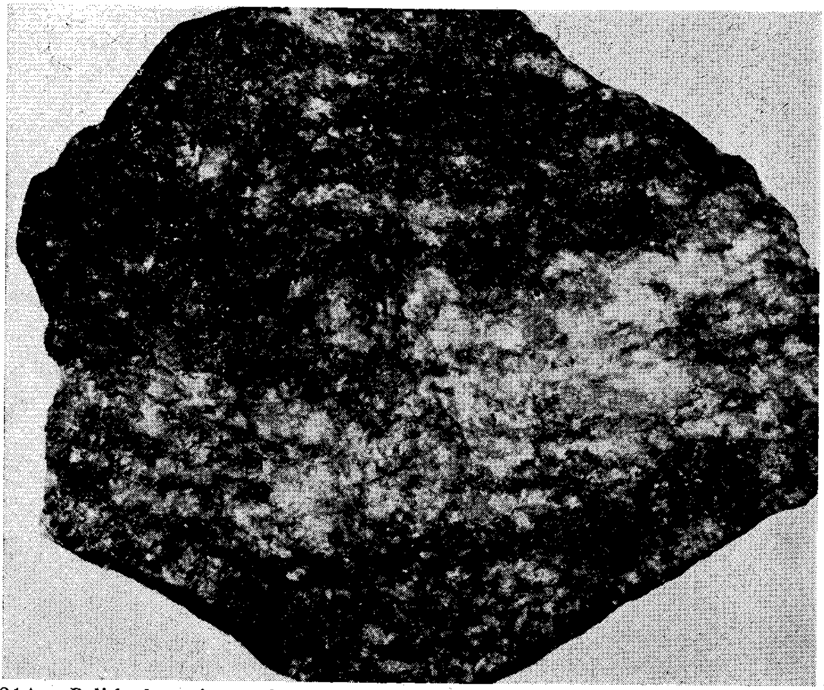
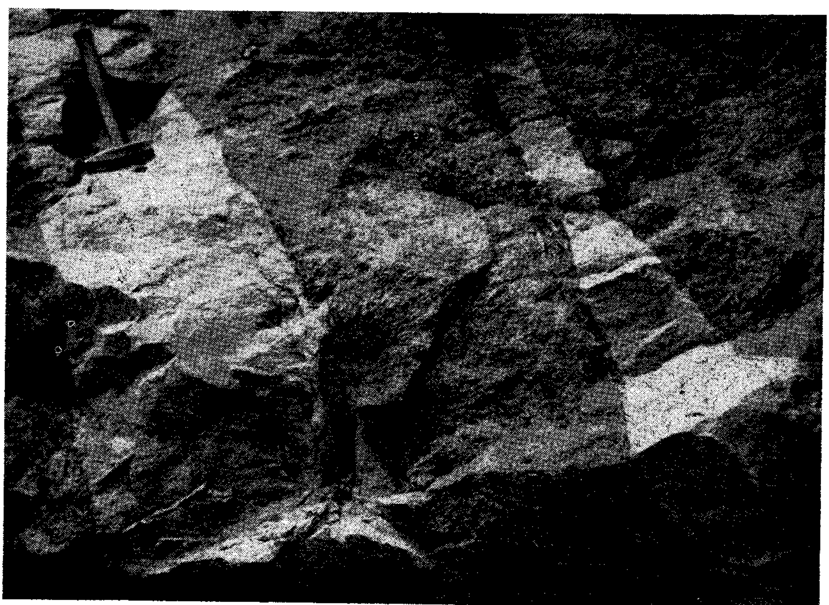
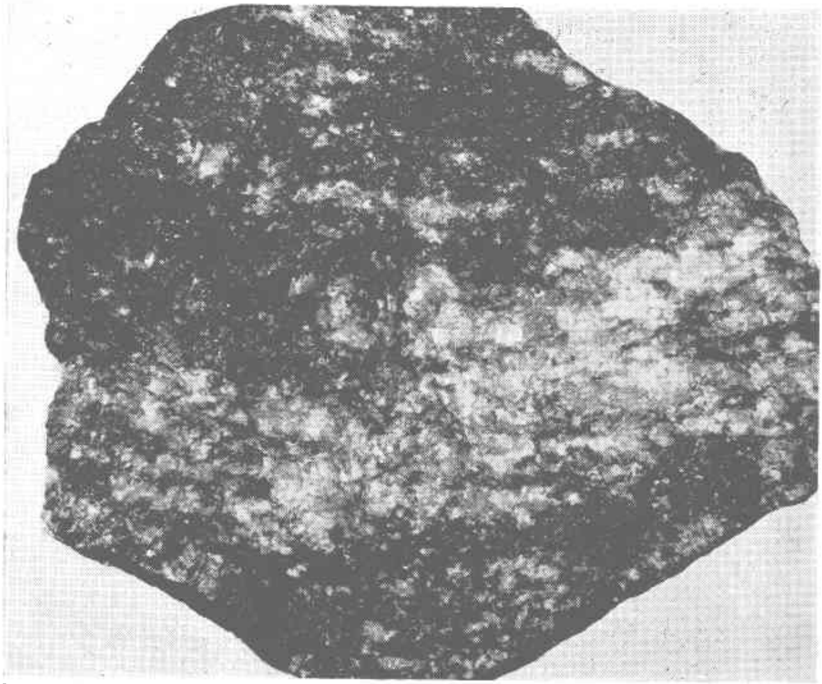


21A. Polished specimen of Cattron diorite with pink aplite replacement. Farmers Branch.



21B. Comers granite gneiss injected by pink pegmatite and aplite. Road on Middle Fox Creek, south of Klims Branch School, Mouth of Wilson quadrangle.



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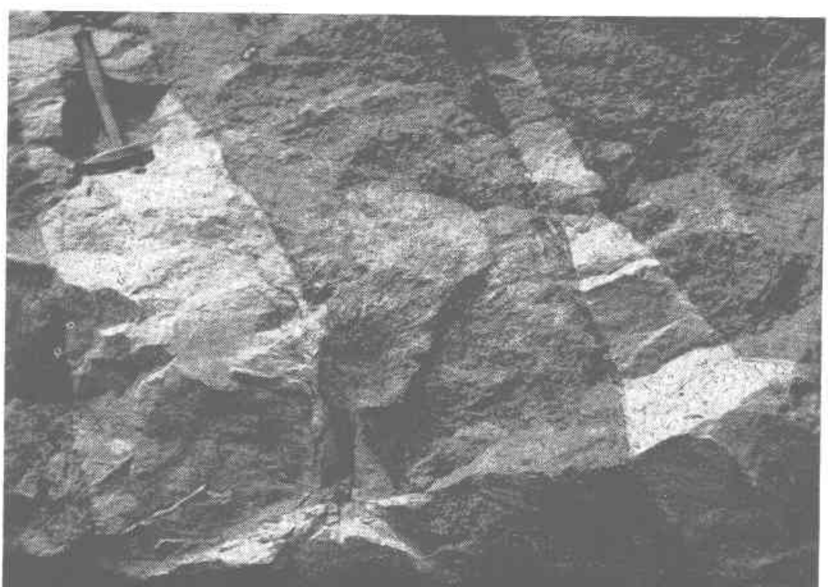
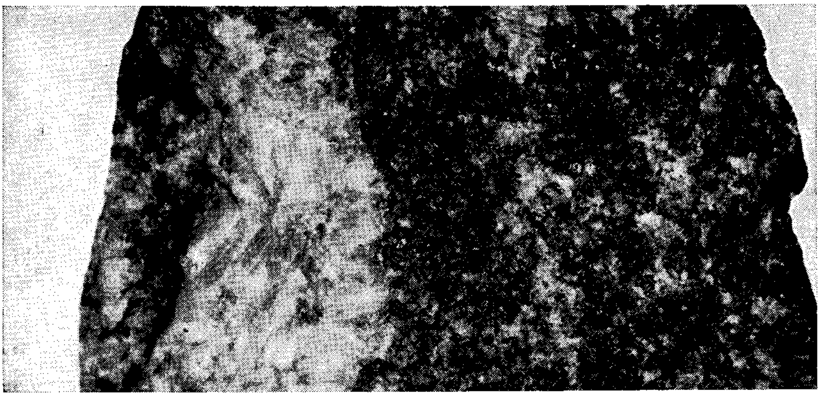
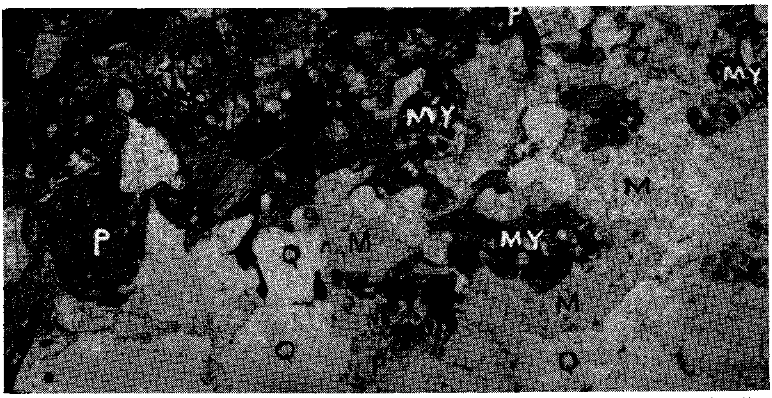


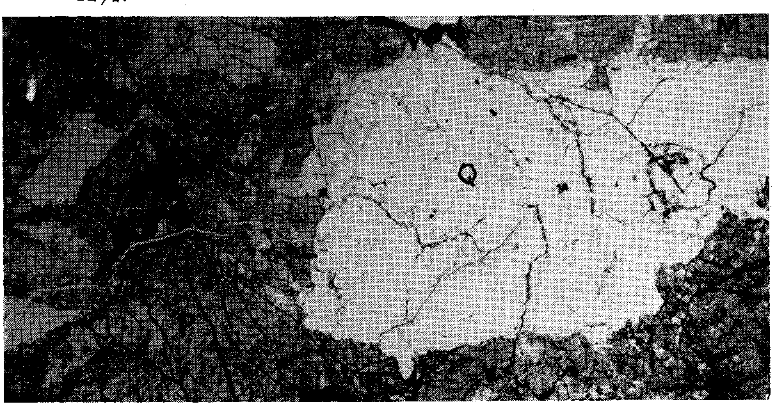
21B. Comers granite gneiss injected by pink pegmatite and aplite. Road on Middle Fox Creek, south of Klims Branch School, Mouth of Wilson quadrangle.



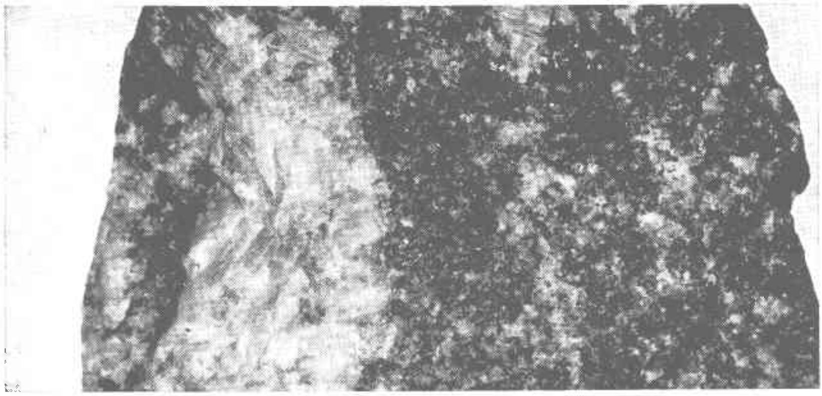
22A. Polished specimen of biotitic Cattron diorite injected and replaced by granite. East of Fallville.



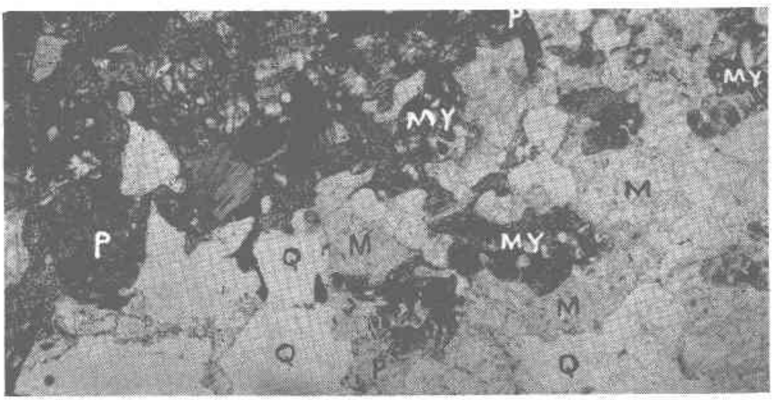
22B. Photomicrograph of diorite replaced by pink pegmatite, from ½ mile east of Fallville. Pegmatite composed of microcline, M, quartz, Q, and myrmekite, MY, with remnants of plagioclase, P. One nicol. x 12½.



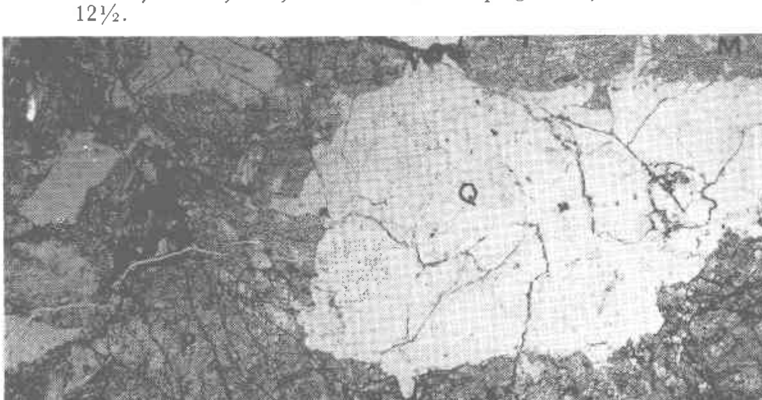
22C. Photomicrograph of Comers granite gneiss from Comers Rock. Made up of microcline, M, quartz, Q, sericitized plagioclase, P, with scanty streaks of chlorite, dark. One nicol. x 12½.



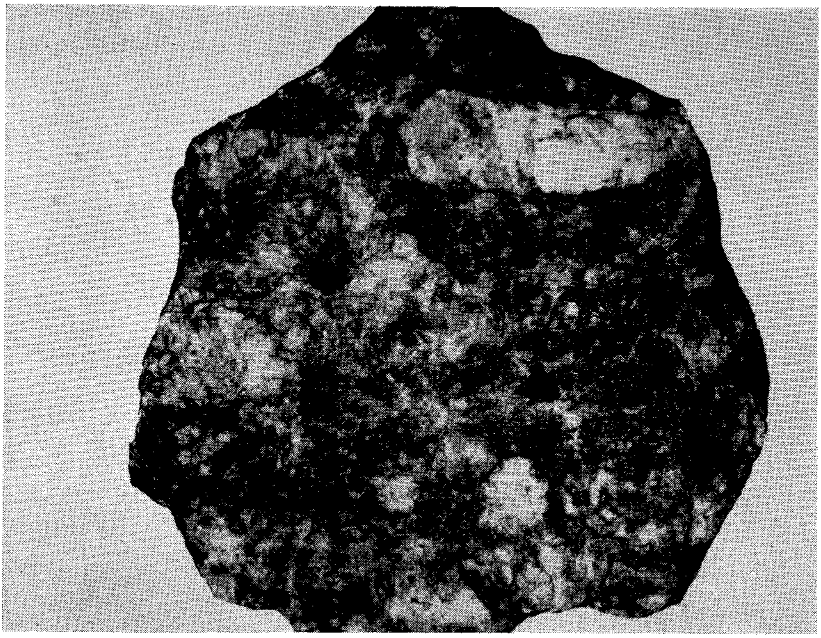
22A. Polished specimen of biotitic Cattron diorite injected and replaced by granite. East of Fallville.



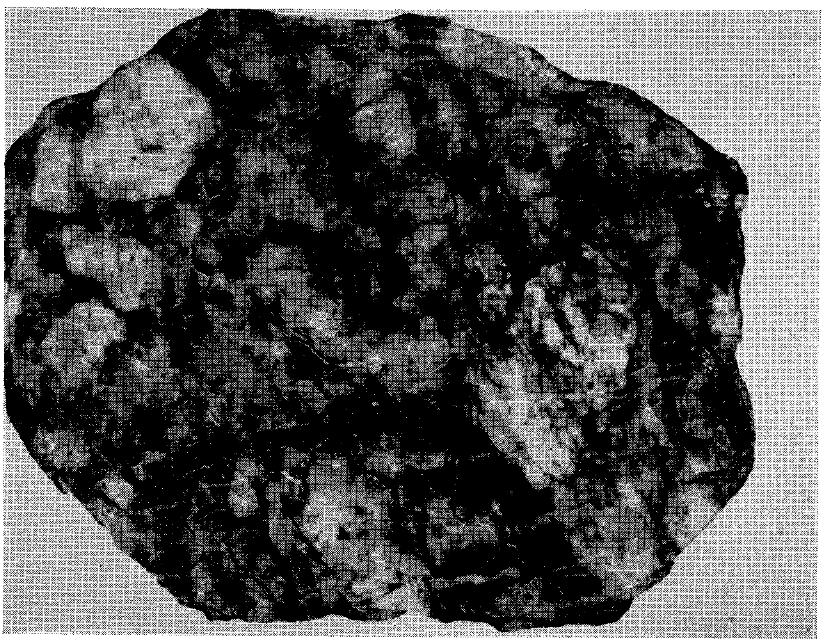
22B. Photomicrograph of diorite replaced by pink pegmatite, from ½ mile east of Fallville. Pegmatite composed of microcline, M, quartz, Q, and myrmekite, MY, with remnants of plagioclase, P. One nicol. x 12½.



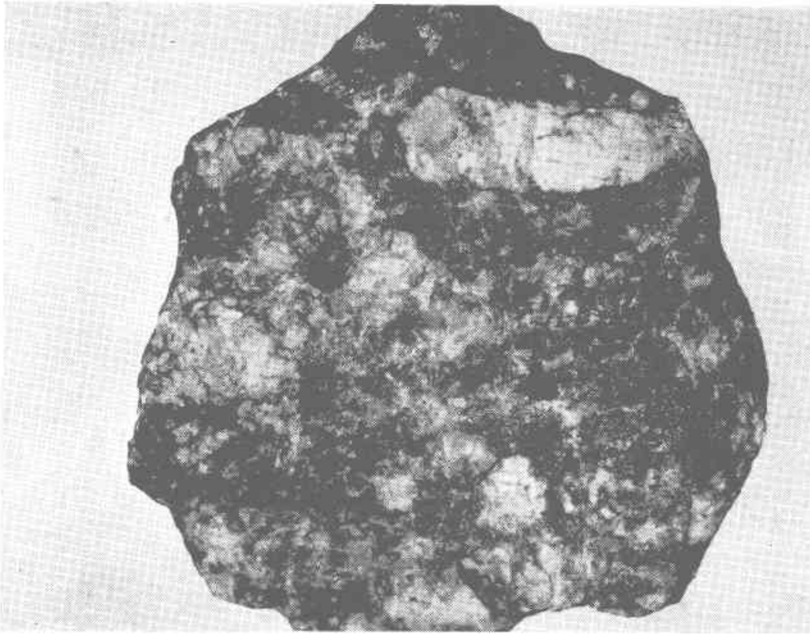
22C. Photomicrograph of Comers granite gneiss from Comers Rock. Made up of microcline, M, quartz, Q, sericitized plagioclase, P, with scanty streaks of chlorite, dark. One nicol. x 12½.



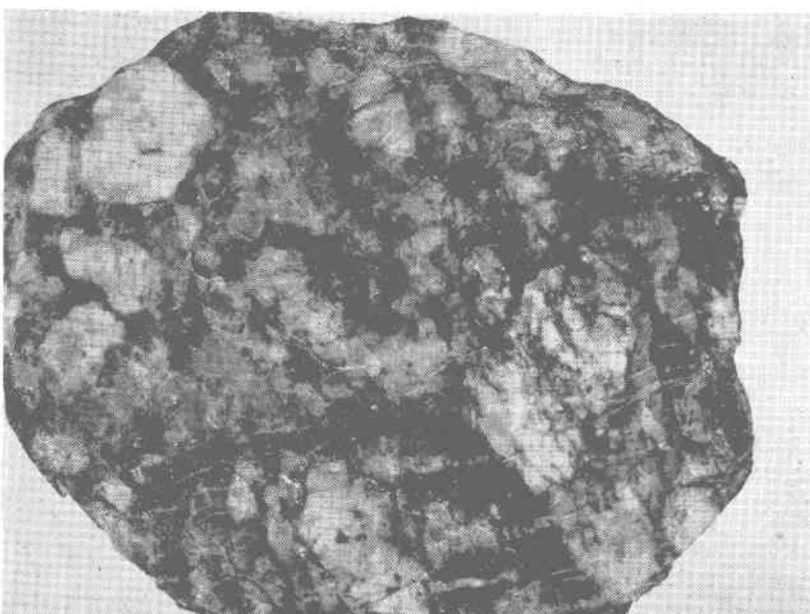
23A. Polished specimen of Grayson granodiorite gneiss, State Highway 95, 2 miles south of Spring Valley. Shows tabular microcline phenocrysts.



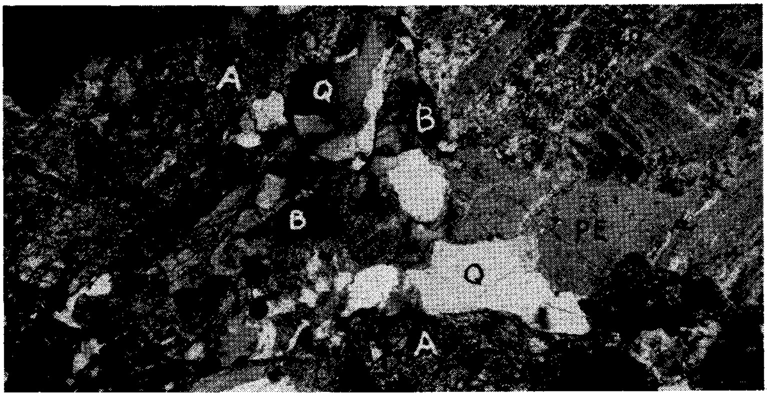
23B. Polished specimen of Grayson granodiorite gneiss, State Highway 95, west of junction with State Highway 94. Shows minor cross fractures in microcline phenocrysts.



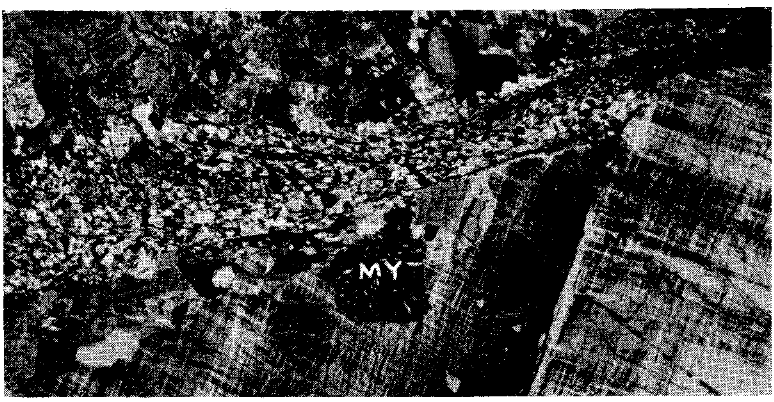
23A. Polished specimen of Grayson granodiorite gneiss, State Highway 95, 2 miles south of Spring Valley. Shows tabular microcline phenocrysts.



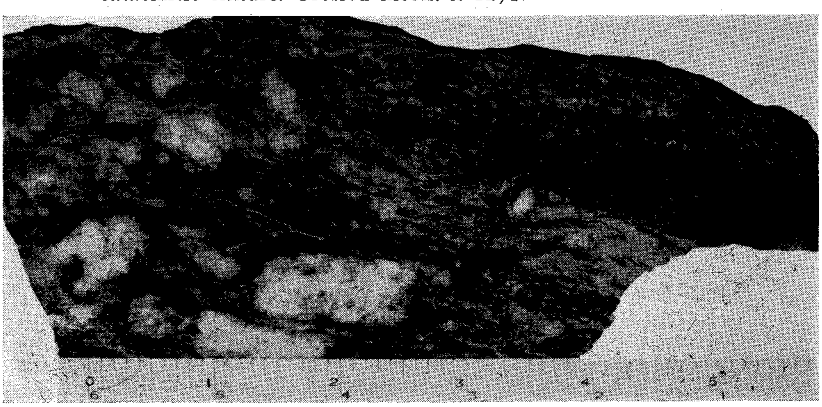
23B. Polished specimen of Grayson granodiorite gneiss, State Highway 95, west of junction with State Highway 94. Shows minor cross fractures in microcline phenocrysts.



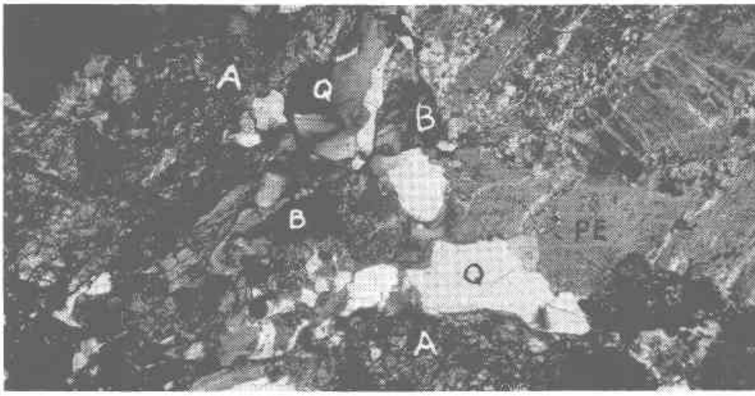
24A. Photomicrograph of Grayson granodiorite gneiss, 2 miles south of Spring Valley. Constituents are large crystals of perthite, PE, quartz, Q, andesine, A, dark with alteration, biotite, B, and hornblende, H. Crossed nicols. x 12½.



24B. Photomicrograph of Shoal gneiss from west of Saddle Creek Church. Contains part of microcline metacryst, M, embayed by myrmekite, MY. Fine crush zone, C, on border of microcline. Matrix of rock has cataclastic texture. Crossed nicols. x 12½.

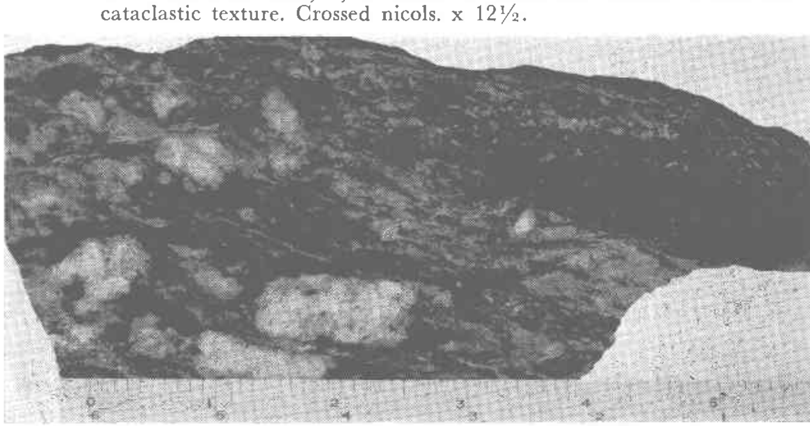


24C. Polished specimen of mylonite schist from Shoal gneiss. U. S. Route 58, west of Saddle Creek Church.

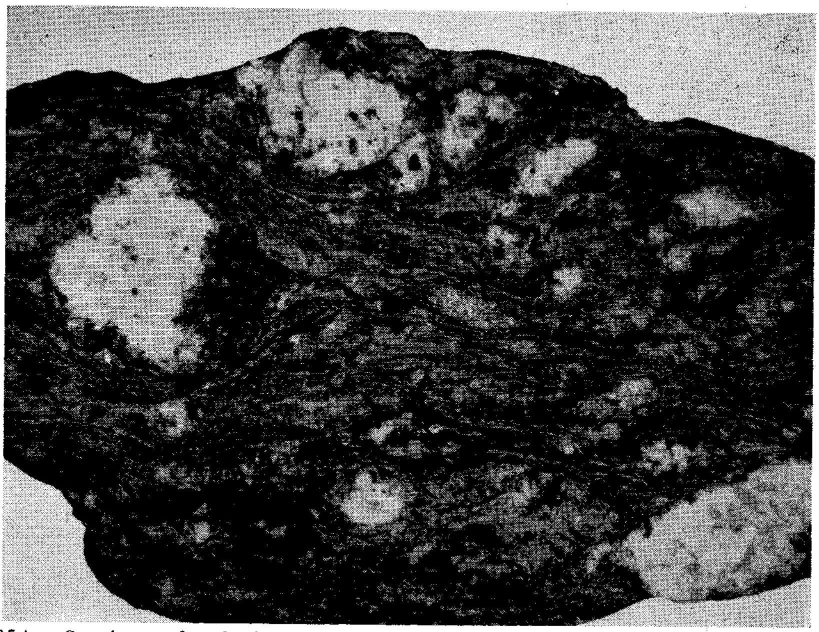


24A. Photomicrograph of Grayson granodiorite gneiss, 2 miles south of Spring Valley. Constituents are large crystals of perthite, PE, quartz, Q, andesine, A, dark with alteration, biotite, B, and hornblende, H. Crossed nicols. x 12½.

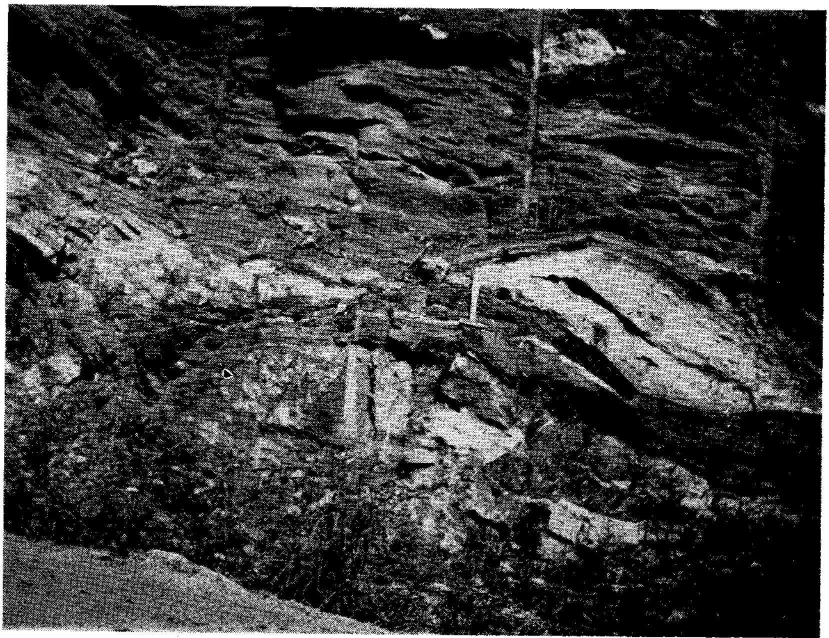
24B. Photomicrograph of Shoal gneiss from west of Saddle Creek Church. Contains part of microcline metacryst, M, embayed by myrmekite, MY. Fine crush zone, C, on border of microcline. Matrix of rock has cataclastic texture. Crossed nicols. x 12½.



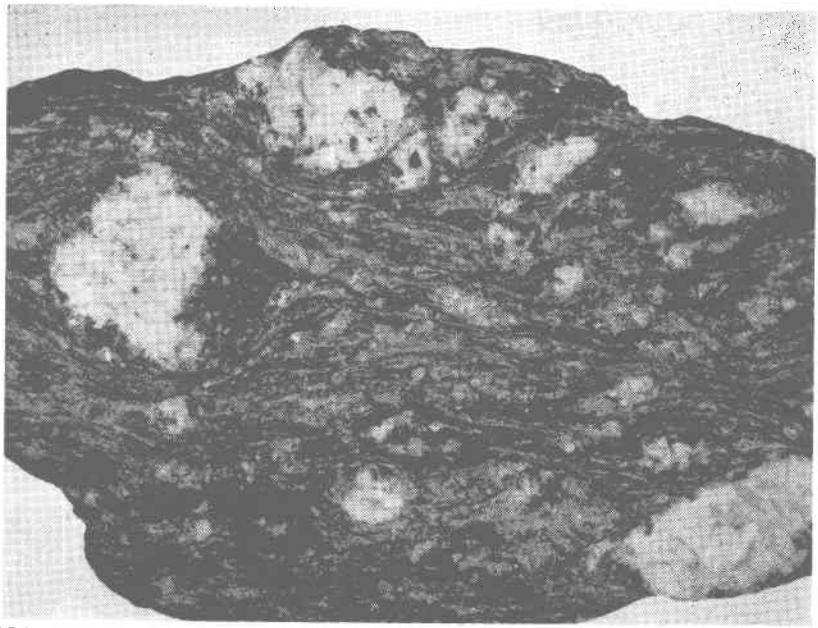
24C. Polished specimen of mylonite schist from Shoal gneiss. U. S. Route 58, west of Saddle Creek Church.



25A. Specimen of mylonite schist from Shoal gneiss. U. S. Route 58, 1 mile east of Mouth of Wilson.

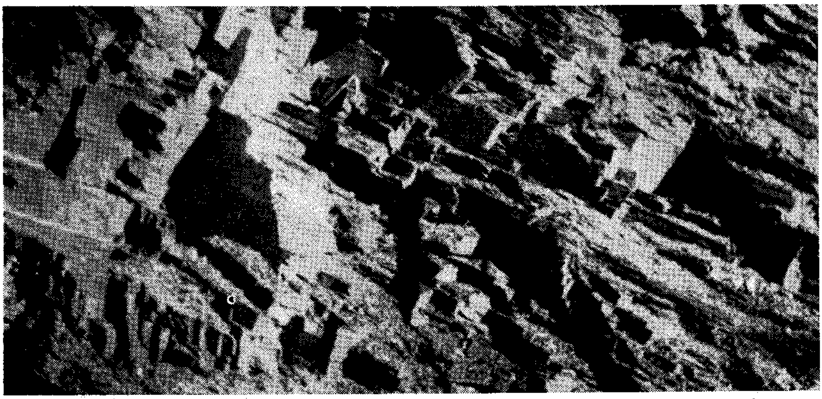


25B. Granite mylonite enclosing lenses of white granite near Fries overthrust, State Highway 94, north of Fries.

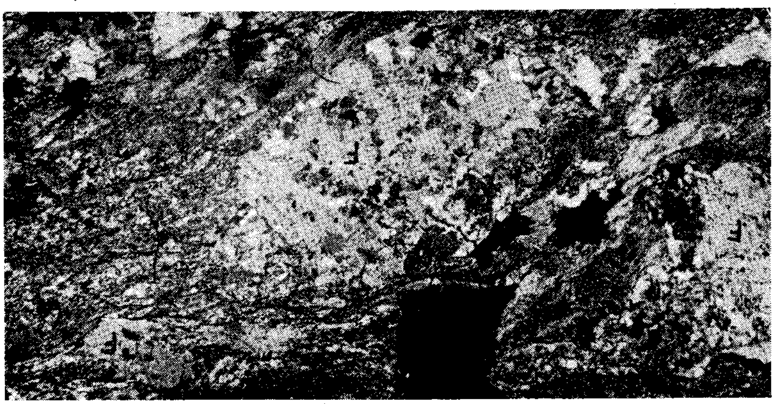


25A. Specimen of mylonite schist from Shoal gneiss. U. S. Route 58, 1 mile east of Mouth of Wilson.

25B. Granite mylonite enclosing lenses of white granite near Fries overthrust, State Highway 94, north of Fries.

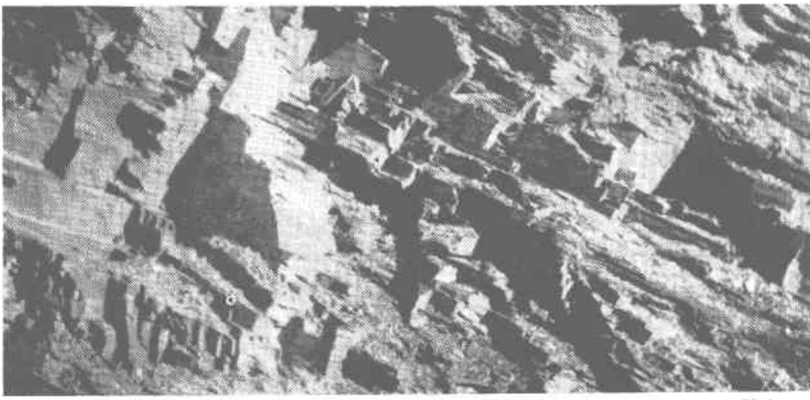


26A. Straight-layered quartzite mylonite near Fries overthrust. State Highway 94, west of Fries.

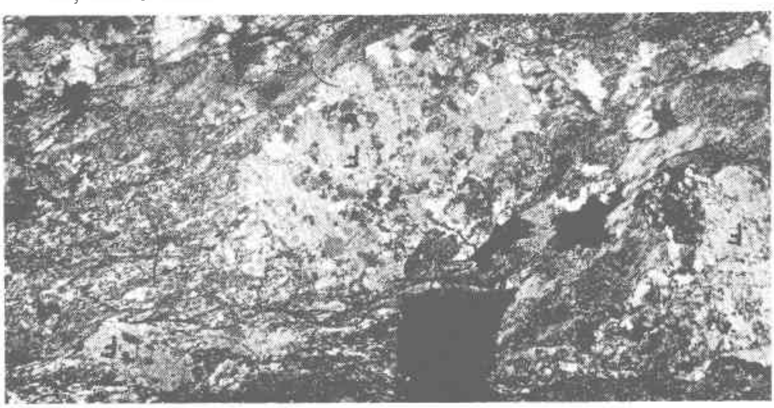


26B. Photomicrograph of granite mylonite from Moore Creek. Porphyroclasts of feldspar, F, in cataclastic groundmass. Crossed nicols. x 12½.

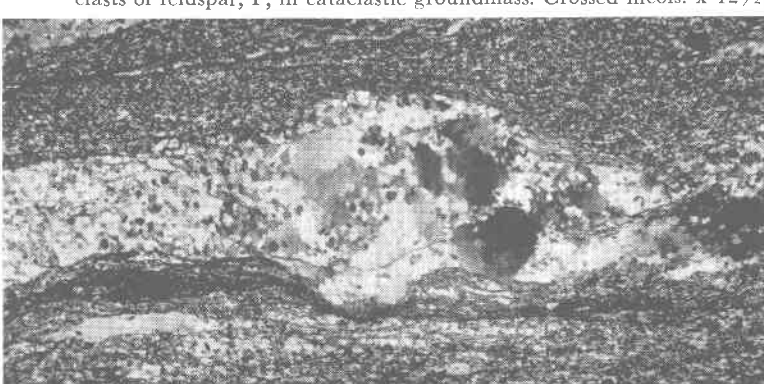
26C. Photomicrograph of quartzite mylonite from east of Moore Creek. Lenticular area of cataclastic quartz wrapped by sericite (dark) in a finer matrix of quartz. Crossed nicols. x 12½.



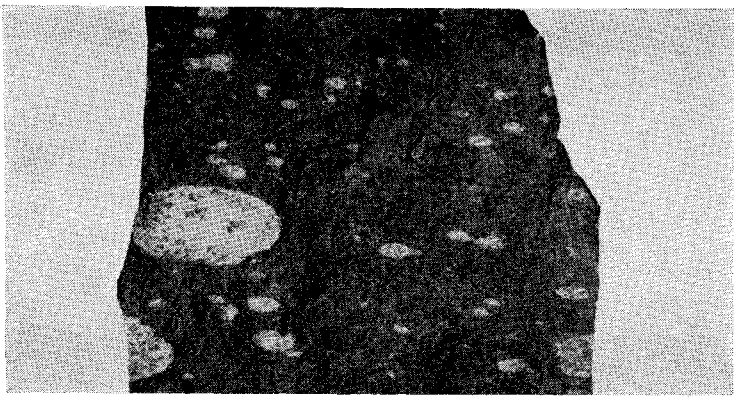
26A. Straight-layered quartzite mylonite near Fries overthrust. State Highway 94, west of Fries.



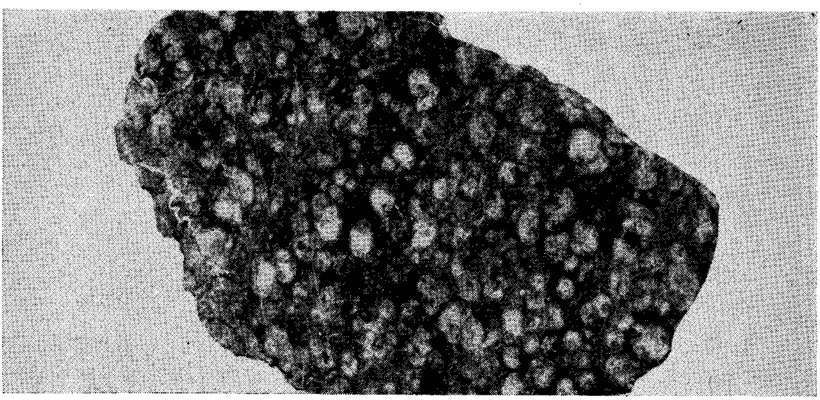
26B. Photomicrograph of granite mylonite from Moore Creek. Porphyroclasts of feldspar, F, in cataclastic groundmass. Crossed nicols. x 12½.



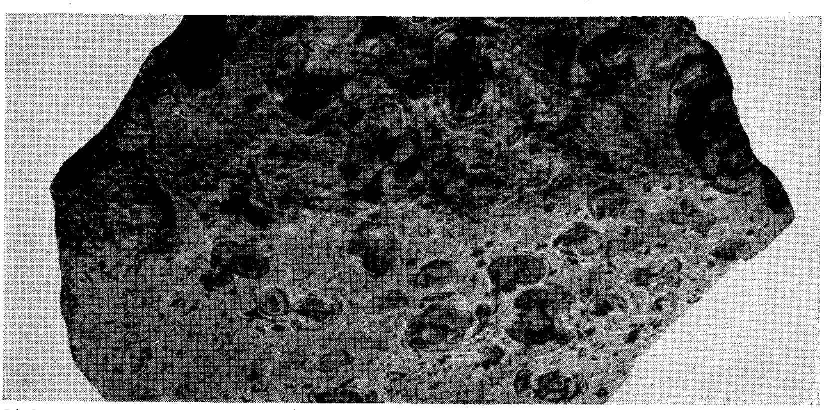
26C. Photomicrograph of quartzite mylonite from east of Moore Creek. Lenticular area of cataclastic quartz wrapped by sericite (dark) in a finer matrix of quartz. Crossed nicols. x 12½.



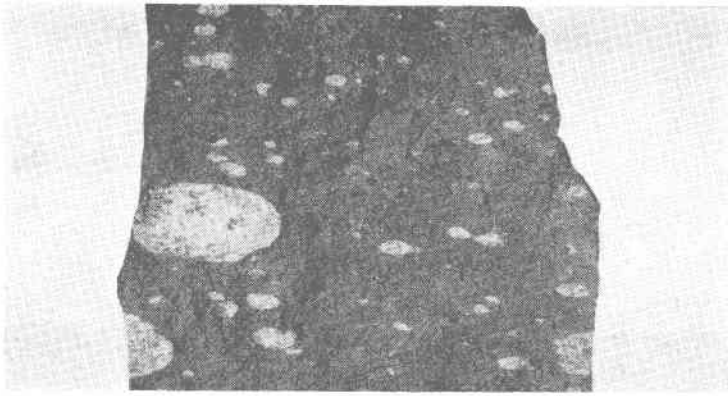
27A. Specimen of spotted red tuffaceous slate, with flattened amygdules, from the Flat Ridge formation.



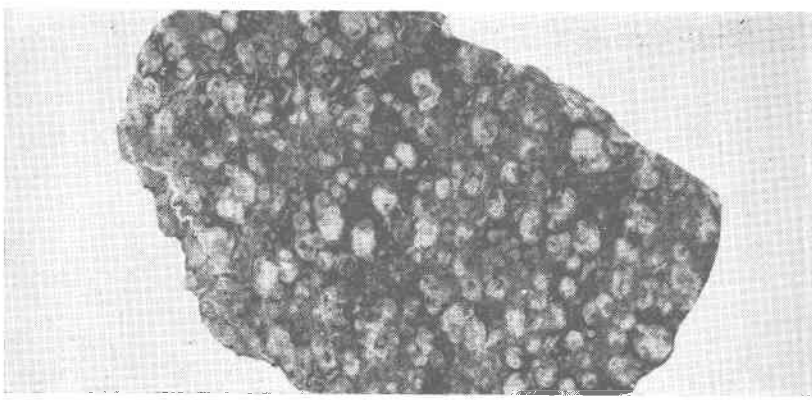
27B. Polished specimen of spherulitic rhyolite. Spherulites composed of white quartz in a pink rhyolite groundmass. From 3 miles west of Troutdale.



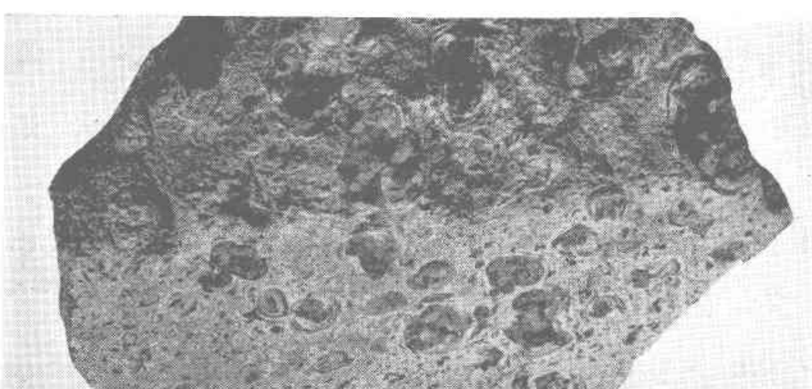
27C. Specimen of rhyolite showing lithophysae brought out by weathering. From 3 miles west of Troutdale.



27A. Specimen of spotted red tuffaceous slate, with flattened amygdules, from the Flat Ridge formation.

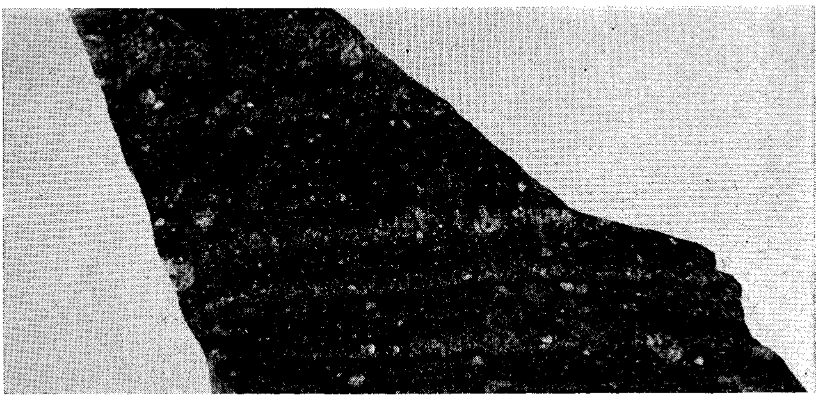


27B. Polished specimen of spherulitic rhyolite. Spherulites composed of white quartz in a pink rhyolite groundmass. From 3 miles west of Troutdale.



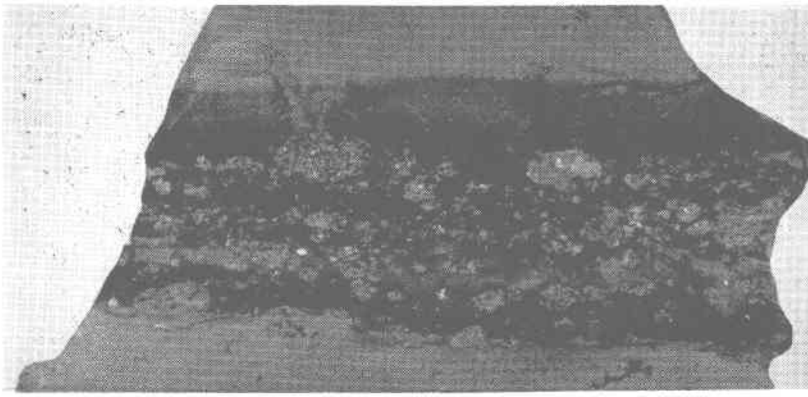
27C. Specimen of rhyolite showing lithophysae brought out by weathering. From 3 miles west of Troutdale.

28A. Specimen of banded buff and red tuffaceous slate with ash bed, 4 miles northeast of Troutdale.

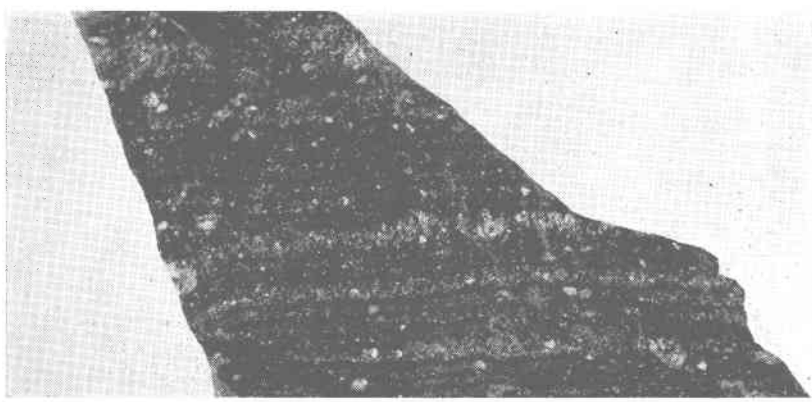


28B. Specimen of banded red tuffaceous slate with fine arkosic layers, 12 miles west of Troutdale.

28C. Specimen of coarse volcanic breccia and tuff, near Mount Rogers.

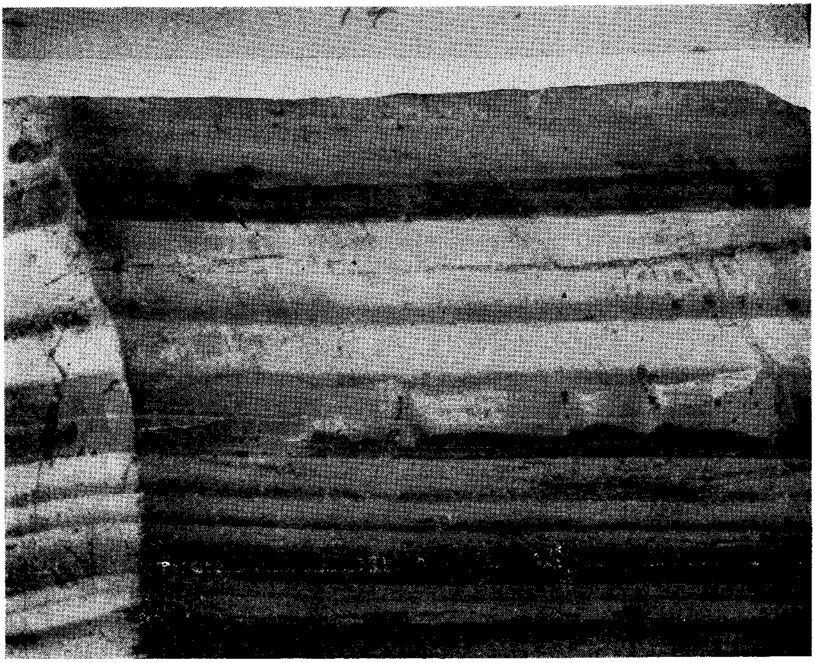


28A. Specimen of banded buff and red tuffaceous slate with ash bed, 4 miles northeast of Troutdale.

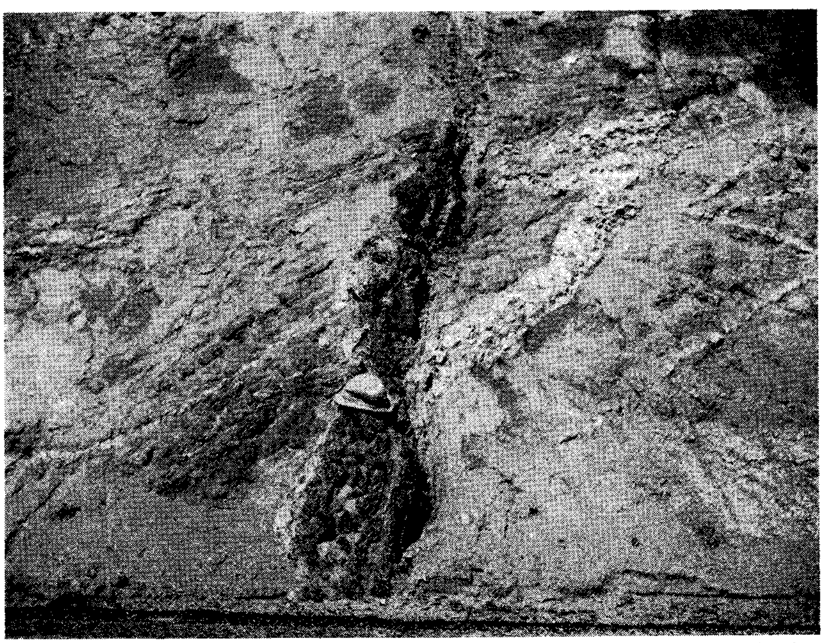


28B. Specimen of banded red tuffaceous slate with fine arkosic layers, 12 miles west of Troutdale.

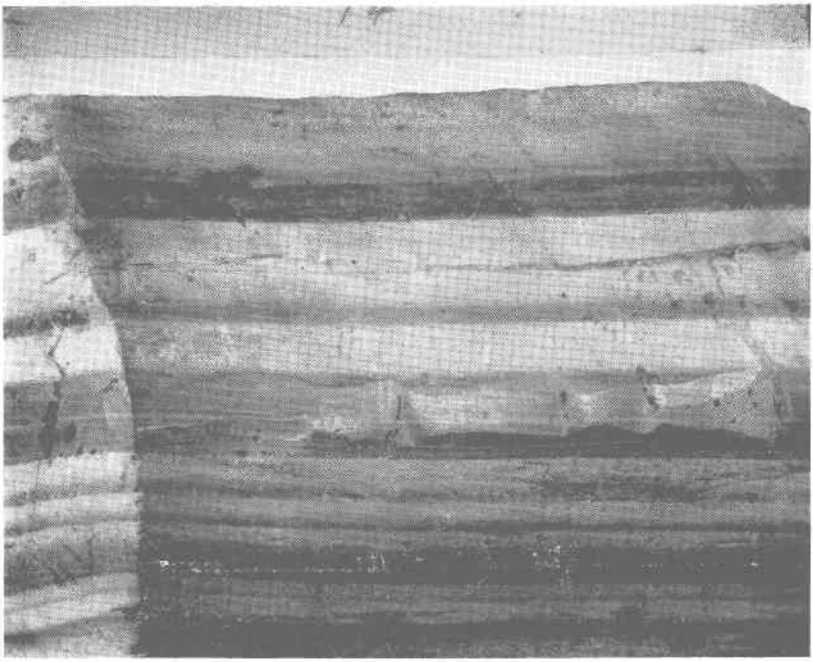
28C. Specimen of coarse volcanic breccia and tuff, near Mount Rogers.



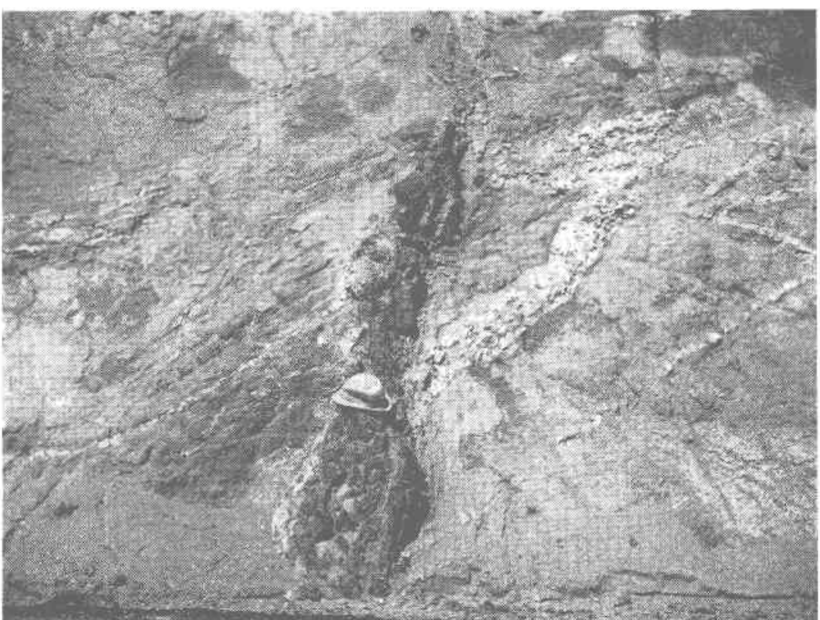
29A. Specimen of buff and red rhythmically banded tuffaceous slate, 4 miles northeast of Troutdale.



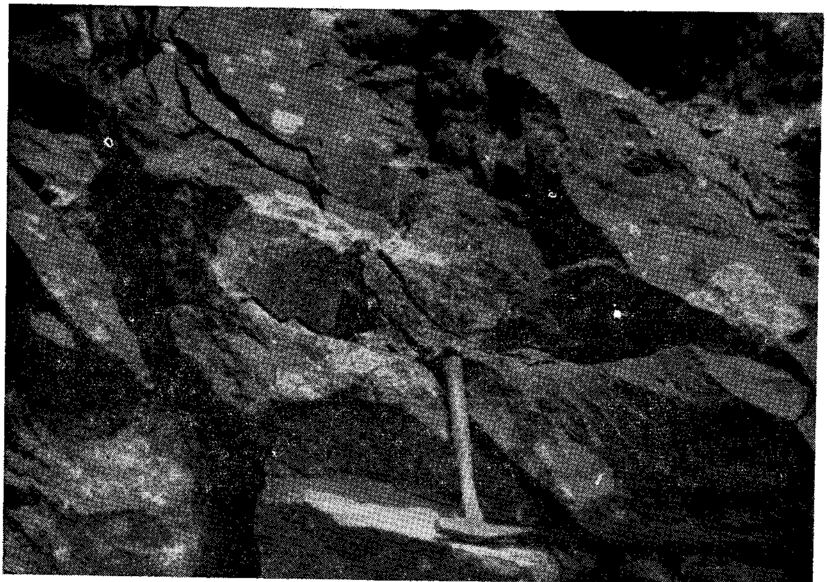
29B. Road cut showing diabase dike of late pre-Cambrian age cutting injection gneiss with pegmatitic veins. State Highway 95, east of junction with Spring Valley road. Looking south.



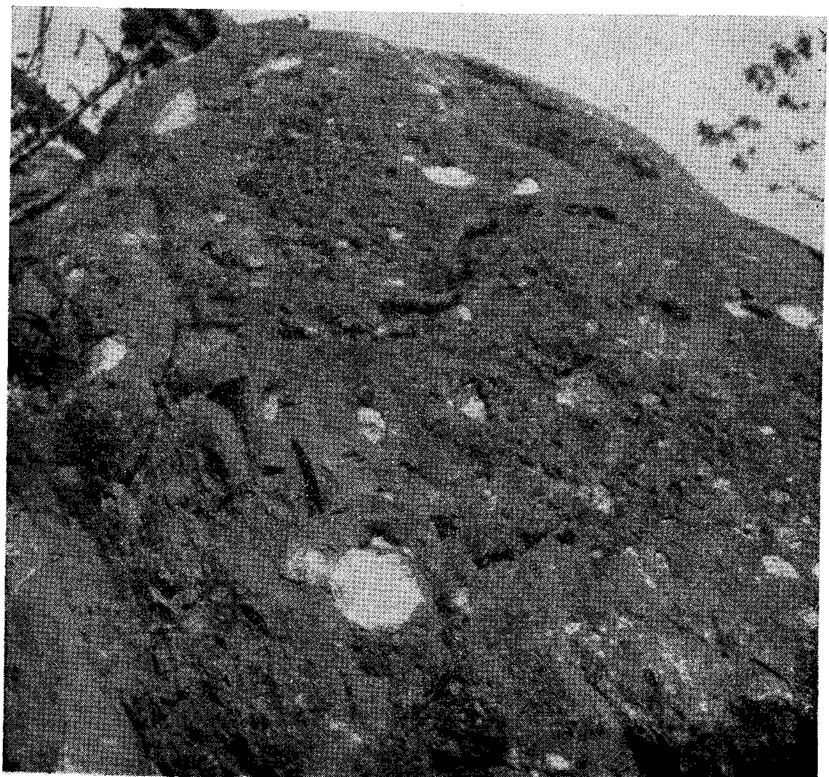
29A. Specimen of buff and red rhythmically banded tuffaceous slate, 4 miles northeast of Troutdale.



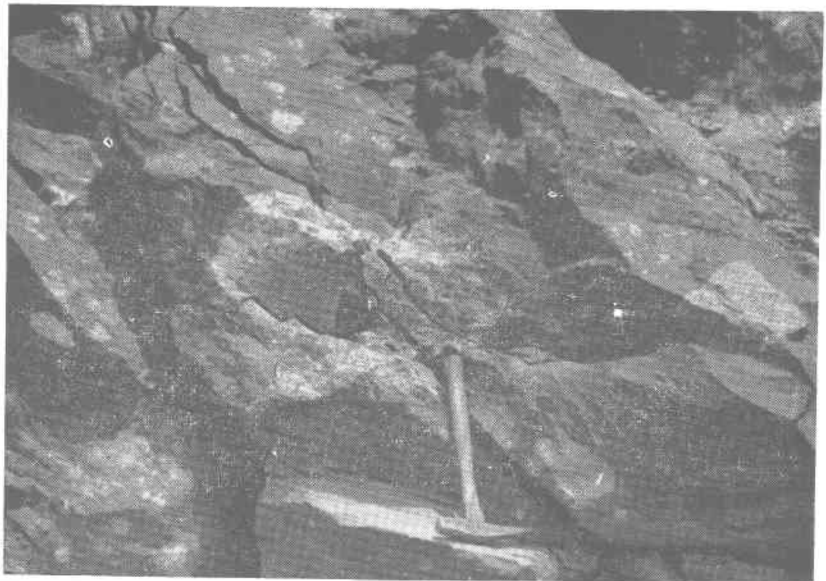
29B. Road cut showing diabase dike of late pre-Cambrian age cutting injection gneiss with pegmatitic veins. State Highway 95, east of junction with Spring Valley road. Looking south.



30A. Red tuffaceous silt or mud flow enclosing large angular fragments of fresh granite and other rocks, 14 miles west of Troutdale.

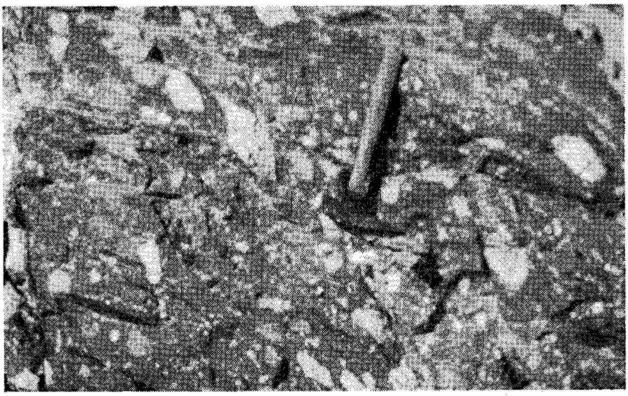


30B. Weathered surface of red conglomerate containing granite boulders, 14 miles west of Troutdale.



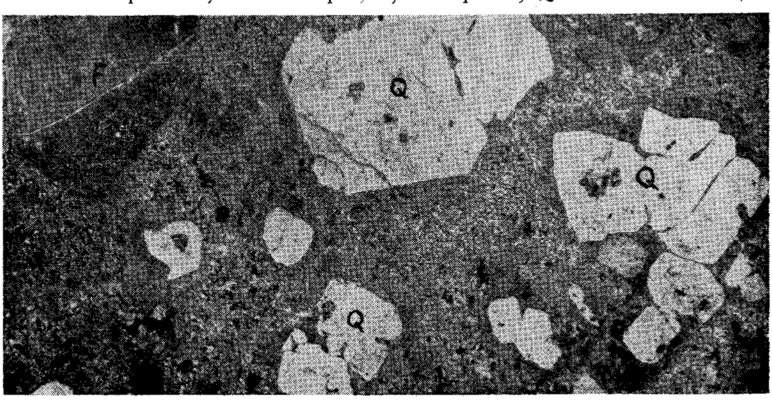
30A. Red tuffaceous silt or mud flow enclosing large angular fragments of fresh granite and other rocks, 14 miles west of Troutdale.

30B. Weathered surface of red conglomerate containing granite boulders, 14 miles west of Troutdale.



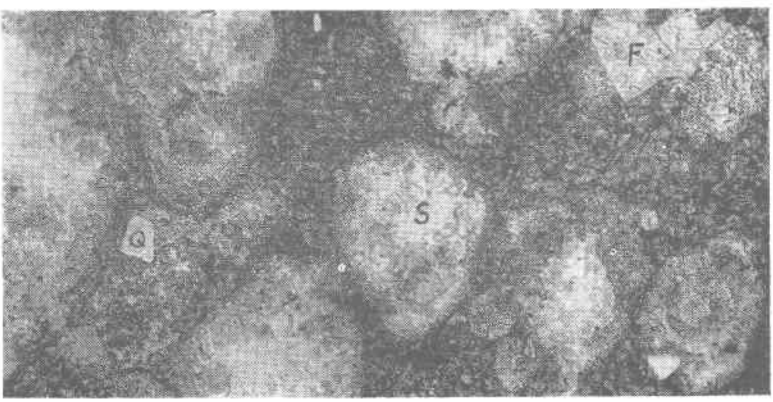
31A. Angular fragments of granite and other rocks in red conglomerate, 14 miles west of Troutdale.

31B. Photomicrograph of spherulitic rhyolite from 3 miles west of Troutdale. Shows round spherulites, S, in a finely spherulitic groundmass with phenocrysts of feldspar, F, and quartz, Q. One nicol. x 12½.

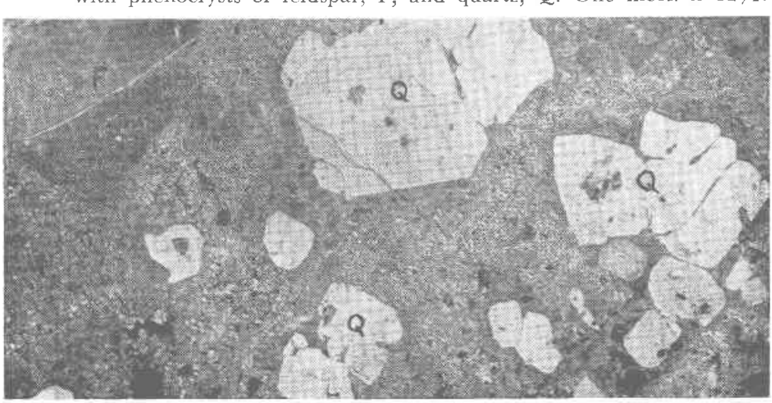


31C. Photomicrograph of porphyritic rhyolite from a dike ½ mile north of Fallville. Phenocrysts of perthite, F, and of quartz, Q, embayed by the groundmass, which has a micrographic texture. One nicol. x 12½.

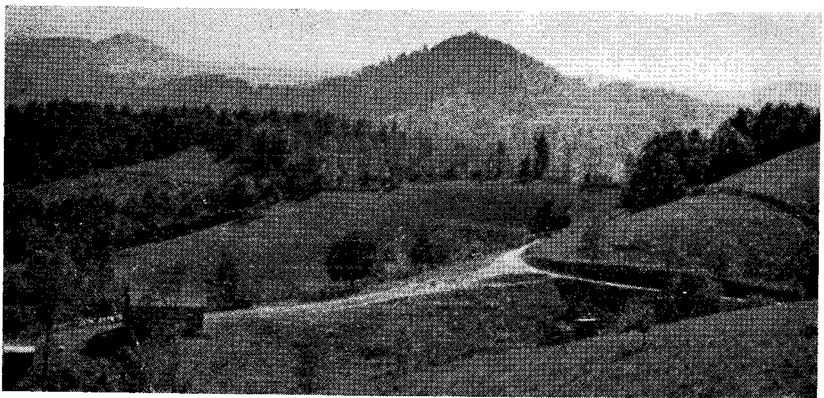
31A. Angular fragments of granite and other rocks in red conglomerate, 14 miles west of Troutdale.



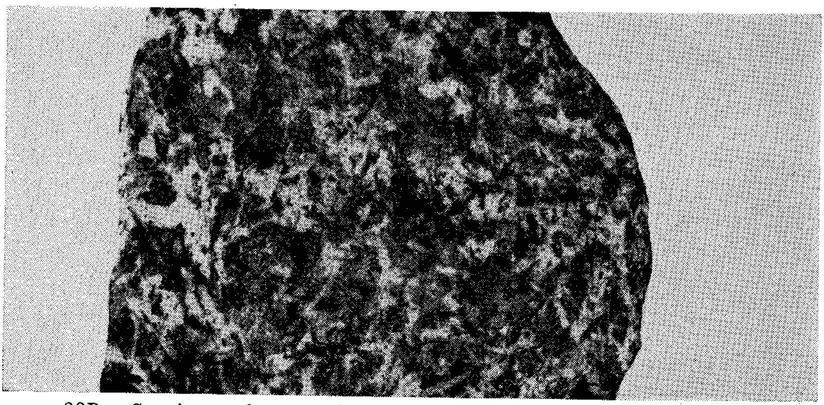
31B. Photomicrograph of spherulitic rhyolite from 3 miles west of Troutdale. Shows round spherulites, S, in a finely spherulitic groundmass with phenocrysts of feldspar, F, and quartz, Q. One nicol. x 12½.



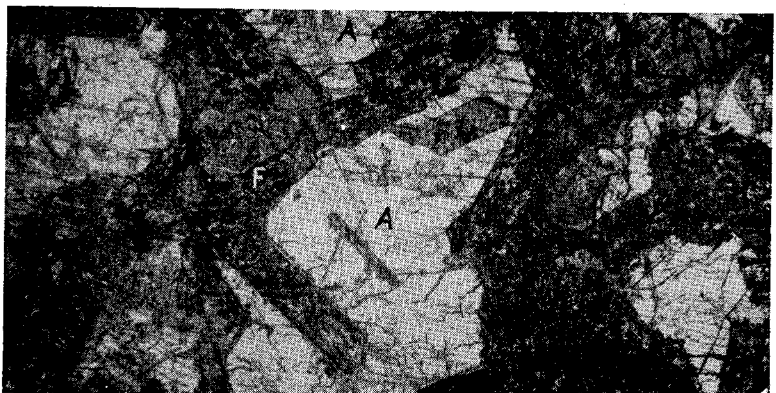
31C. Photomicrograph of porphyritic rhyolite from a dike ½ mile north of Fallville. Phenocrysts of perthite, F, and of quartz, Q, embayed by the groundmass, which has a micrographic texture. One nicol. x 12½.



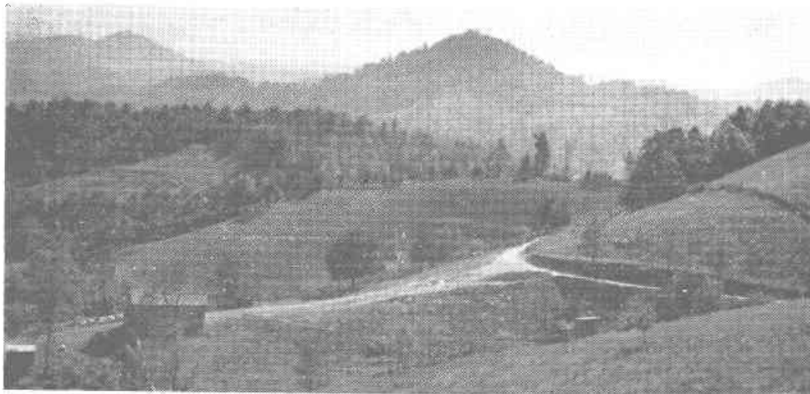
32A. Stevens Knob, composed largely of rhyolite dikes. Looking south from Iron Mountain. Turkey Knob in left distance.



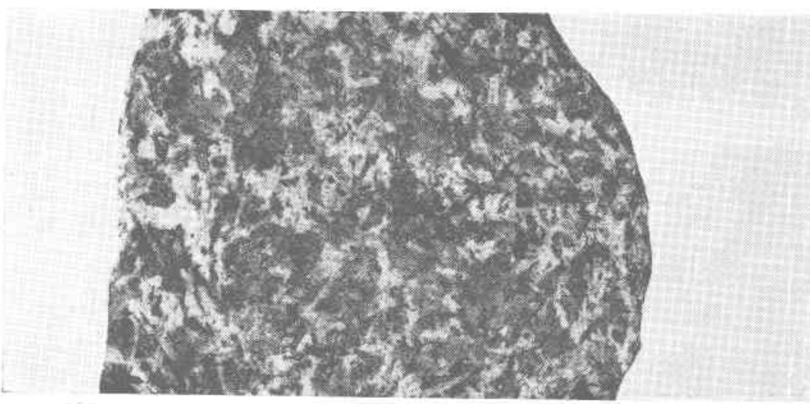
32B. Specimen of porphyritic diabase, from ½ mile east of Fallville.



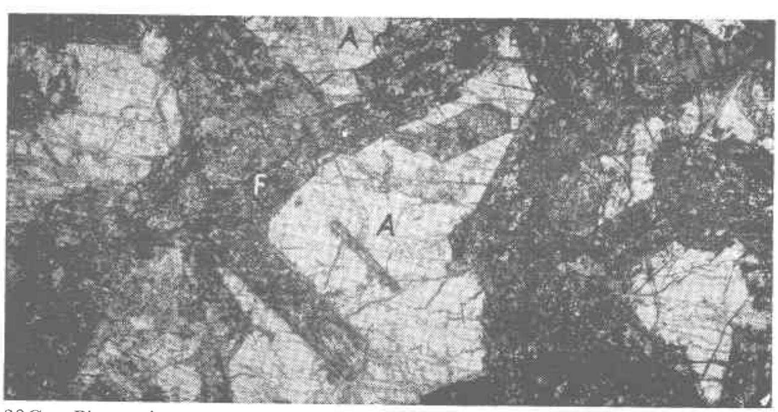
32C. Photomicrograph of diabase from ½ mile east of Fallville. Feldspar laths, much altered, F, enveloped by augite crystals, A. Crossed nicols. x 12½.



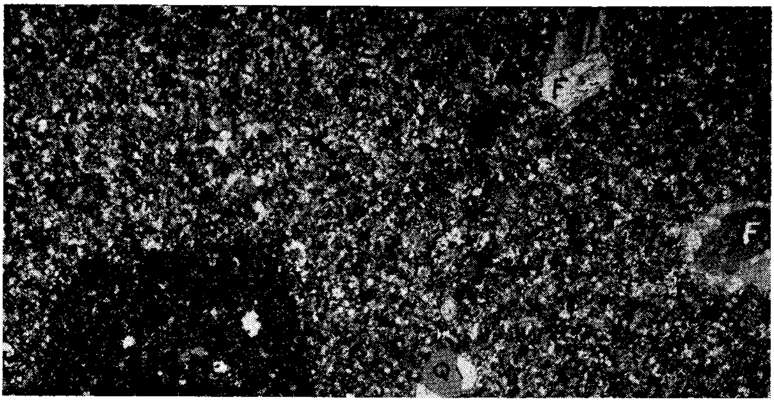
32A. Stevens Knob, composed largely of rhyolite dikes. Looking south from Iron Mountain. Turkey Knob in left distance.



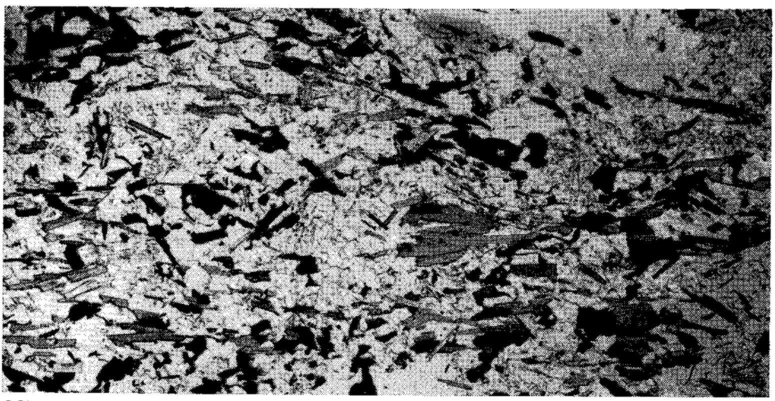
32B. Specimen of porphyritic diabase, from ½ mile east of Fallville.



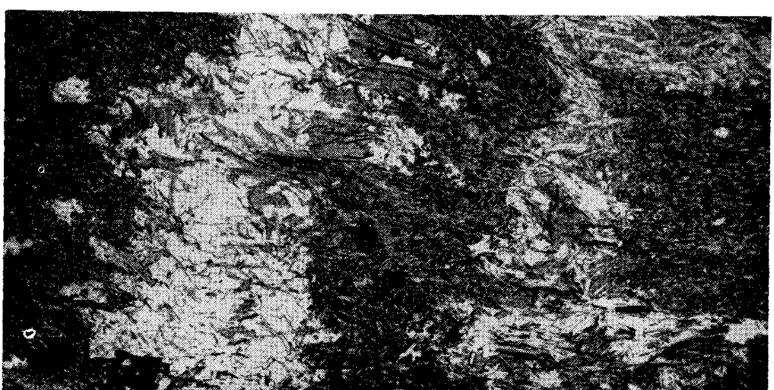
32C. Photomicrograph of diabase from ½ mile east of Fallville. Feldspar laths, much altered, F, enveloped by augite crystals, A. Crossed nicols. x 12½.



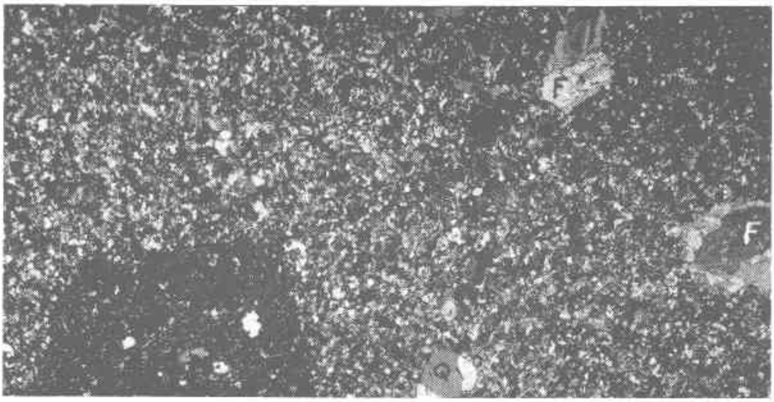
33A. Photomicrograph of porphyritic rhyolite from western 40 feet of dike ½ mile east of Fallville. Feldspar, F, and quartz. Q, phenocrysts in cryptocrystalline groundmass; dark area is inclusion. Crossed nicols. x 12½.



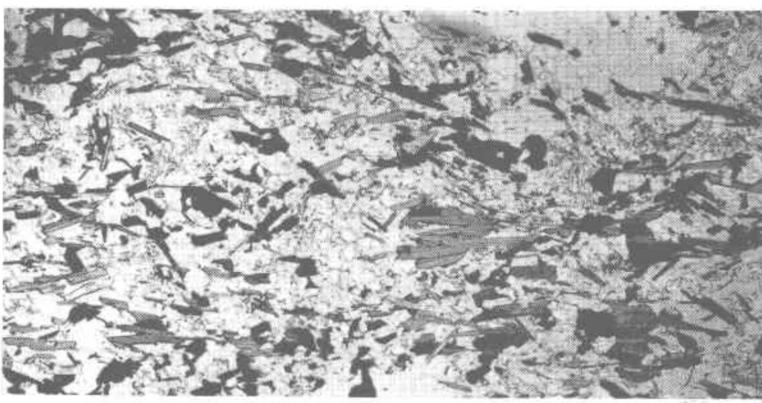
33B. Photomicrograph of Lynchburg gneiss from near Chisel Knob. Shows muscovite and biotite blades (gray or dark), with quartz and feldspar. One nicol. x 12½.



33C. Photomicrograph of muscovite-garnet schist from Fisher Peak. Shows quartzose layers (light) with transposition cleavage in the darker layers of muscovite and chlorite. Garnets are black. One nicol. x 12½.

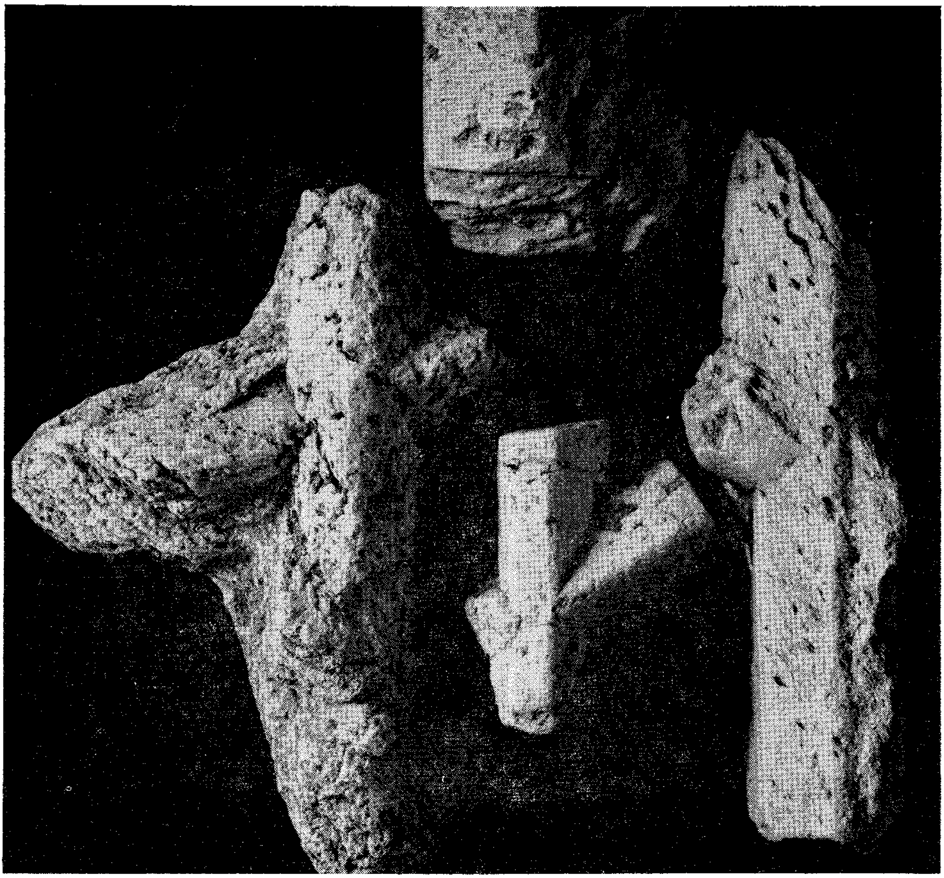


33A. Photomicrograph of porphyritic rhyolite from western 40 feet of dike ½ mile east of Fallville. Feldspar, F, and quartz. Q, phenocrysts in cryptocrystalline groundmass; dark area is inclusion. Crossed nicols. x 12½.

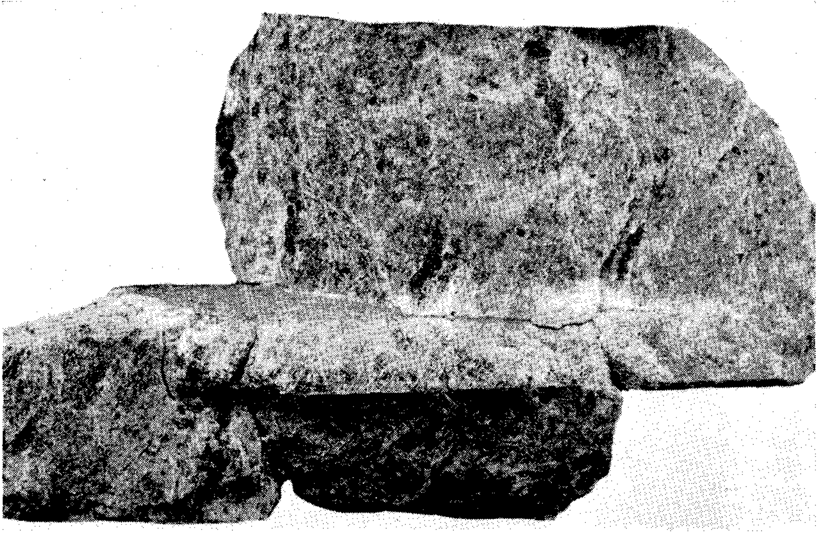


33B. Photomicrograph of Lynchburg gneiss from near Chisel Knob. Shows muscovite and biotite blades (gray or dark), with quartz and feldspar. One nicol. x 12½.

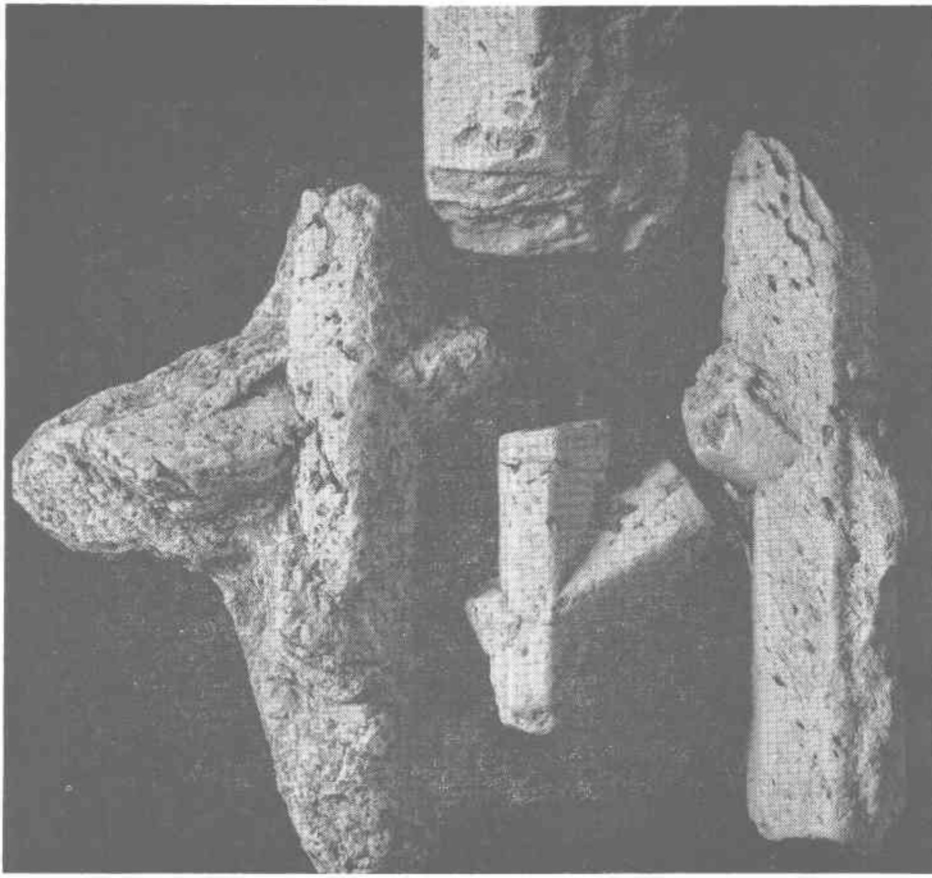
33C. Photomicrograph of muscovite-garnet schist from Fisher Peak. Shows quartzose layers (light) with transposition cleavage in the darker layers of muscovite and chlorite. Garnets are black. One nicol. x 12½.



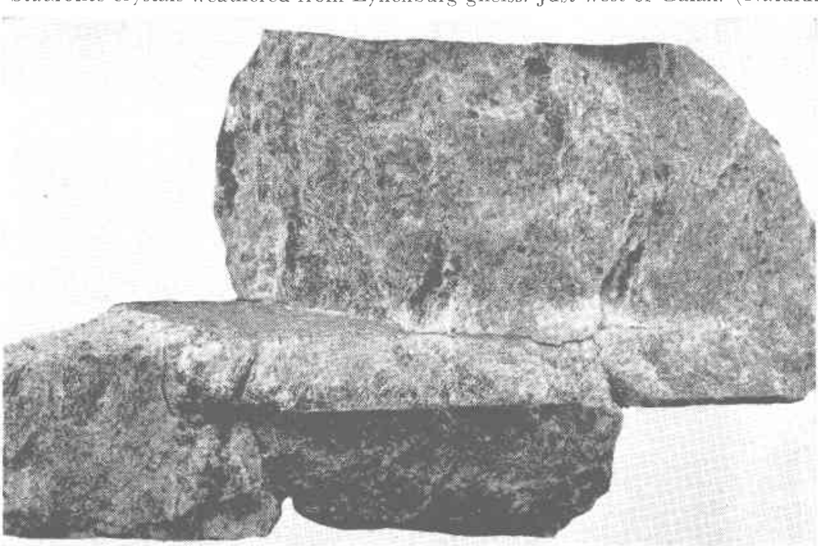
34A. Staurolite crystals weathered from Lynchburg gneiss. Just west of Galax. (Natural size.)



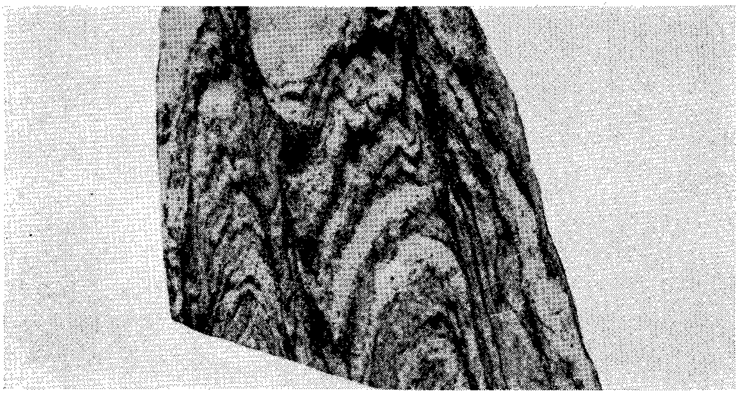
34B. Specimen of fresh staurolite crystals from muscovite schist, U. S. Route 58, east of Chestnut Creek, Galax. (Natural size.)



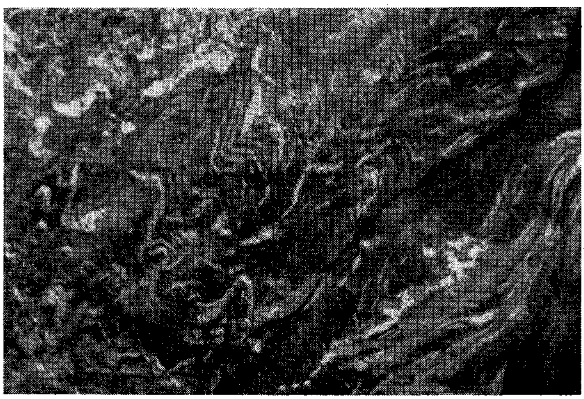
34A. Staurolite crystals weathered from Lynchburg gneiss. Just west of Galax. (Natural size.)



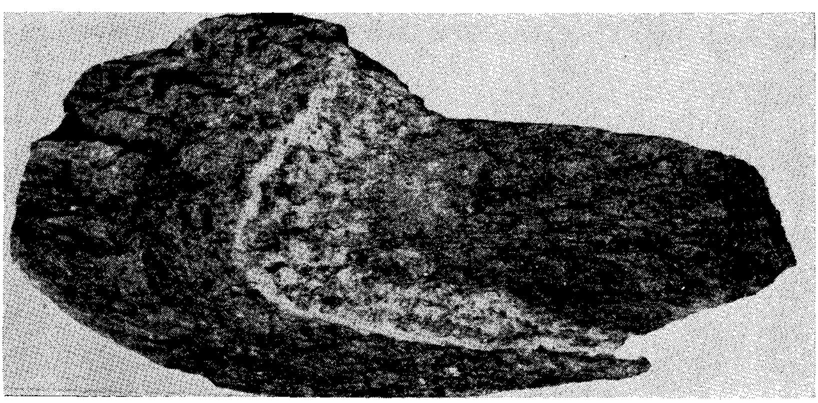
34B. Specimen of fresh staurolite crystals from muscovite schist, U. S. Route 58, east of Chestnut Creek, Galax. (Natural size.)



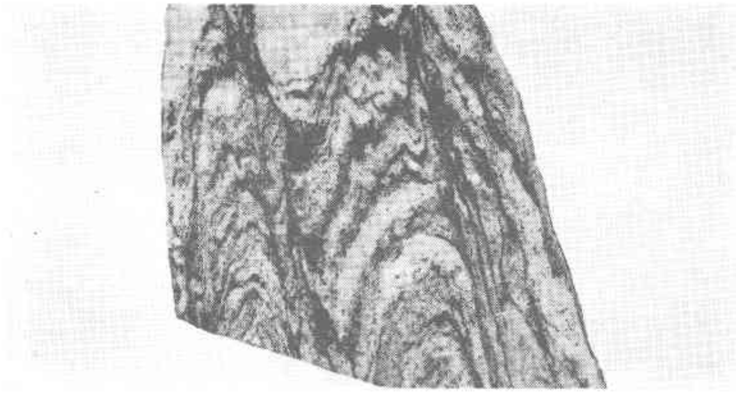
35A. Specimen of folded biotite gneiss (Lynchburg), showing transposition cleavage. From U. S. Route 52, south of Fancy Gap.



35B. Contorted Lynchburg gneiss showing pitching folds. Blue Ridge Parkway, west of the district.

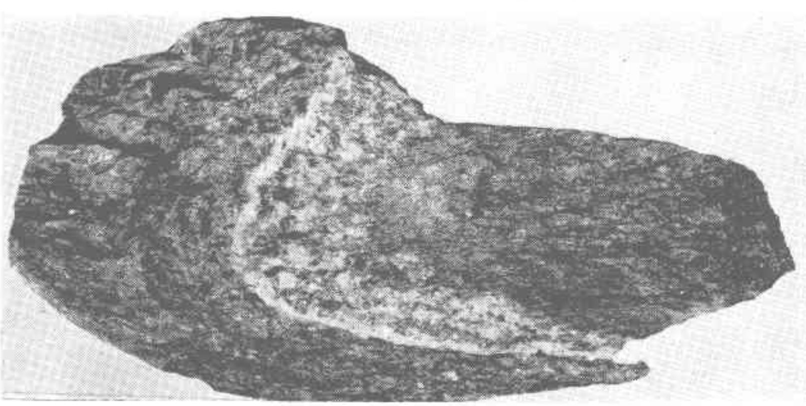


35C. Specimen of ferruginous schist in Lynchburg gneiss, from Mill Creek north of U. S. Route 58.

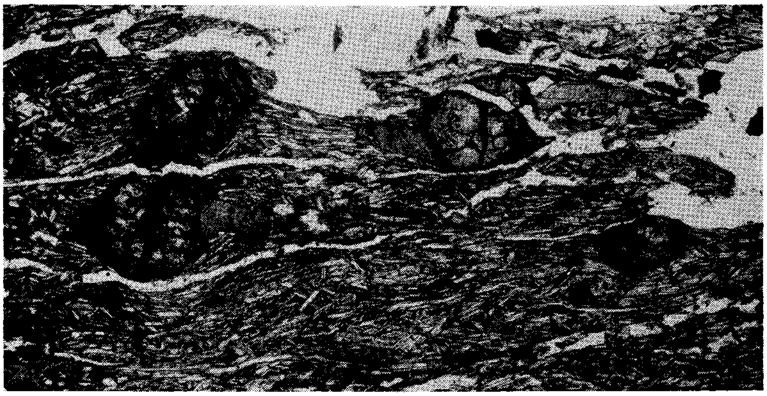


35A. Specimen of folded biotite gneiss (Lynchburg), showing transposition cleavage. From U. S. Route 52, south of Fancy Gap.

35B. Contorted Lynchburg gneiss showing pitching folds. Blue Ridge Parkway, west of the district.

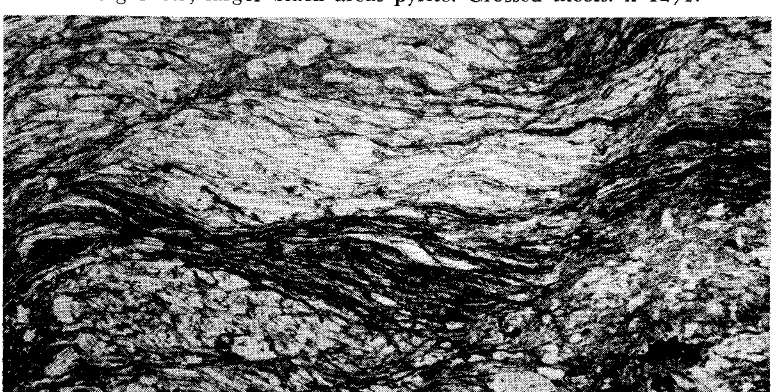


35C. Specimen of ferruginous schist in Lynchburg gneiss, from Mill Creek north of U. S. Route 58.

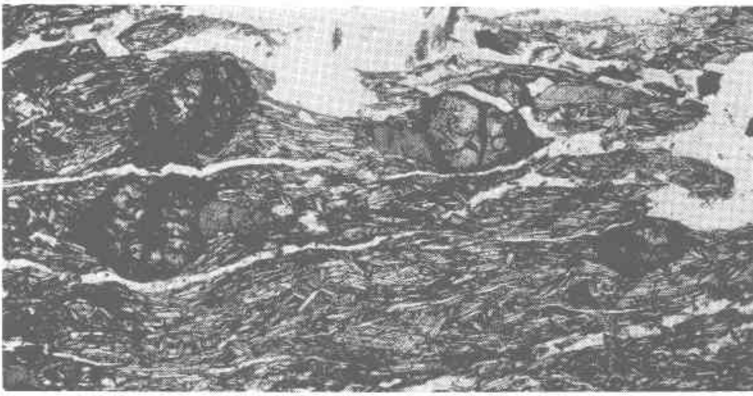


36A. Photomicrograph of garnet-mica schist from near Iron Ridge. Garnets, (dark) have a rim of chlorite, which penetrates the cracks and forms "tails" at the ends of the garnets. One nicol. x 12½.

36B. Photomicrograph of ferruginous mica schist from Mill Creek. Closely crinkled biotite layers made dark by fine iron dust. The black specks are garnets; larger black areas pyrite. Crossed nicols. x 12½.

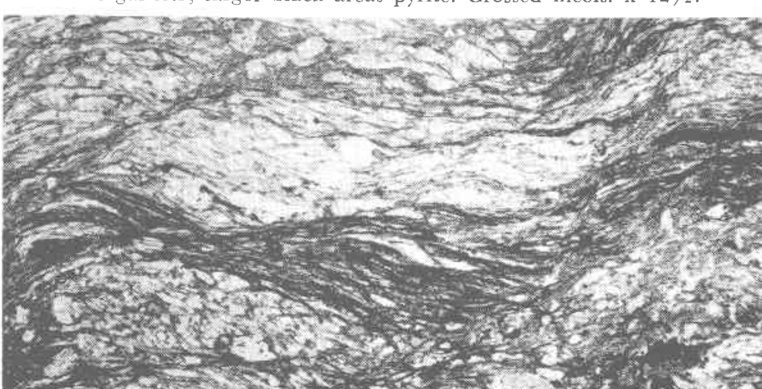


36C. Photomicrograph of mica schist from Chestnut Creek, ¼ mile south of Stoneman Hill. Lenticular quartzose areas wrapped by muscovite fibers. One nicol. x 12½.



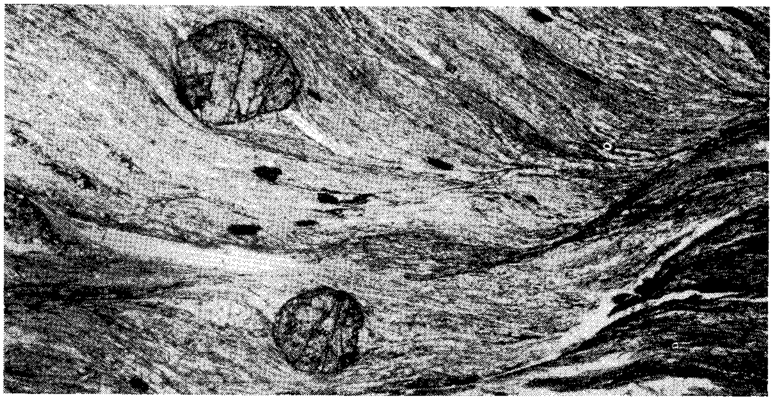
36A. Photomicrograph of garnet-mica schist from near Iron Ridge. Garnets, (dark) have a rim of chlorite, which penetrates the cracks and forms "tails" at the ends of the garnets. One nicol. x 12½.

36B. Photomicrograph of ferruginous mica schist from Mill Creek. Closely crinkled biotite layers made dark by fine iron dust. The black specks are garnets; larger black areas pyrite. Crossed nicols. x 12½.



36C. Photomicrograph of mica schist from Chestnut Creek, ¼ mile south of Stoneman Hill. Lenticular quartzose areas wrapped by muscovite fibers. One nicol. x 12½.

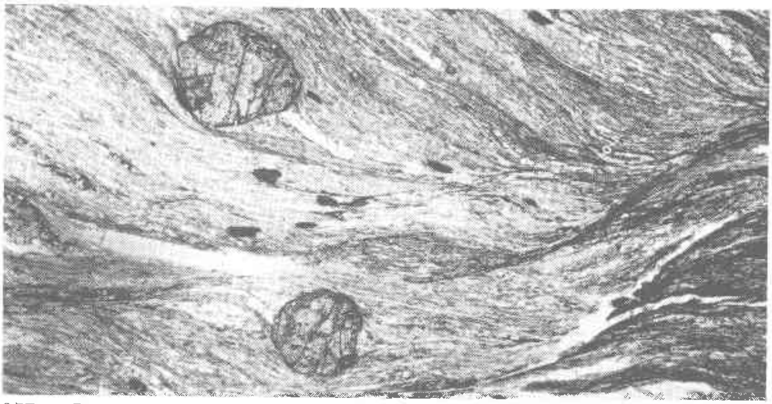
37A. Photomicrograph of mica schist from near Blair Ferry. Close folds, in which mica follows the folds.



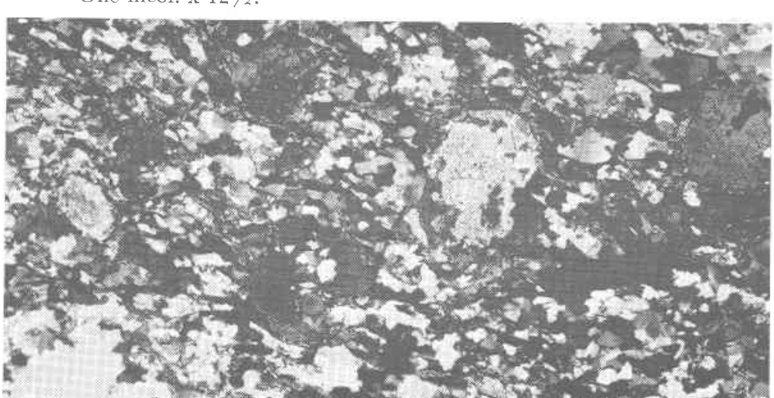
37B. Photomicrograph of lenticular biotite schist from near Todd Ford. Garnet porphyroblasts wrapped by biotite containing fine iron dust. One nicol. x 12½.

37C. Photomicrograph of quartzite from near Hebron. Shows quartz and feldspar grains in quartzose matrix, with biotite and muscovite flakes. Crossed nicols. x 12½.

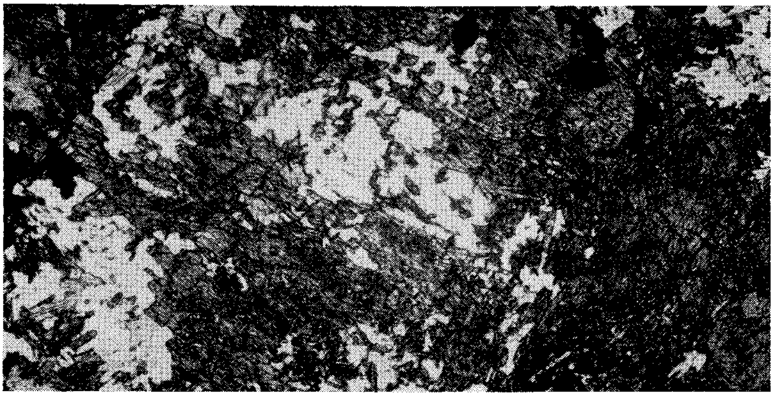
37A. Photomicrograph of mica schist from near Blair Ferry. Close folds, in which mica follows the folds.



37B. Photomicrograph of lenticular biotite schist from near Todd Ford. Garnet porphyroblasts wrapped by biotite containing fine iron dust. One nicol. x 12½.



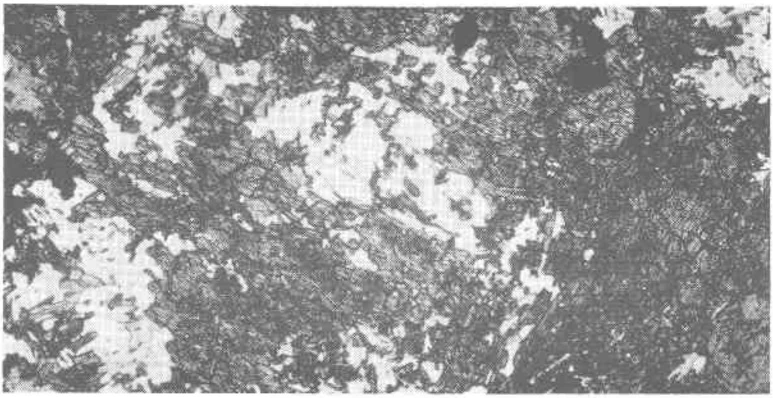
37C. Photomicrograph of quartzite from near Hebron. Shows quartz and feldspar grains in quartzose matrix, with biotite and muscovite flakes. Crossed nicols. x 12½.



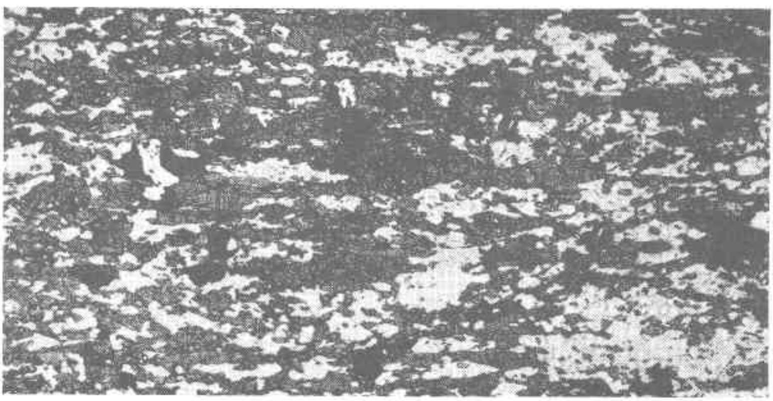
38A. Photomicrograph of hornblende gneiss from near Daniel Branch. Coarse pale-green hornblende (black areas) in crystal groups intergrown with quartz and albite (white). One nicol. x 12½.

38B. Photomicrograph of hornblende gneiss from Meadow Creek. Hornblende crystals are aligned with foliation. Feldspar and quartz show white. Crossed nicols, x 12½.

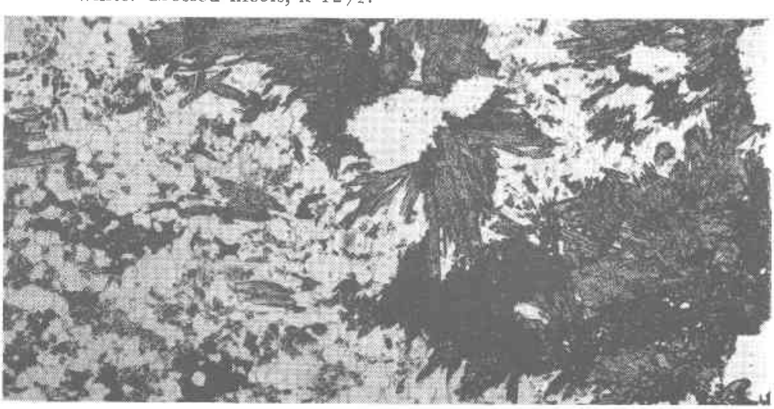
38C. Photomicrograph of actinolite schist from Oldtown. Actinolite fibers (dark) in quartz (light), with epidote and clinozoisite in fine interstitial grains (gray). One nicol. x 12½.



38A. Photomicrograph of hornblende gneiss from near Daniel Branch. Coarse pale-green hornblende (black areas) in crystal groups intergrown with quartz and albite (white). One nicol. x 12½.

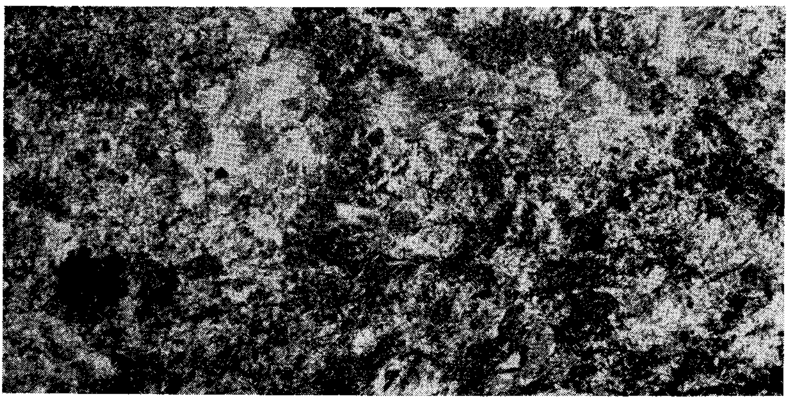


38B. Photomicrograph of hornblende gneiss from Meadow Creek. Hornblende crystals are aligned with foliation. Feldspar and quartz show white. Crossed nicols, x 12½.

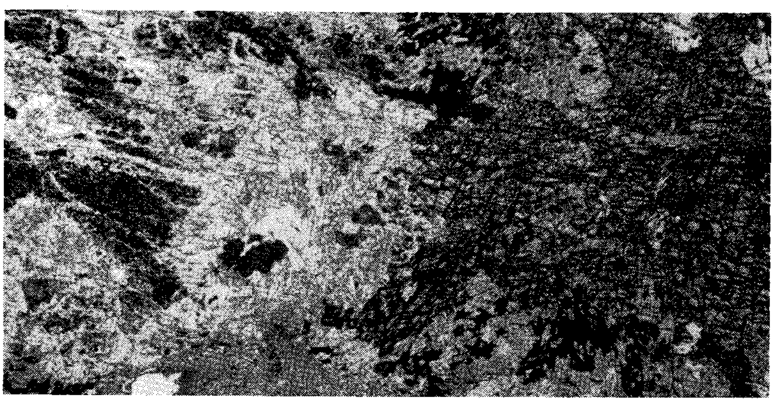


38C. Photomicrograph of actinolite schist from Oldtown. Actinolite fibers (dark) in quartz (light), with epidote and clinozoisite in fine interstitial grains (gray). One nicol. x 12½.

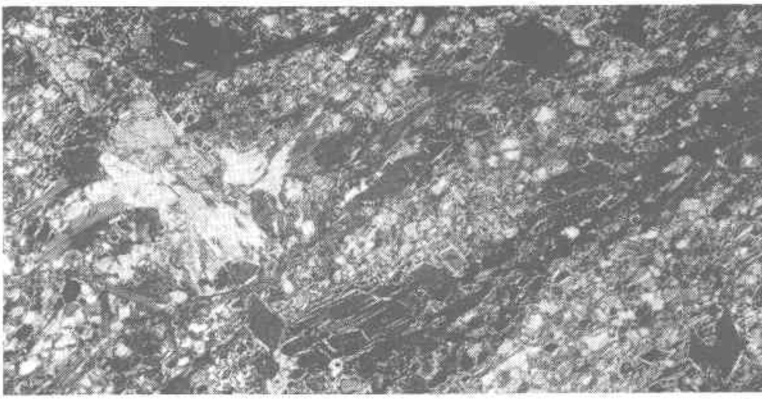
39A. Photomicrograph of metaperidotite from near Edmonds. Shows residual grains of olivine with serpentine in cracks (dark). Long blades of hematite (black) and talc and chrysotile fibers (mostly light). Crossed nicols. x 12½.



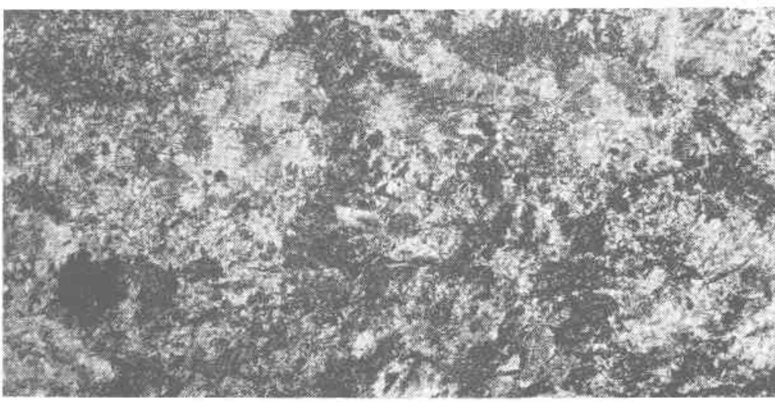
39B. Photomicrograph of serpentine from Blue Ridge Mill. Serpentine is in dark felty fibers. Talc blades are light. Crossed nicols. x 12½.



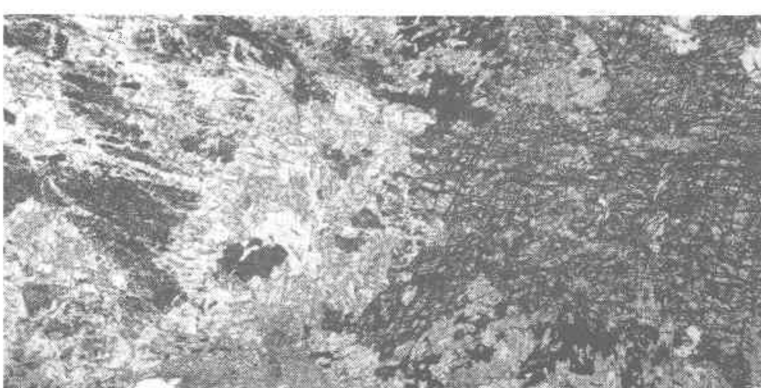
39C. Photomicrograph of metapyroxenite from southwest of Baywood. Enstatite crystal showing cleavage altered to talc and chrysotile fibers (white). Iron oxide, tremolite, and epidote show dark. Crossed nicols. x 12½.



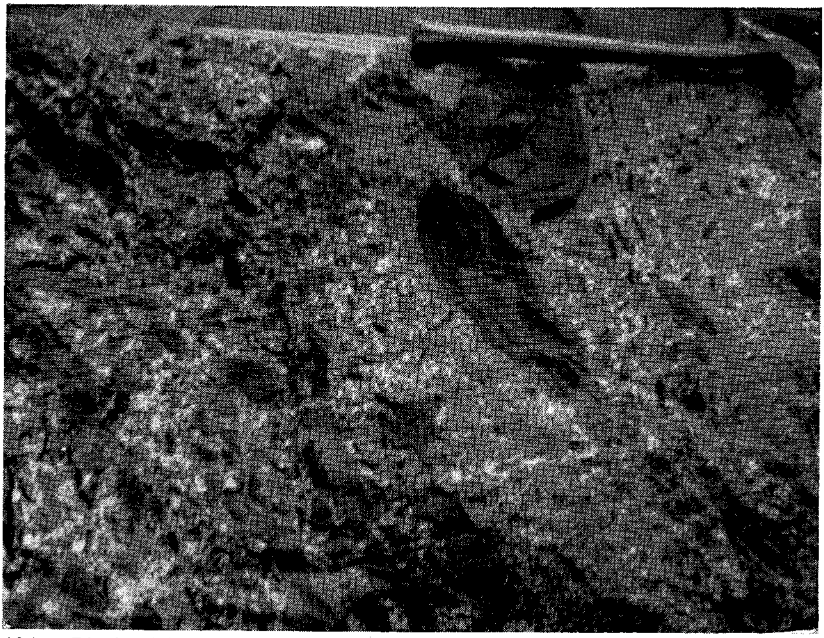
39A. Photomicrograph of metaperidotite from near Edmonds. Shows residual grains of olivine with serpentine in cracks (dark). Long blades of hematite (black) and talc and chrysotile fibers (mostly light). Crossed nicols. x 12½.



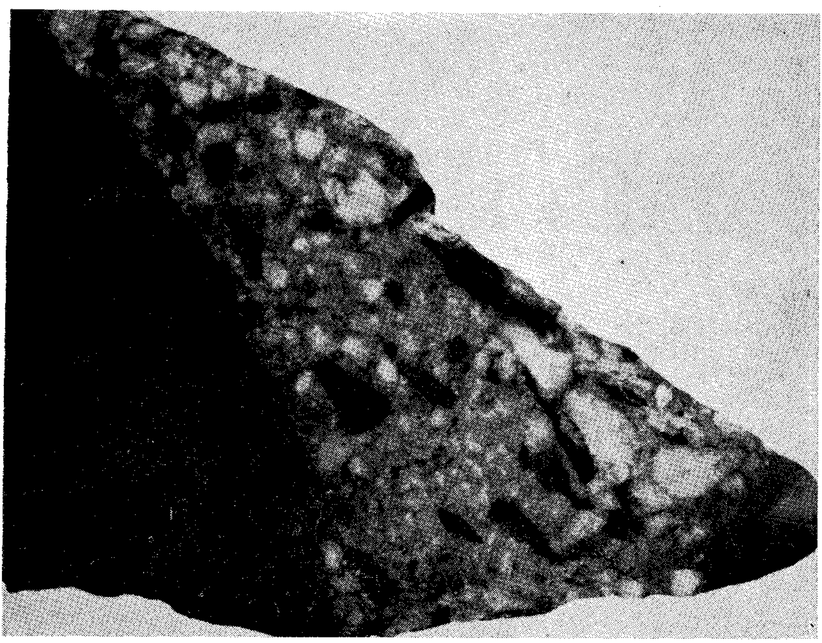
39B. Photomicrograph of serpentine from Blue Ridge Mill. Serpentine is in dark felty fibers. Talc blades are light. Crossed nicols. x 12½.



39C. Photomicrograph of metapyroxenite from southwest of Baywood. Enstatite crystal showing cleavage altered to talc and chrysotile fibers (white). Iron oxide, tremolite, and epidote show dark. Crossed nicols. x 12½.

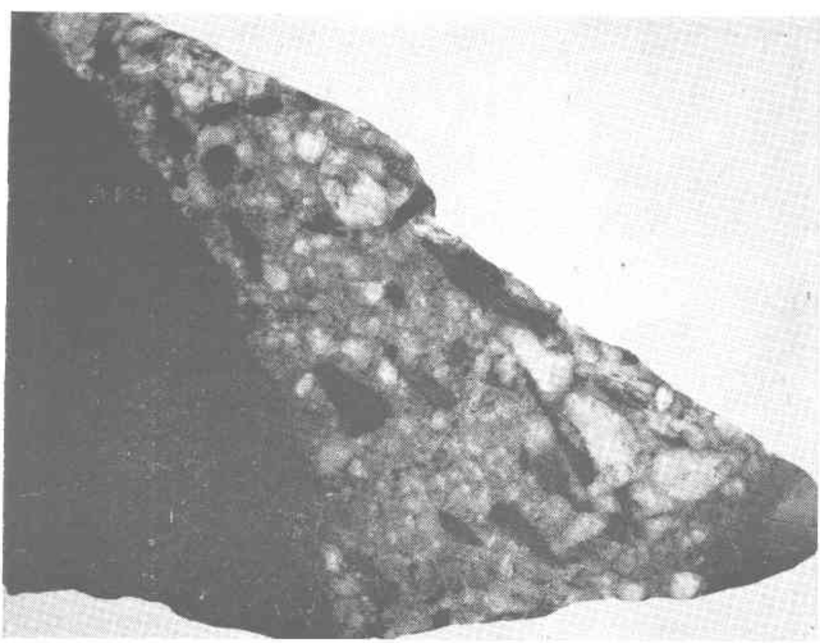


40A. Block of black-pebble conglomerate from Unicoi formation. U. S. Route 21, ¾ mile south of Dry Run Gap.

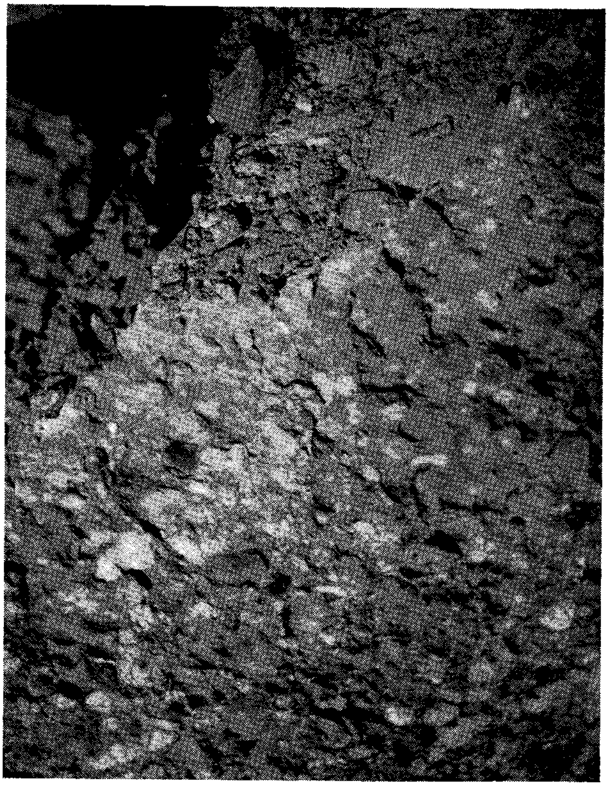


40B. Polished specimen of black-pebble conglomerate and adjacent source bed from same locality. Natural size.

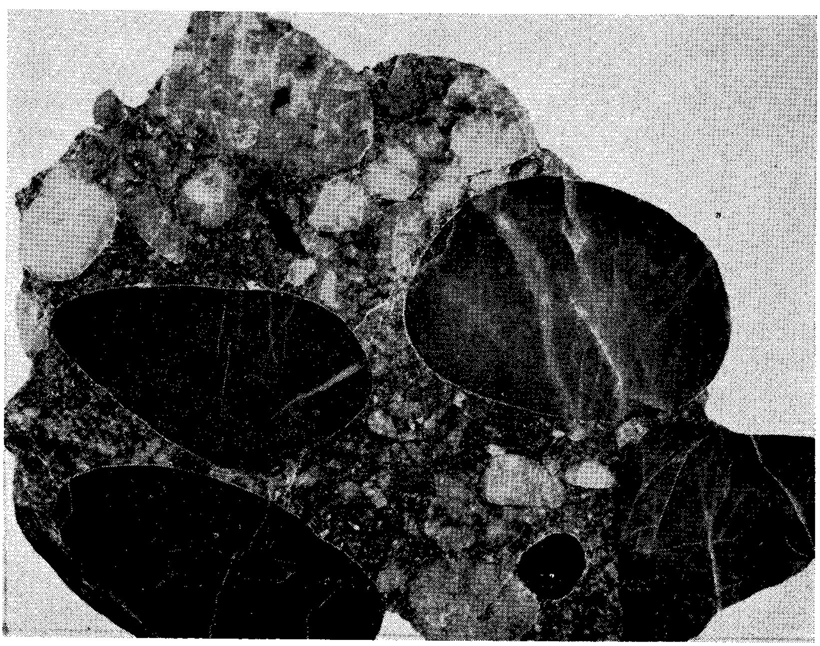
40A. Block of black-pebble conglomerate from Unicoi formation. U. S. Route 21, ¾ mile south of Dry Run Gap.



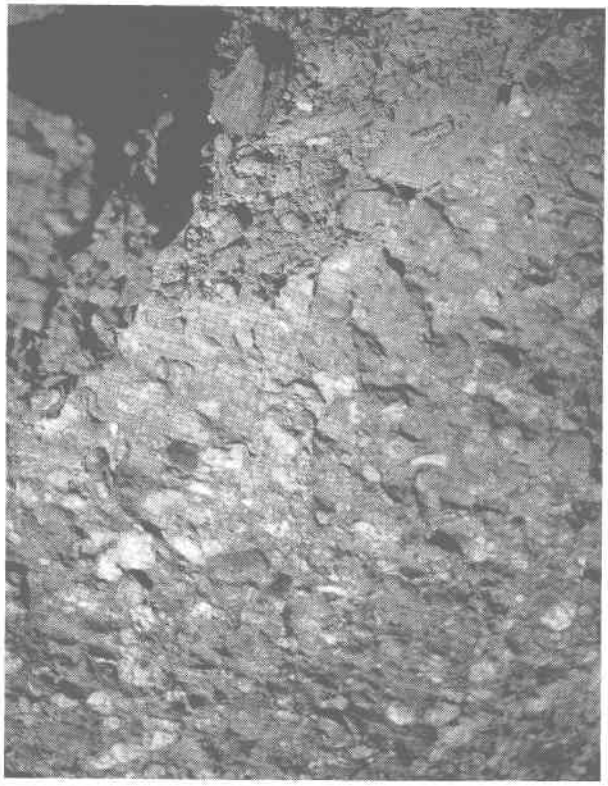
40B. Polished specimen of black-pebble conglomerate and adjacent source bed from same locality. Natural size.



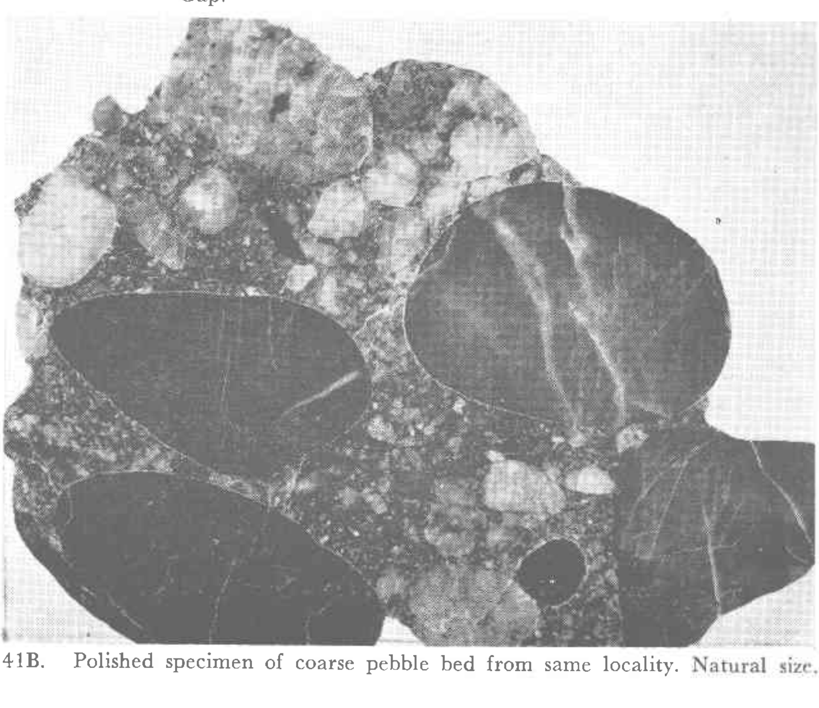
41A. Coarse pebble bed in middle member of Unicoi formation. U. S. Route 21, ¾ mile south of Dry Run Gap.



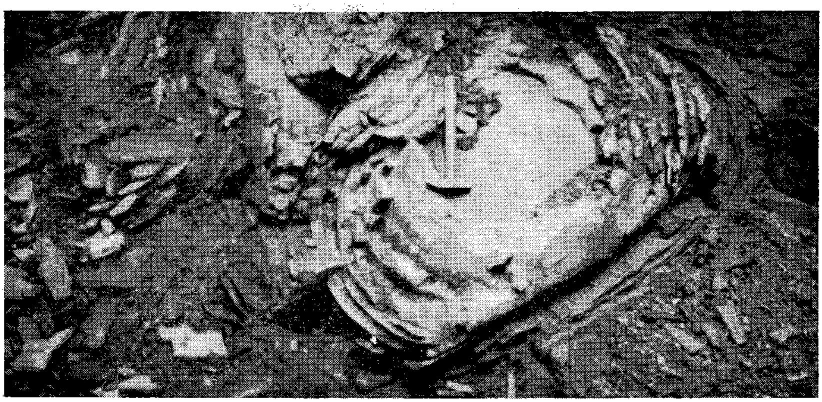
41B. Polished specimen of coarse pebble bed from same locality. Natural size.



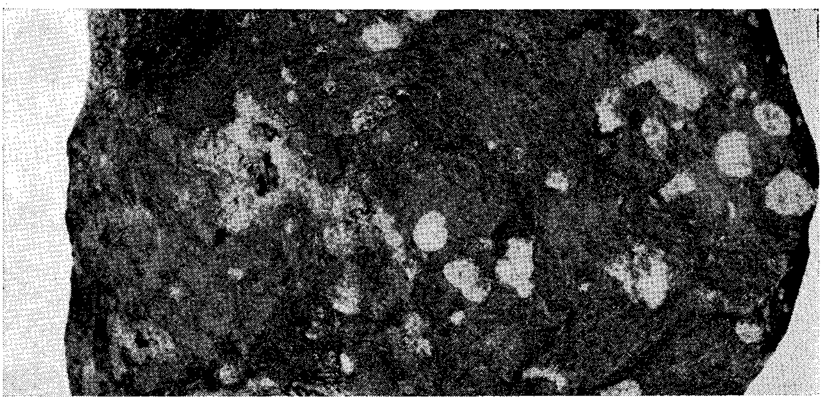
41A. Coarse pebble bed in middle member of Unicoi formation. U. S. Route 21, ¾ mile south of Dry Run Gap.



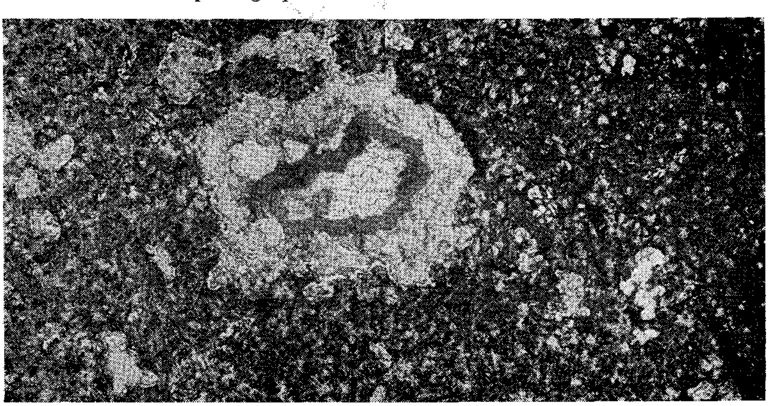
41B. Polished specimen of coarse pebble bed from same locality. Natural size.



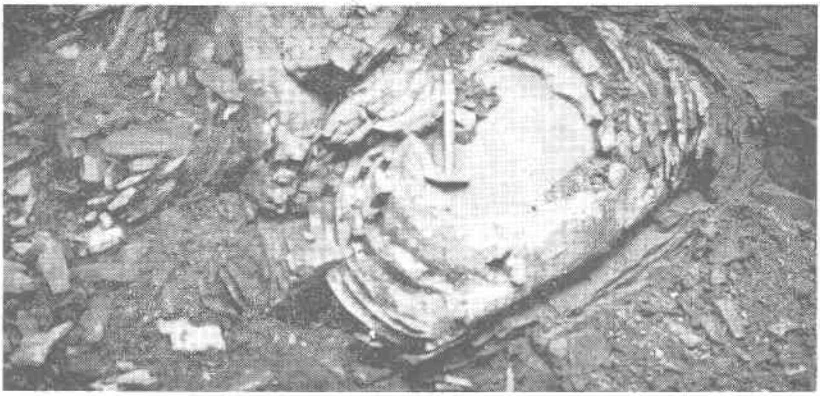
42A. Spheroidal weathering of homogeneous arkosic quartzite in the Unicoi formation. State Highway 94, north of White Oak Grove School.



42B. Specimen of basalt from Unicoi formation. From 1½ miles north of Spring Valley. Bluish-green basalt with amygdules filled with pink feldspar, which show white in photograph. Natural size.



42C. Photomicrograph of green basalt from same locality as Plate 42B. Shows fine groundmass composed of feldspar laths. Chlorite and actinolite replaced by hematite. The large circular vesicle has a border and center of calcite (white) and a medial dark band of chlorite. One nicol. x 12½.



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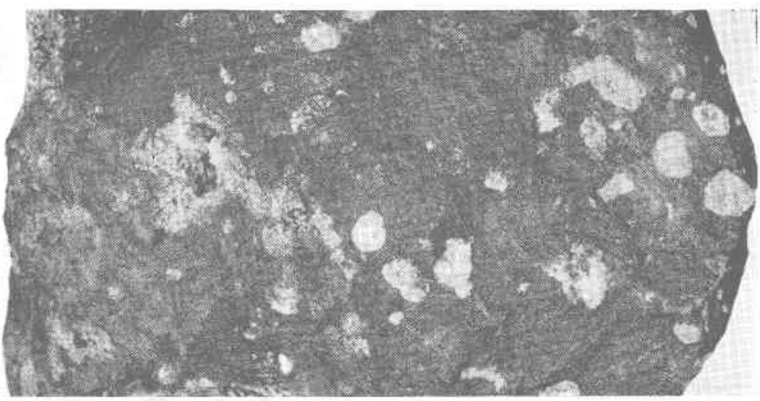

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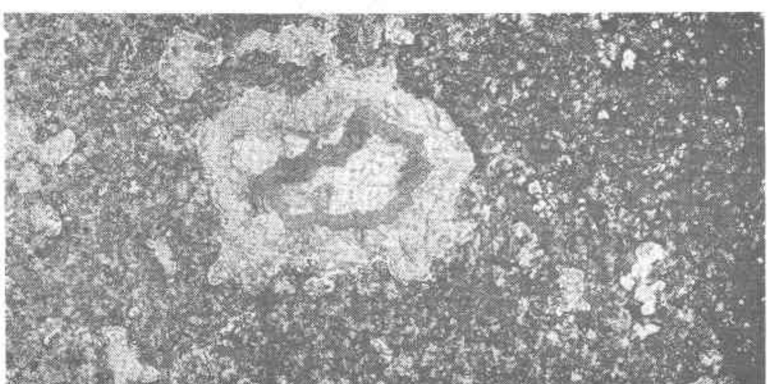

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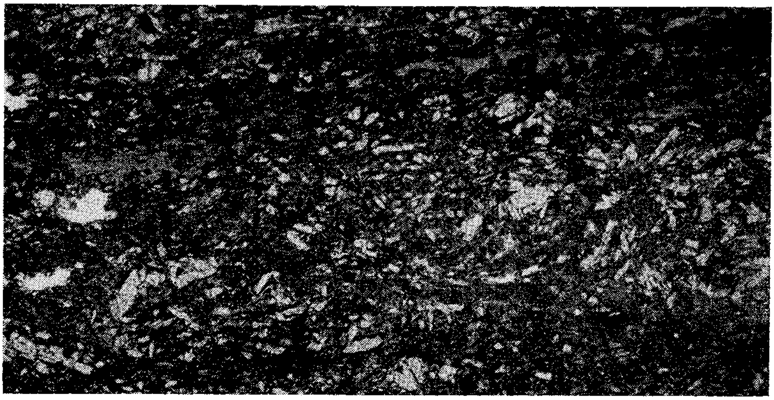
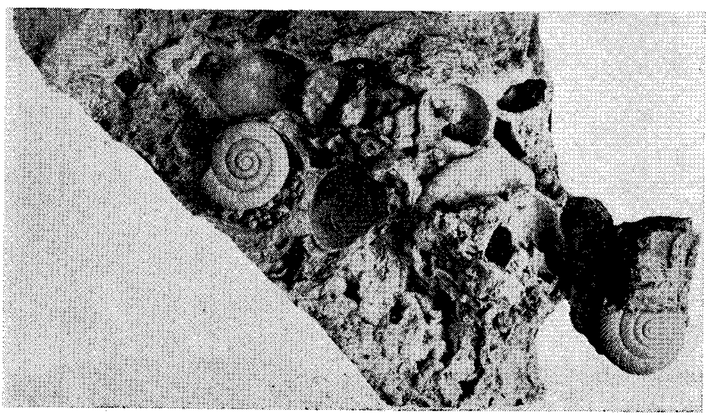
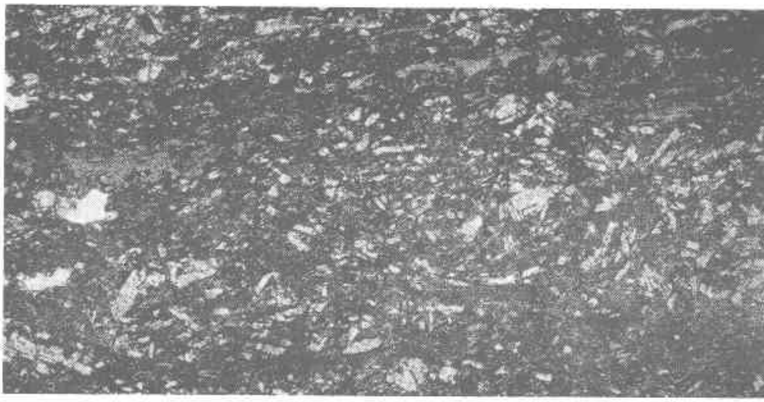


43A. Photomicrograph of schistose basalt from the falls on Poor Branch near McGee School. Composed of laths of feldspar (light) in a groundmass of hornblende, chlorite, and epidote which exhibits a schistose structure. One nicol. x 12½.

43B. Specimen of schistose basalt with shiny black ribbons of chlorite, representing drawn-out flattened amygdules. From near Fowler Ferry.



43C. Fossil land snails in travertine from a cave in Vintage dolomite, 1½ miles east of Ivanhoe.



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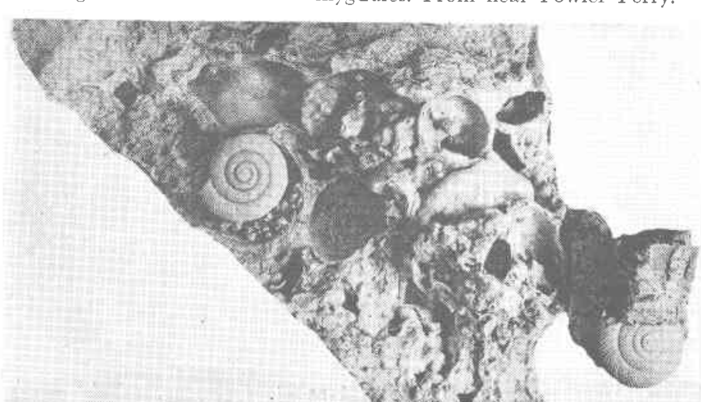
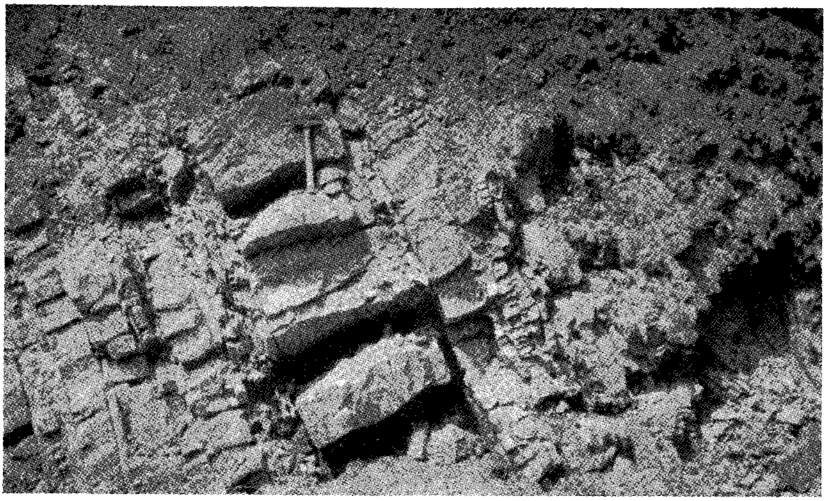
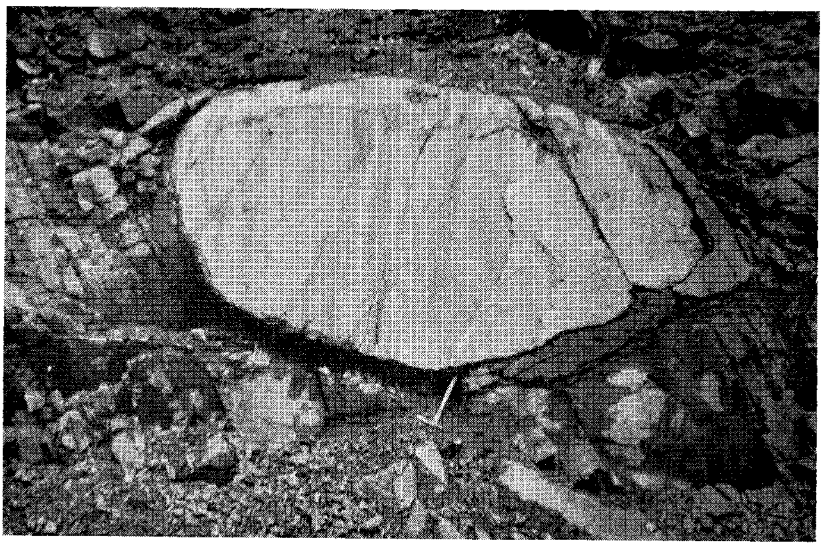


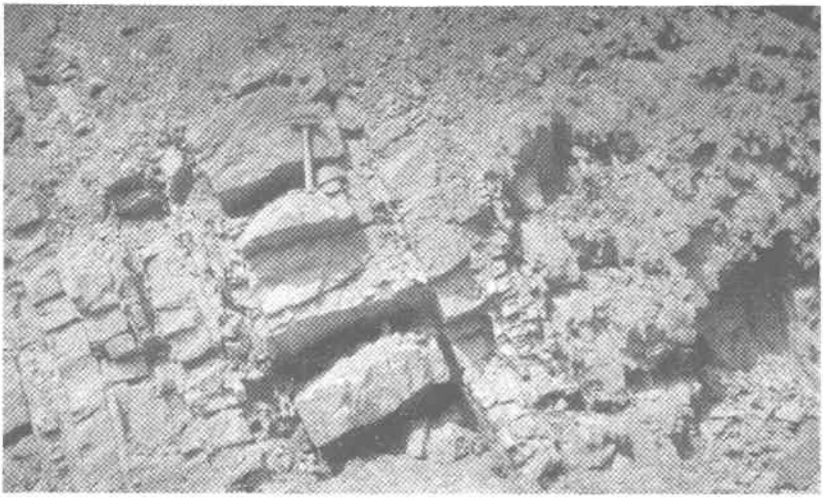
43C. Fossil land snails in travertine from a cave in Vintage dolomite, 1½ miles east of Ivanhoe.



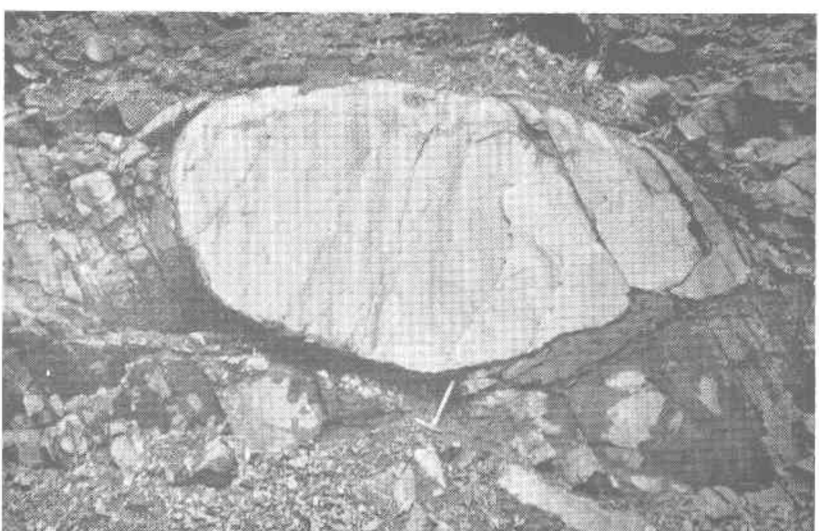
44A. Layers of quartzite in Hampton shale. U. S. Route 21, north of Dry Run Gap. (Photograph by L. W. Currier.)



44B. Concretionary mass of sandstone in Hampton shale. In deep cut at Dry Run Gap on U. S. Route 21.



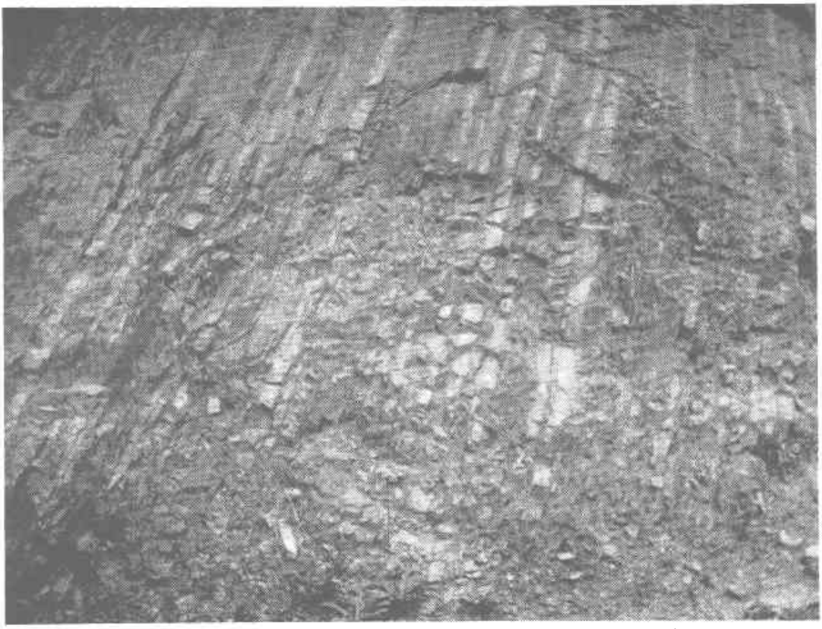
44A. Layers of quartzite in Hampton shale. U. S. Route 21, north of Dry Run Gap. (Photograph by L. W. Currier.)



44B. Concretionary mass of sandstone in Hampton shale. In deep cut at Dry Run Gap on U. S. Route 21.

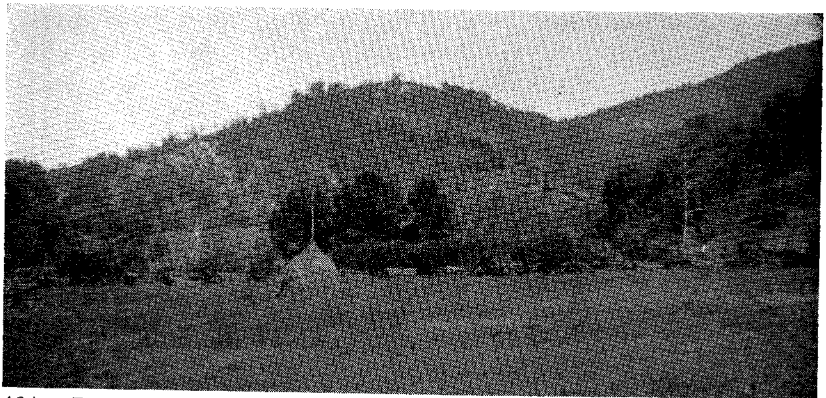
45A. Rhythmically banded quartzite and shale in lower member of Erwin quartzite. U. S. Route 52, 1 mile south of Poplar Camp.

45B. Well-bedded Erwin quartzite, rhythmically banded at the right. U. S. Route 21, north of Henley Hollow.

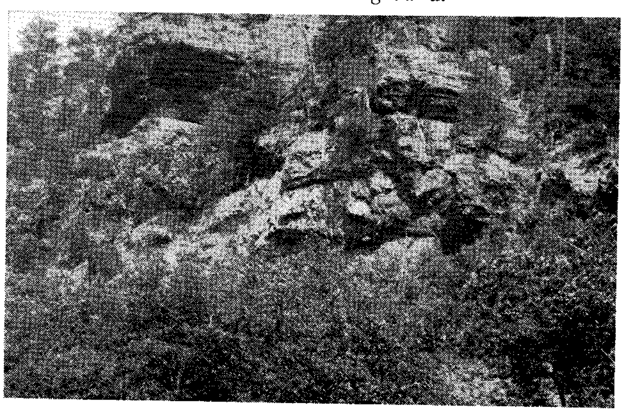


45A. Rhythmically banded quartzite and shale in lower member of Erwin quartzite. U. S. Route 52, 1 mile south of Poplar Camp.

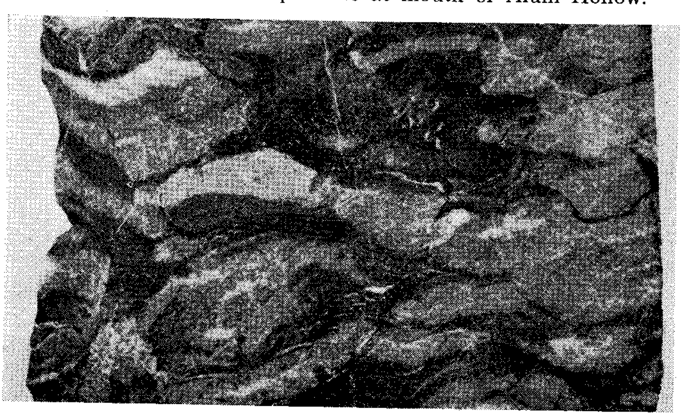
45B. Well-bedded Erwin quartzite, rhythmically banded at the right. U. S. Route 21, north of Henley Hollow.



46A. Dry Pond Mountain at mouth of Alum Hollow. The Erwin quartzite in the promontory at the left is thrust over Shady dolomite at the left base of the hill and in the lowland in the foreground.

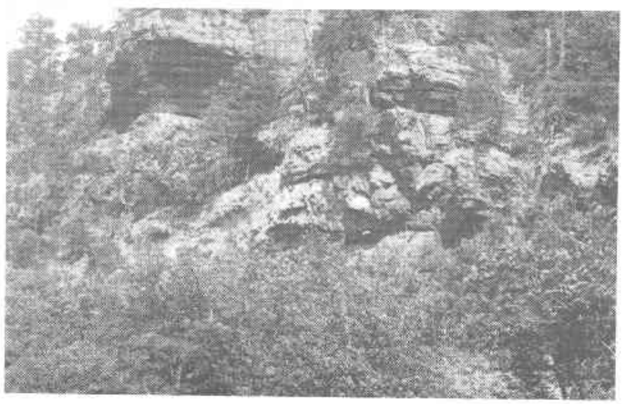


46B. Cliffs of Erwin quartzite at mouth of Alum Hollow.



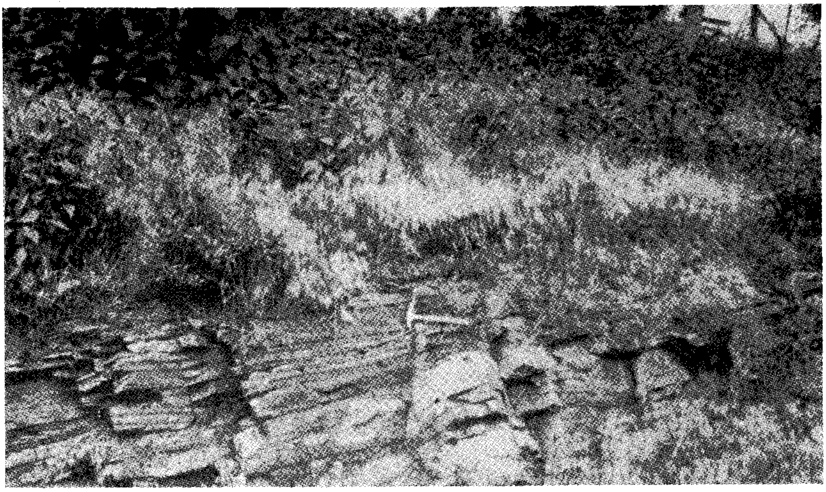
46C. Specimen of irregularly banded blue argillaceous limestone and coarse white dolomite of the Patterson member of the Shady dolomite. West of Speedwell.

46A. Dry Pond Mountain at mouth of Alum Hollow. The Erwin quartzite in the promontory at the left is thrust over Shady dolomite at the left base of the hill and in the lowland in the foreground.

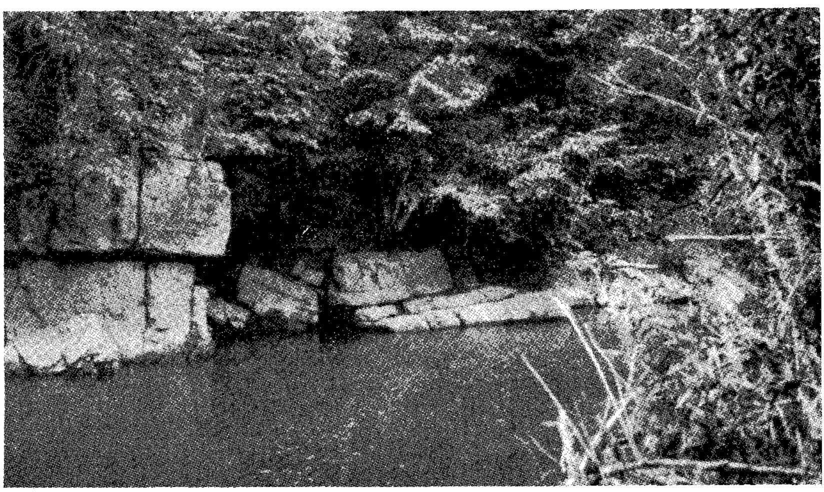


46B. Cliffs of Erwin quartzite at mouth of Alum Hollow.

46C. Specimen of irregularly banded blue argillaceous limestone and coarse white dolomite of the Patterson member of the Shady dolomite. West of Speedwell.

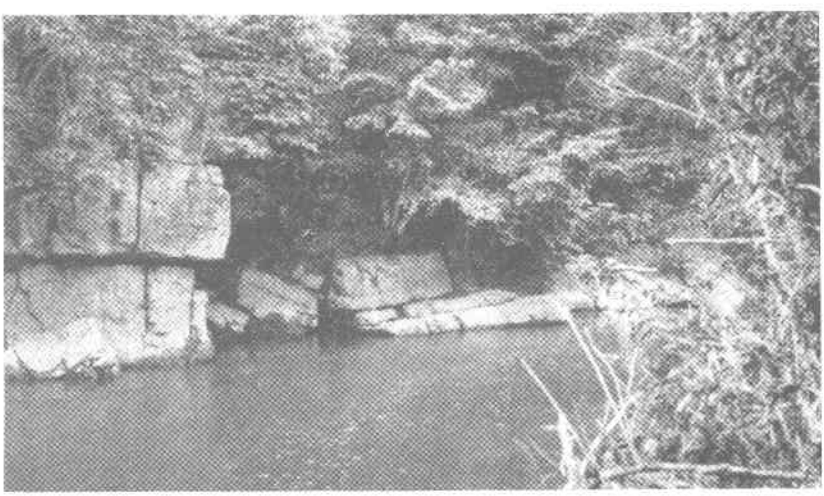


47A. Erwin quartzite, thin-bedded at top. U. S. Route 52, ½ mile southeast of Galena. (Photograph by L. W. Currier.)

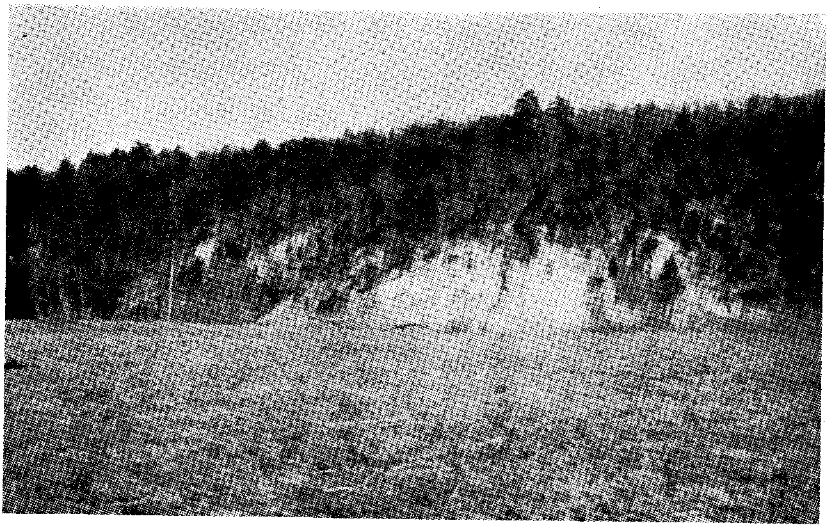


47B. Massive dolomite in the Patterson member of the Shady dolomite on Little Reed Island Creek, ¾ mile southwest of Boom Furnace. (Photograph by L. W. Currier.)

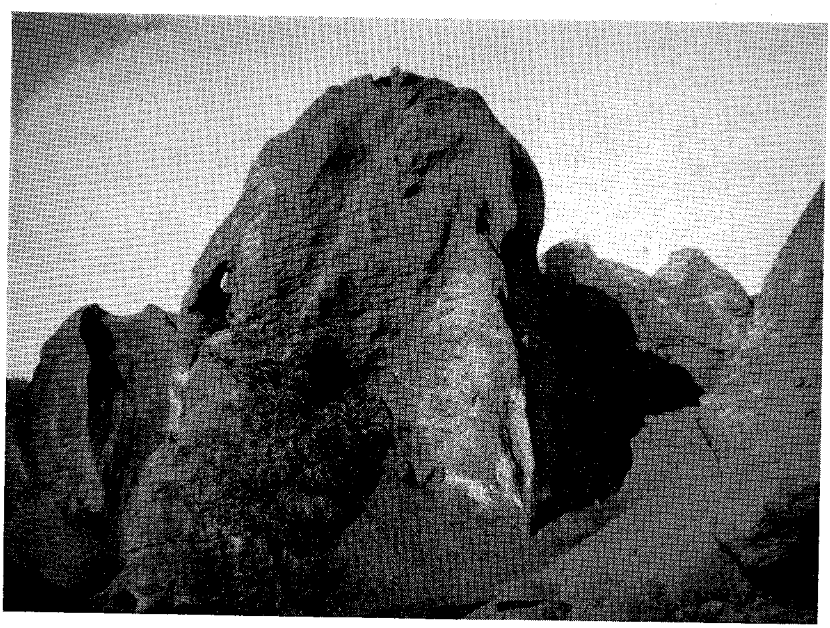
47A. Erwin quartzite, thin-bedded at top. U. S. Route 52, ½ mile southeast of Galena. (Photograph by L. W. Currier.)



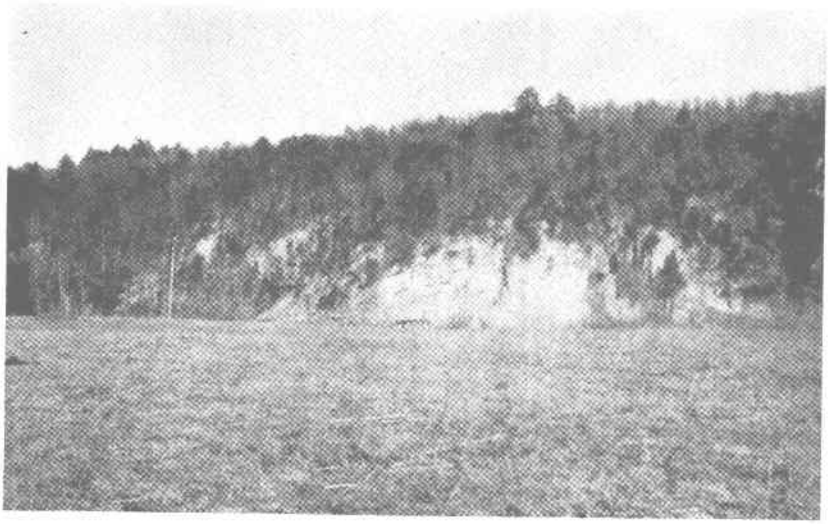
47B. Massive dolomite in the Patterson member of the Shady dolomite on Little Reed Island Creek, ¾ mile southwest of Boom Furnace. (Photograph by L. W. Currier.)



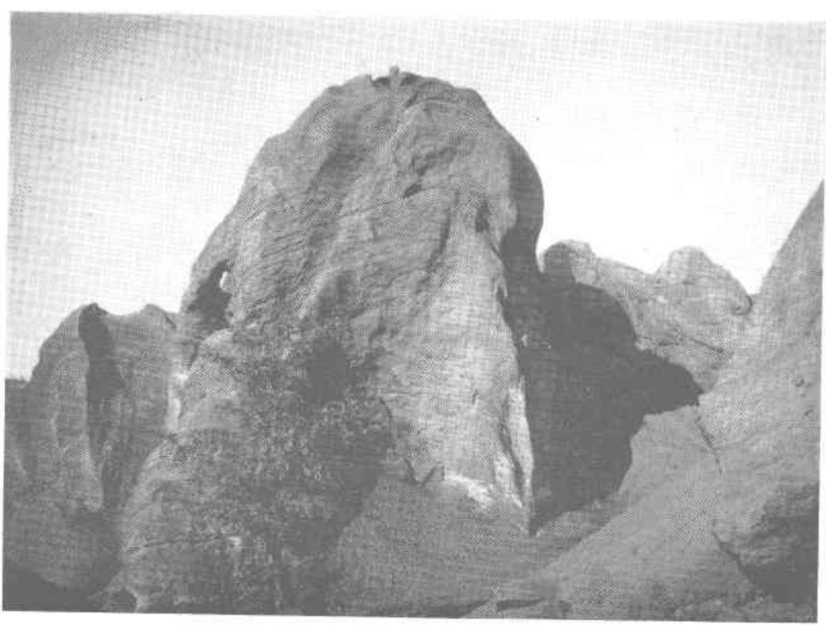
48A. Patterson member of the Shady dolomite overlain by the saccaroidal member, exposed in small anticline at Chiswell Hole. (Photograph by L. W. Currier.)



48B. Patterson member of the Shady dolomite exposed by stripping in an abandoned ore pit south of Fry Hill.

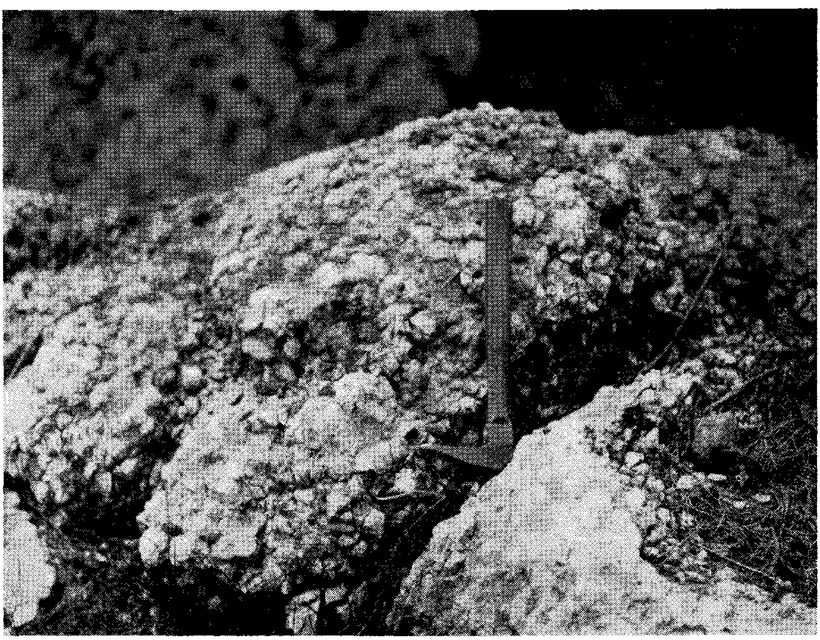


48A. Patterson member of the Shady dolomite overlain by the saccaroidal member, exposed in small anticline at Chiswell Hole. (Photograph by L. W. Currier.)



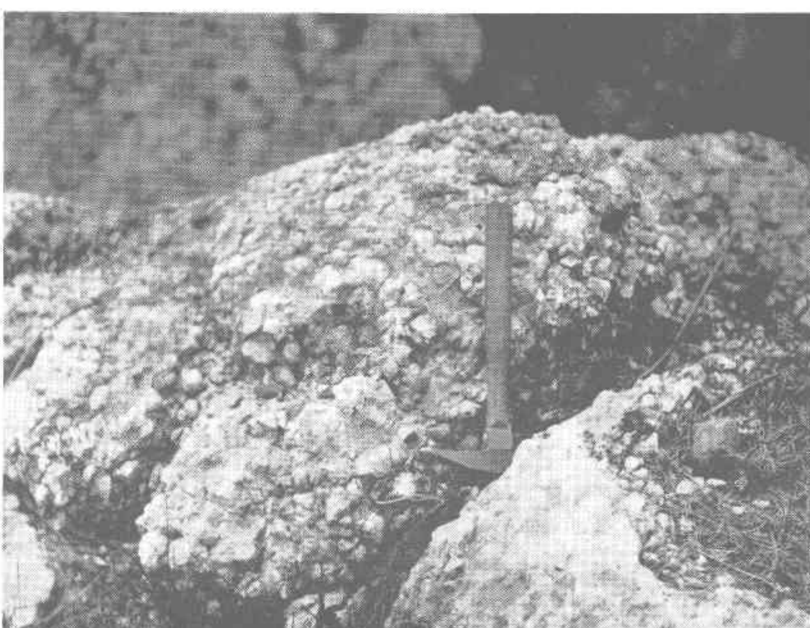
48B. Patterson member of the Shady dolomite exposed by stripping in an abandoned ore pit south of Fry Hill.

49A. Limestone conglomerate beds in upper member of Kinzers formation. 1 mile west of Bethany. (Photograph by L. W. Currier.)

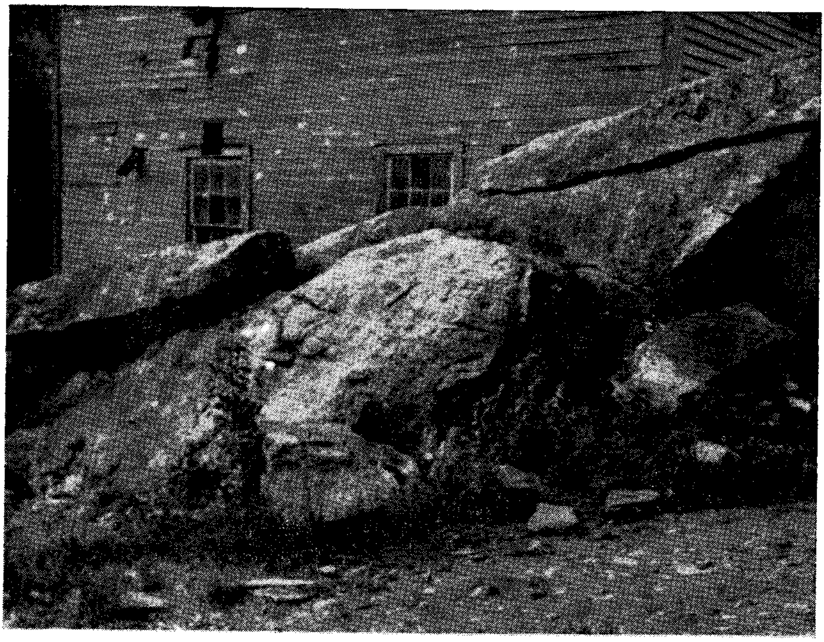


49B. Archeocyathid reef in lower member of Kinzers formation, Fossil Point near Austinville.

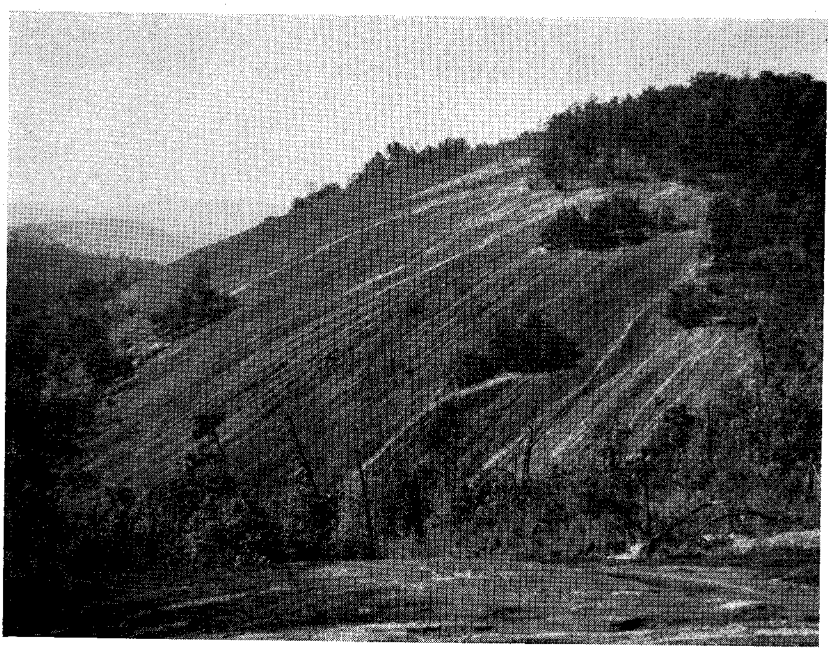
49A. Limestone conglomerate beds in upper member of Kinzers formation. 1 mile west of Bethany. (Photograph by L. W. Currier.)



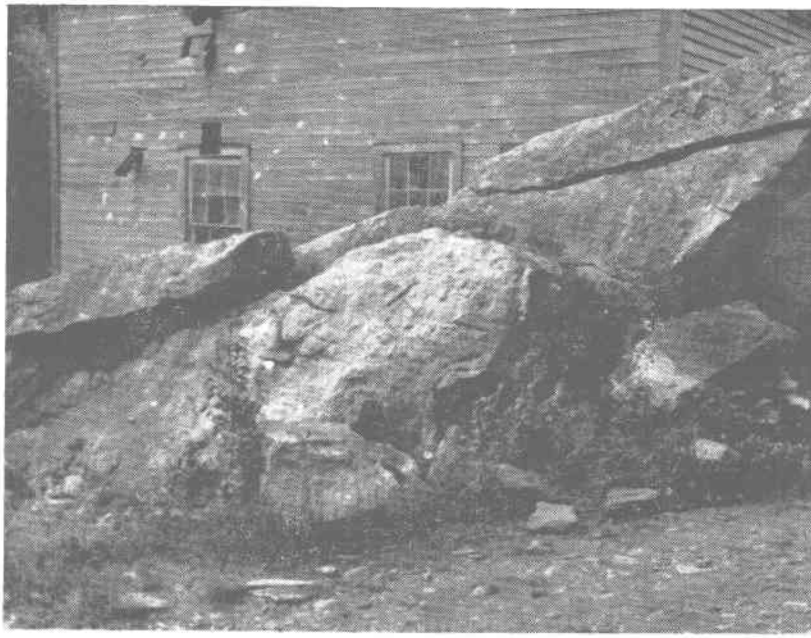
49B. Archeocyathid reef in lower member of Kinzers formation, Fossil Point near Austinville.



50A. Late Paleozoic pegmatite dike at Rutherford Mill.



50B. Stone Mountain, North Carolina. Composed of late Paleozoic granite.



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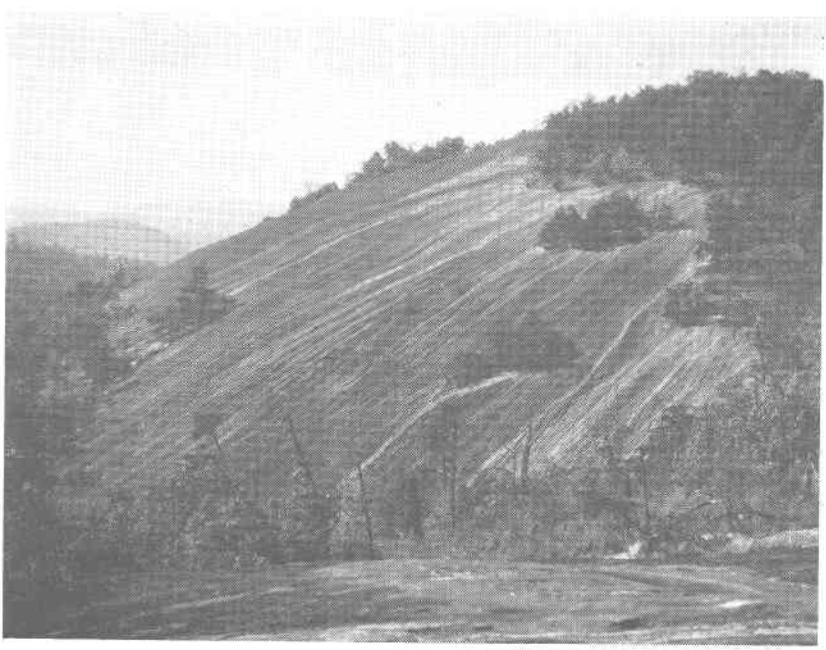

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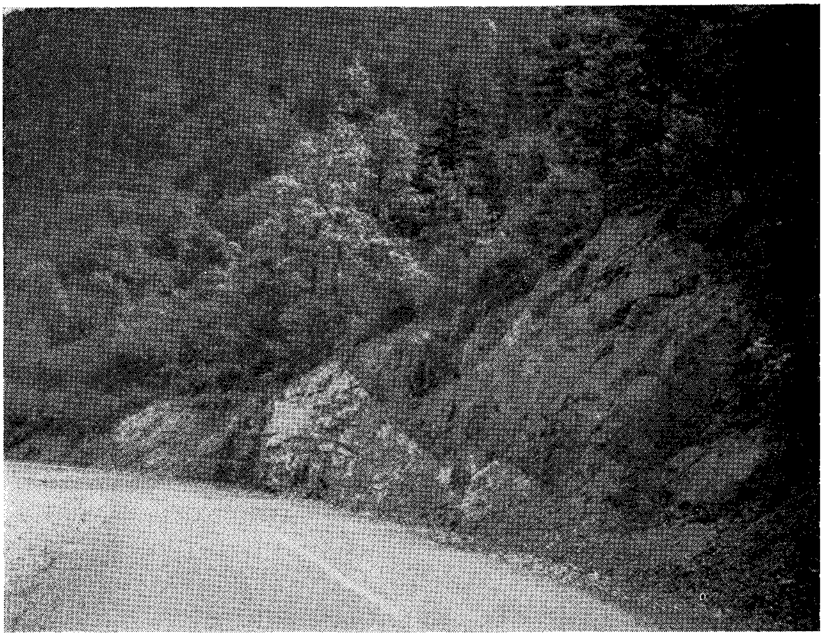
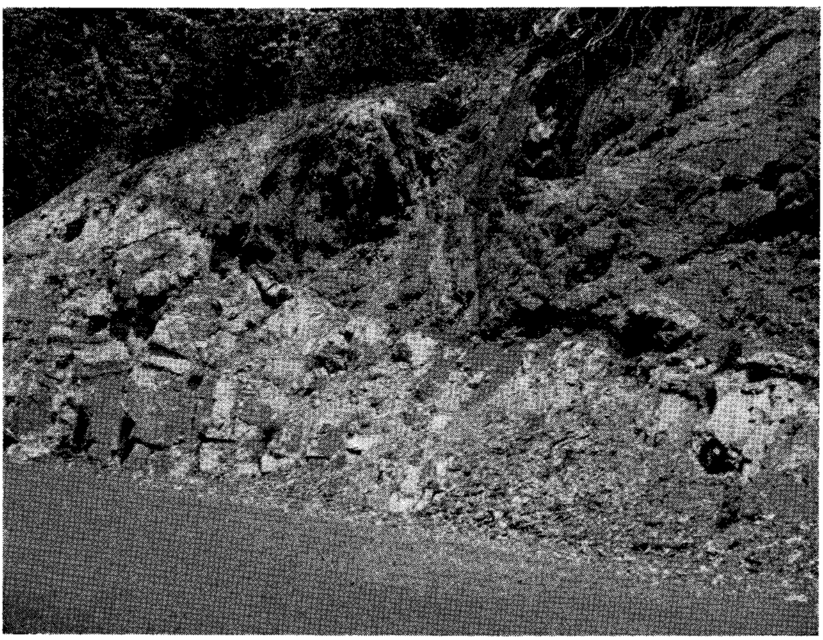
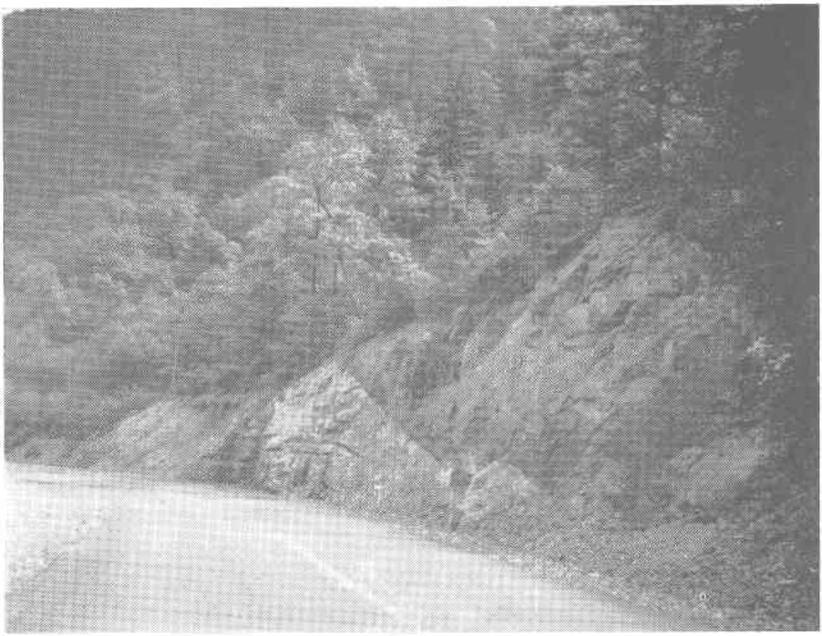


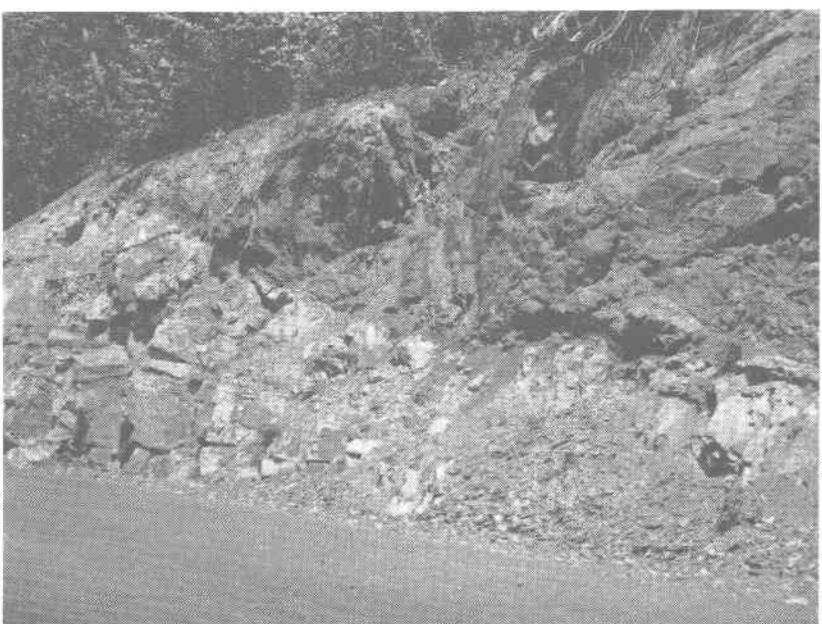
51A. Road-cut exposure of Poplar Camp overthrust on U. S. Route 21, ½ mile south of Henley Hollow. Black shale and quartzite of the middle member of the Erwin thrust over the ridge-making member.



51B. Nearer view of same exposure. Shows nearly vertical bedding in the over-thrust shaly mass, and truncation of nearly horizontal quartzite beds in the over-ridden mass. (See Fig. 32.)

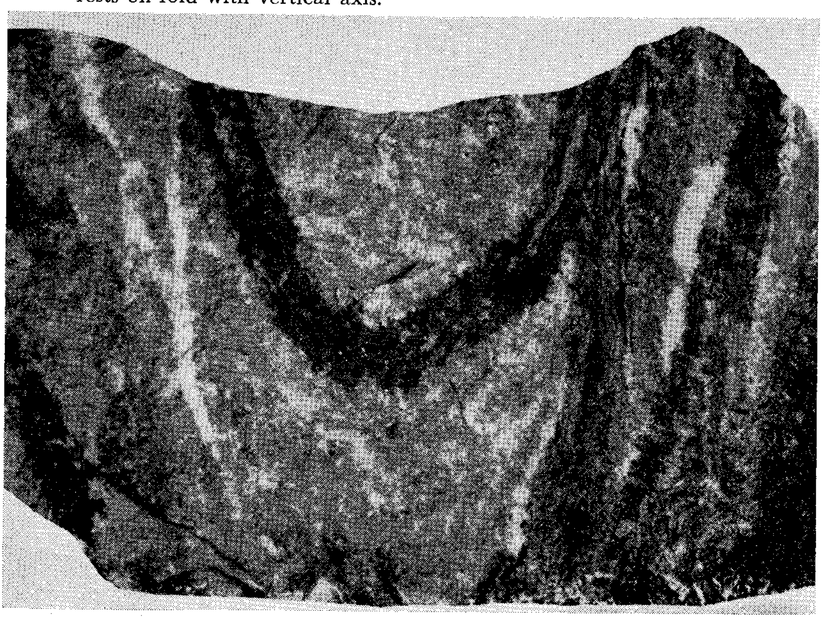


51A. Road-cut exposure of Poplar Camp overthrust on U. S. Route 21, ½ mile south of Henley Hollow. Black shale and quartzite of the middle member of the Erwin thrust over the ridge-making member.



51B. Nearer view of same exposure. Shows nearly vertical bedding in the over-thrust shaly mass, and truncation of nearly horizontal quartzite beds in the over-ridden mass. (See Fig. 32.)

52A. Pitching folds in basalt of middle member of the Unicoi formation near the Byllesby overthrust. New River, 1 mile south of Fowler Ferry. Hammer rests on fold with vertical axis.



52B. Folded hornblende schist with quartz and calcite veins, 2 miles northwest of Lamsburg.

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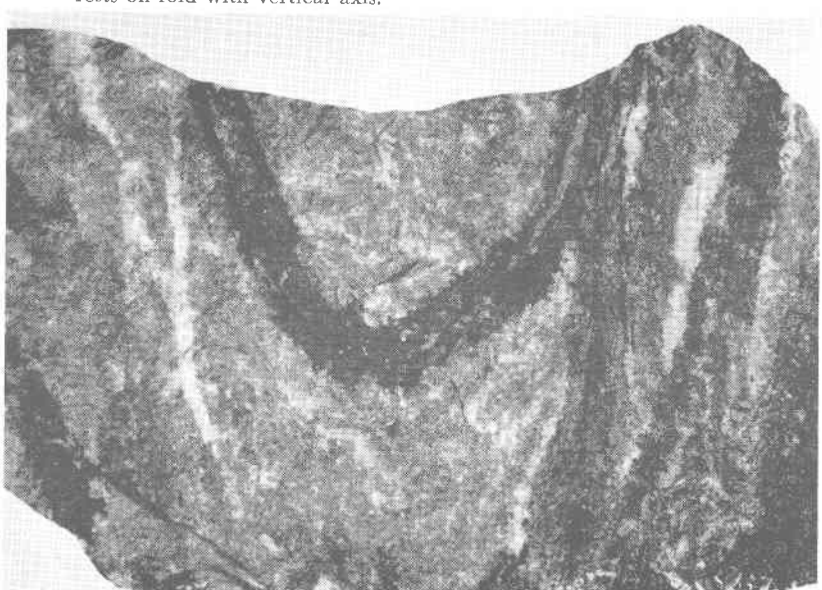

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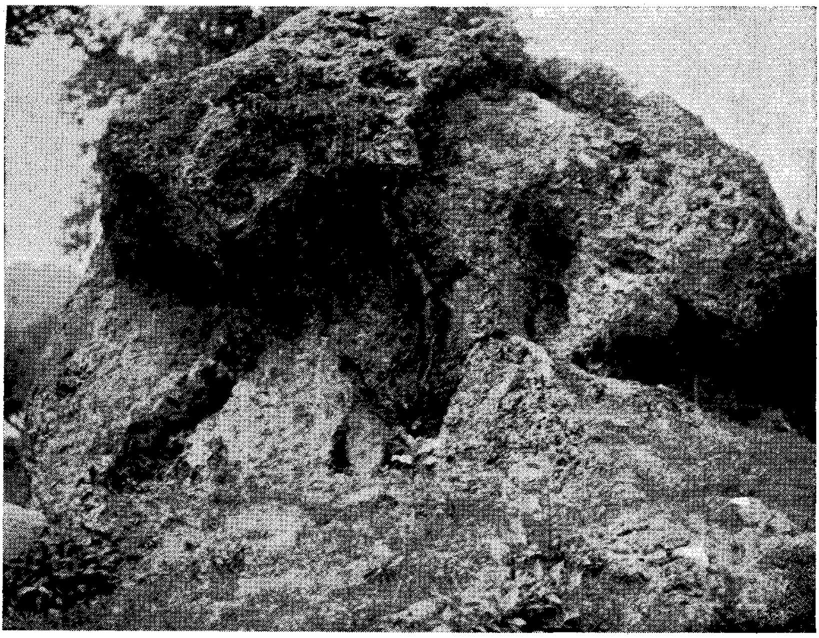
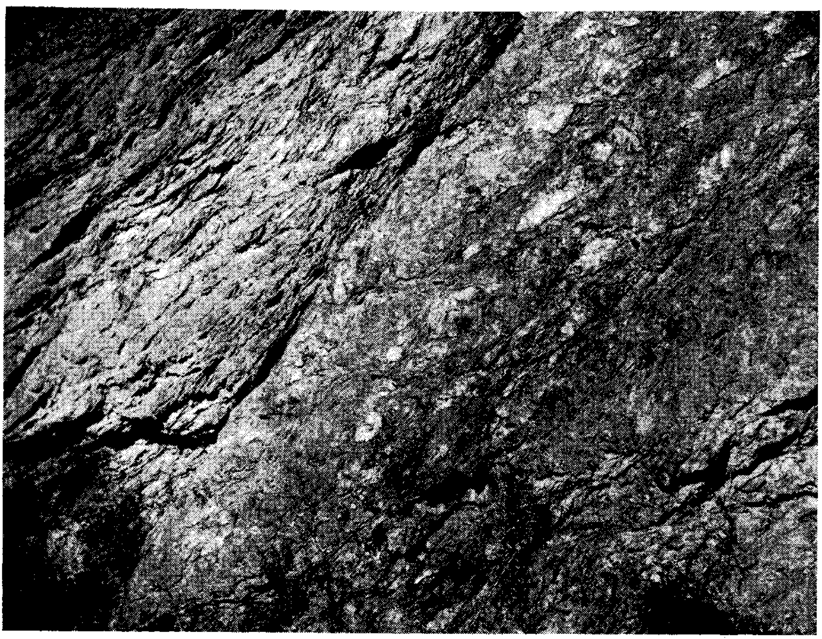
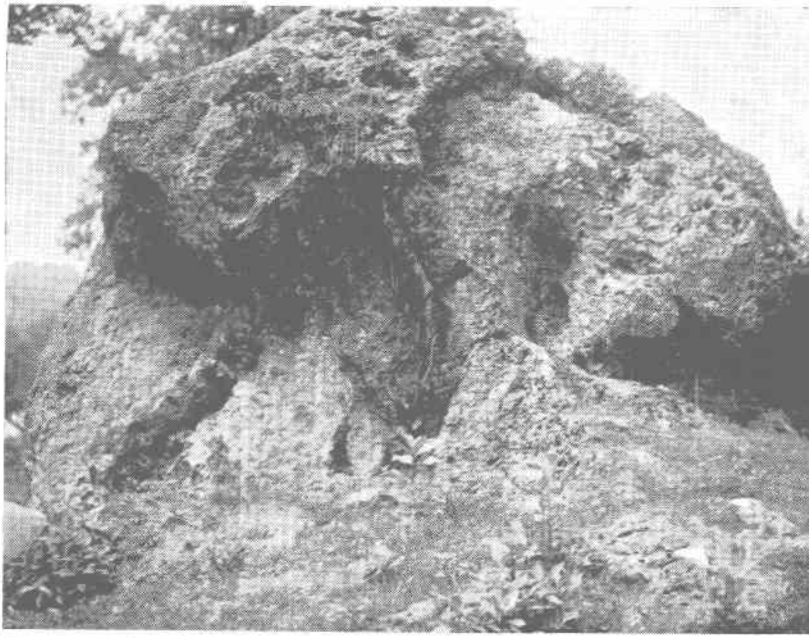


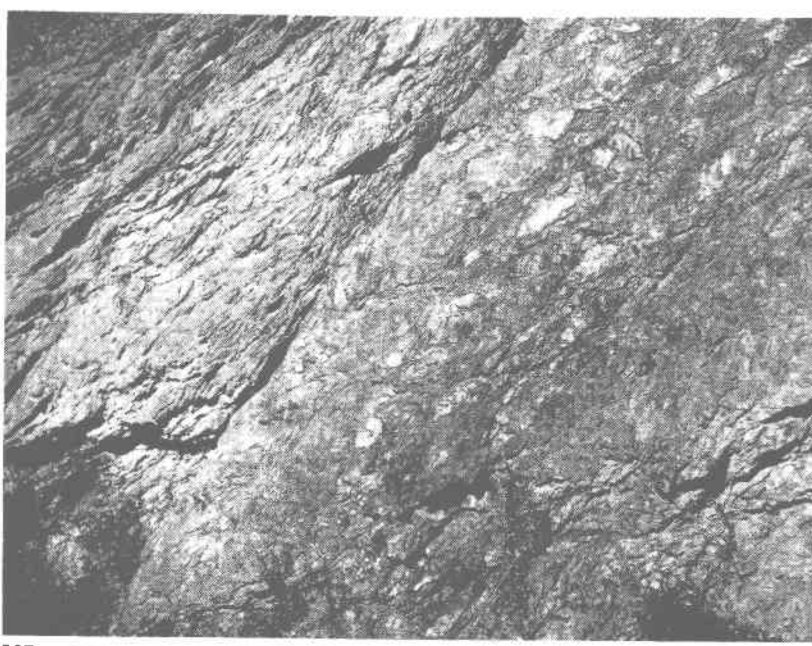
53A. Large pitted ferruginous chert breccia along the Gleaves Knob overthrust, 1 mile northeast of Austinville.



53B. Wavy, "lumpy shiny," sheared slate, with quartzose lenses, near Bowers Ferry overthrust, U. S. Route 52, ½ mile east of Shorts Creek village.



53A. Large pitted ferruginous chert breccia along the Gleaves Knob overthrust, 1 mile northeast of Austinville.



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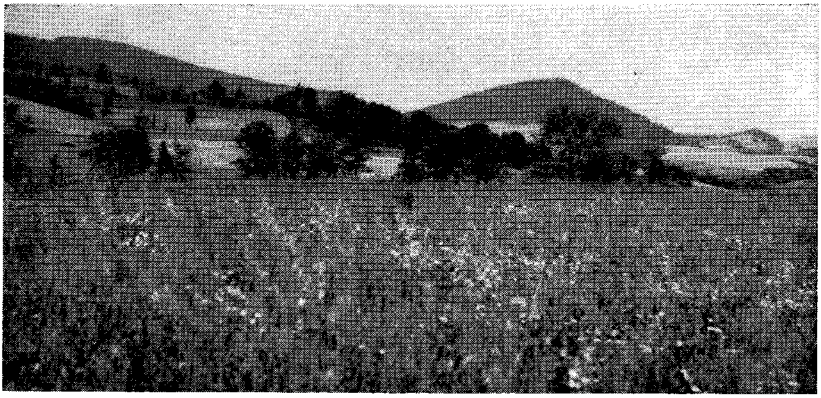
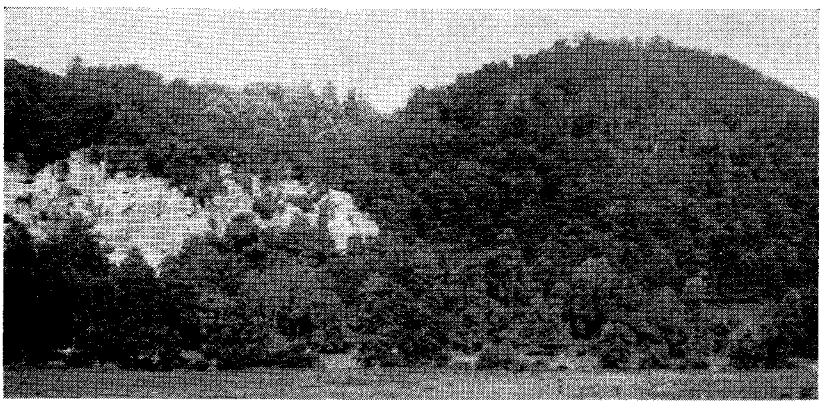
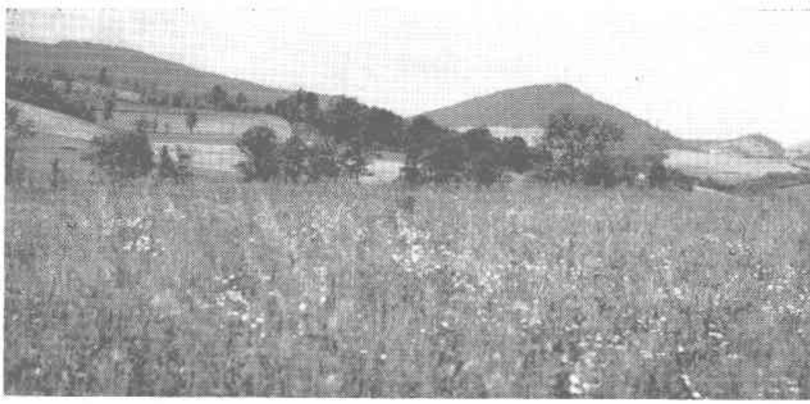


54A. Gleaves Knob, the high point composed of Erwin quartzite at the west end of the Gleaves Knob fault block, seen from the east. Raven Cliff hill, also composed of Erwin quartzite in the fault block, in the left distance.



54B. Horizontal dolomite of the Kinzers formation in cliff on east side of New River, 1 mile southeast of Ivanhoe, overridden by Erwin quartzite which forms the north end of Short Hill, the high wooded knob at the right.

54C. Specimen of closely folded Lynchburg gneiss with transposition cleavage, from 2 miles northeast of Lambsburg.



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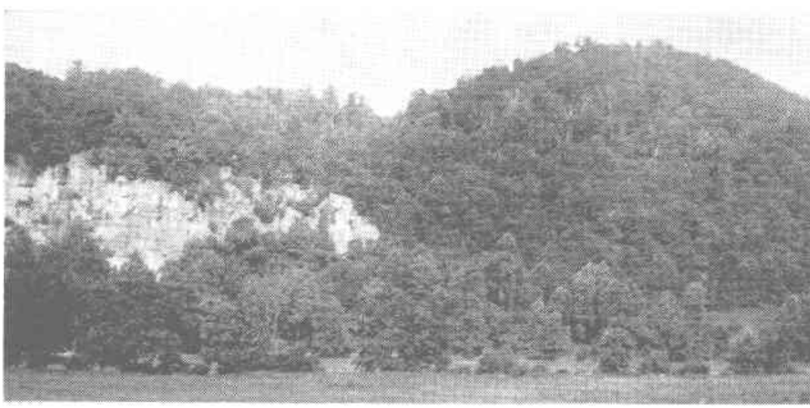

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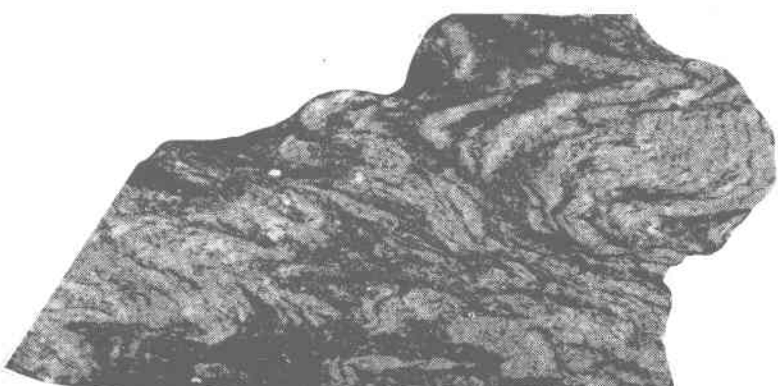
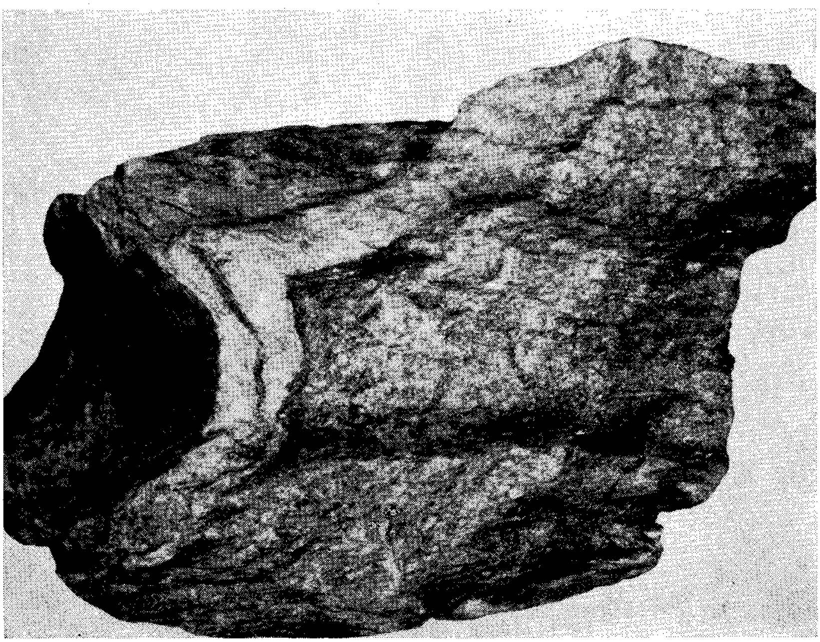
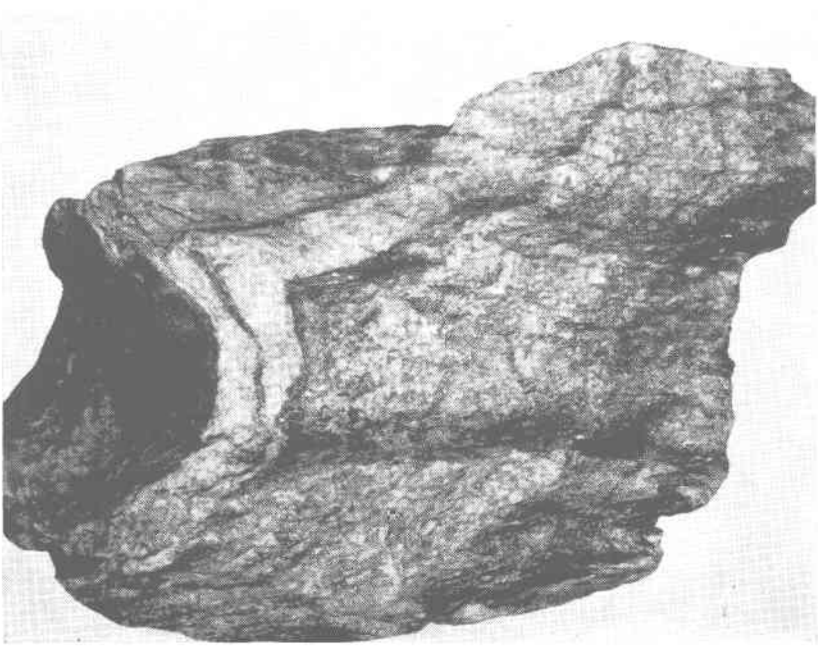


54C. Specimen of closely folded Lynchburg gneiss with transposition cleavage, from 2 miles northeast of Lambsburg.



55A. Specimen of folded mylonitized injection-gneiss from the Fries overthrust, Johns Creek.

55B. Close folding in mylonitized injection-gneiss from the Fries overthrust on Peach Bottom Creek near the mouth of Beaverdam Creek.



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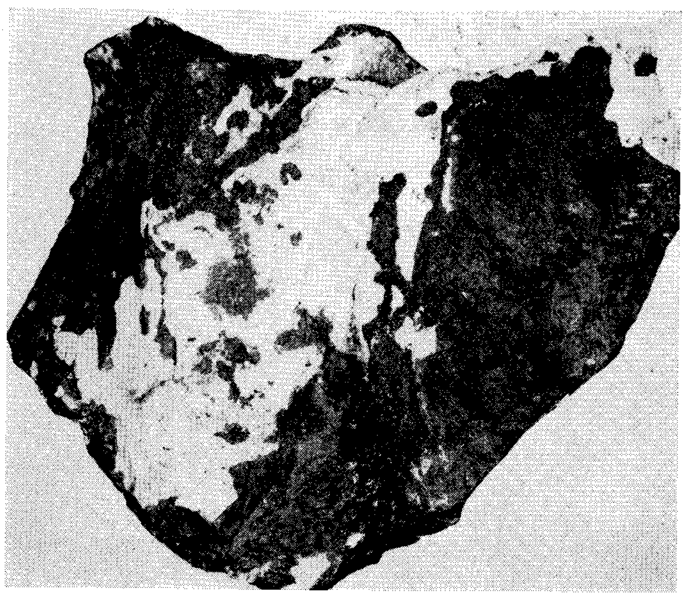
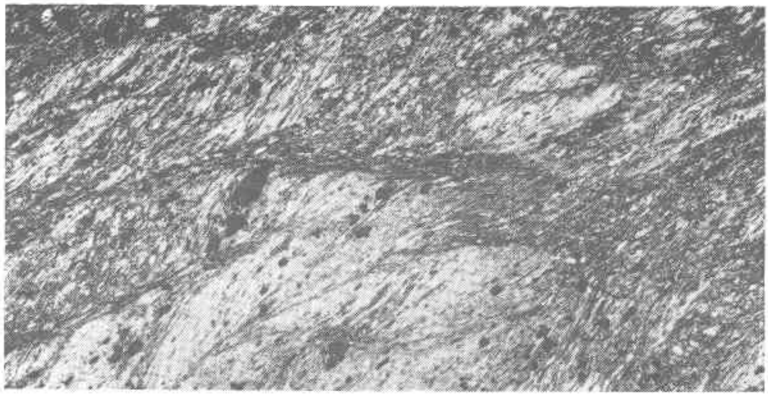
55B. Close folding in mylonitized injection-gneiss from the Fries overthrust on Peach Bottom Creek near the mouth of Beaverdam Creek.

56A. Photomicrograph of quartzose schist from the Gossan Lead overthrust. Muscovite fibers bend around lenticular areas of cataclastic quartz. 1 mile south of Stoneman Hill. Crossed nicols. x 12½.



56B. Specimen of massive spessartite garnet from Higgins manganese prospect on Beaver Creek. Light-colored rock, massive granular pinkish spessartite. Weathered partings coated with thin manganese oxide (black).



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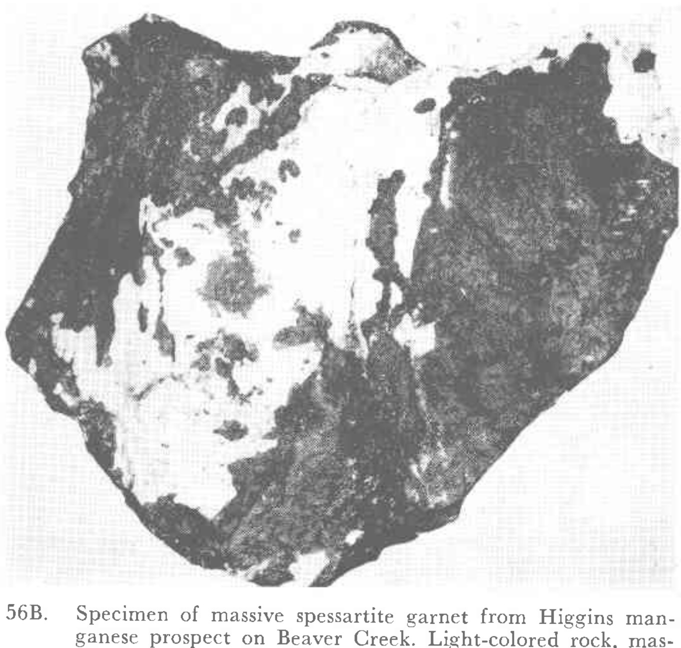
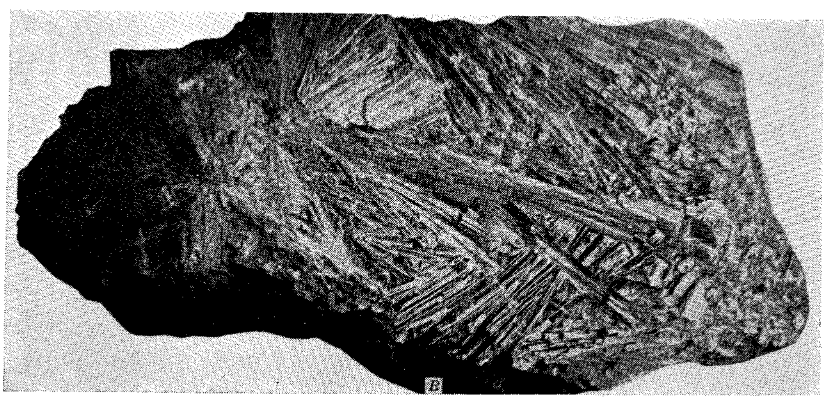
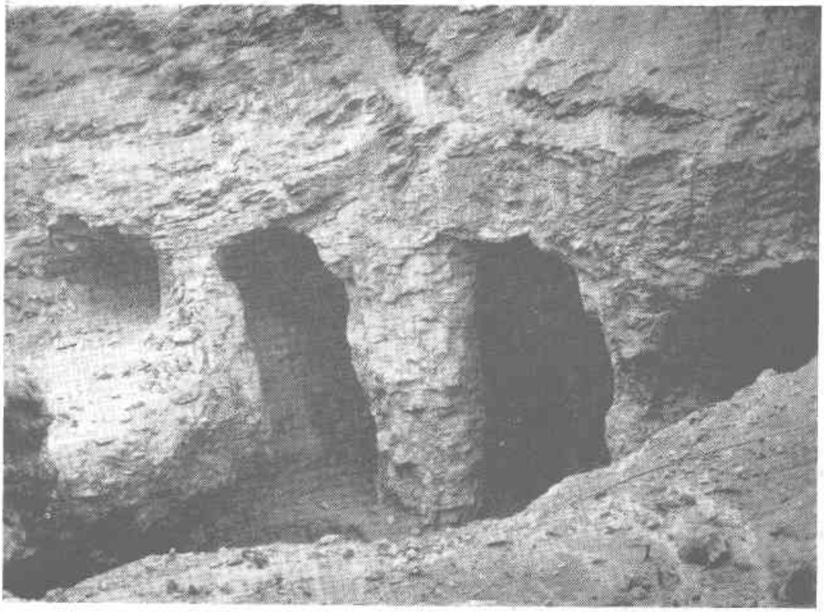


56B. Specimen of massive spessartite garnet from Higgins manganese prospect on Beaver Creek. Light-colored rock, massive granular pinkish spessartite. Weathered partings coated with thin manganese oxide (black).

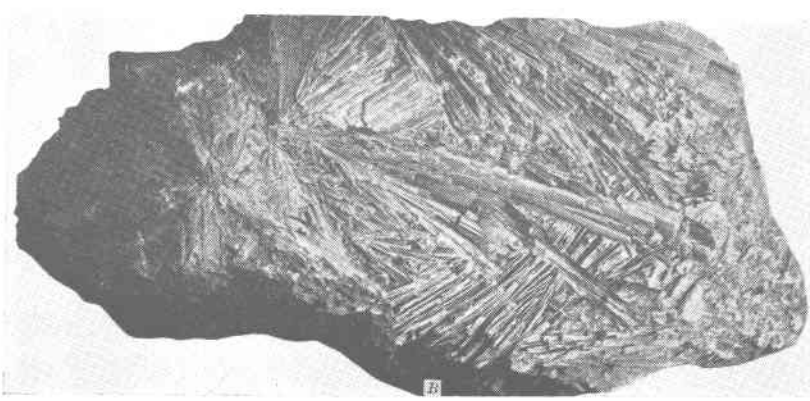
57A. Open cut and underground chambers of Bumbarger pit of the Iron Ridge mine in 1928.



57B. Specimen of a radial group of actinolite crystals enclosed in sulphides, from Iron Ridge Mine. (From U. S. G. S. Prof. Paper 179, C. S. Ross.)



57A. Open cut and underground chambers of Bumbarger pit of the Iron Ridge mine in 1928.



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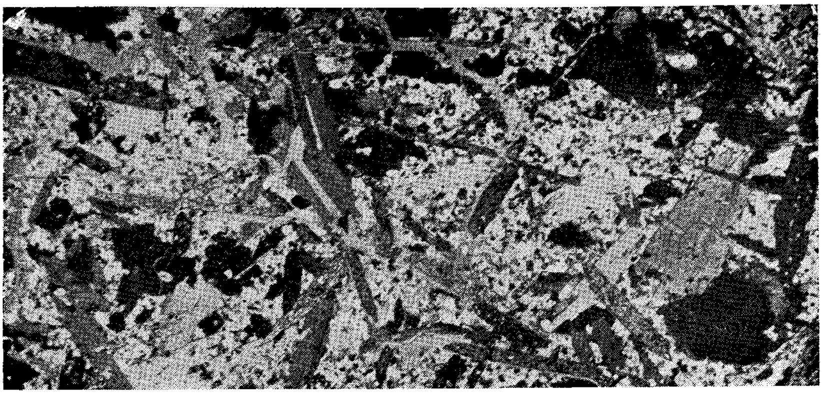
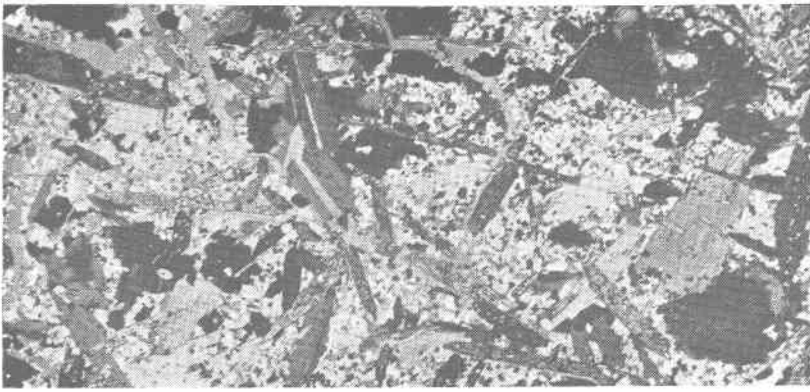


58A. Photomicrograph of rock from Iron Ridge mine showing quartz-feldspar groundmass replaced by actinolite blades of high relief and biotite blades with parallel cleavage later replaced by pyrrhotite (black). (From U. S. G. S. Prof. Paper 179, C. S. Ross.)

58B. Polished specimen of ore from Gossan Lead on U. S. Route 52, showing mica schist (dark) in part replaced by sulphides, largely pyrrhotite (light-gray). (From U. S. G. S. Prof. Paper 179, C. S. Ross.)



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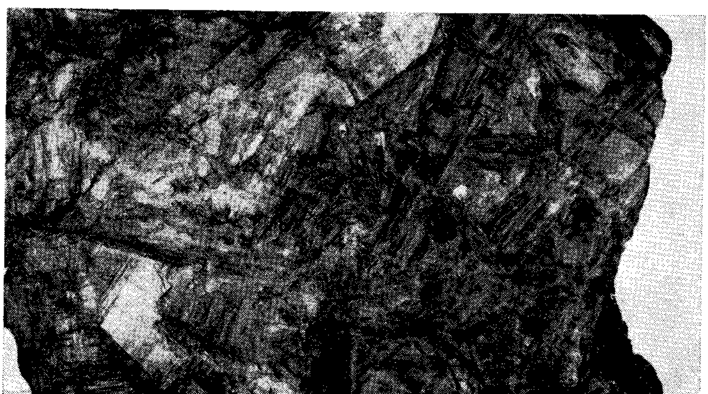
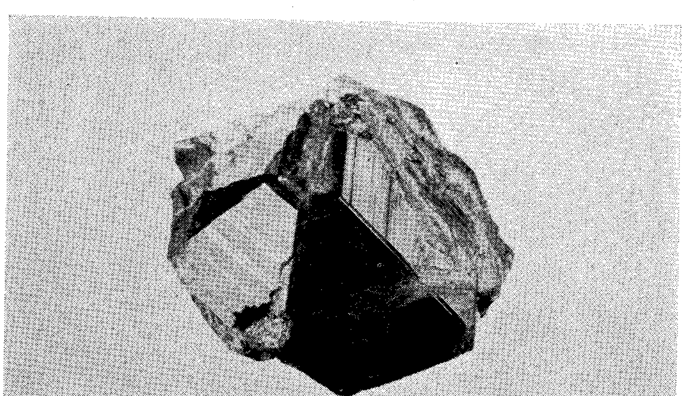
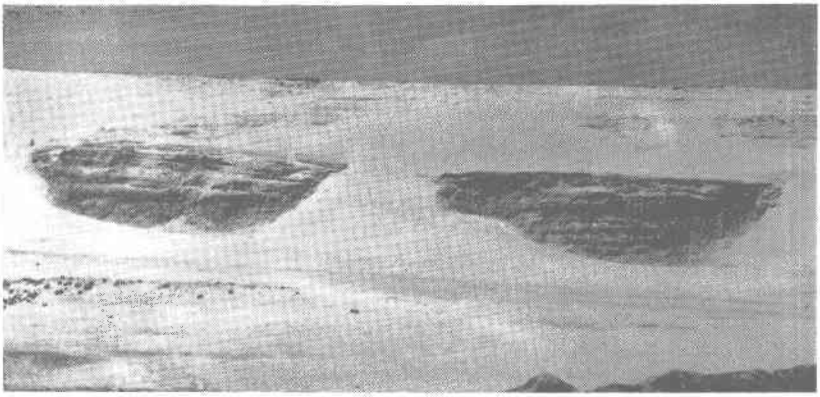
59A. Lime-silt deposit from tailings of the mill of the Bertha Mineral Co., Austinville. Note wind-rippled surface.



59B. Specimen of bladed blue kyanite in radiating aggregates from a quartz vein 1 mile northeast of Baywood.



59C. Multiple-twin crystal of rutile, associated with kyanite, from Pierce kyanite prospect, West Galax.



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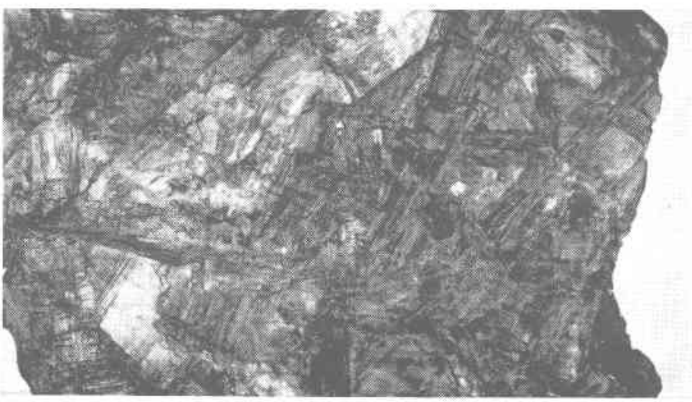
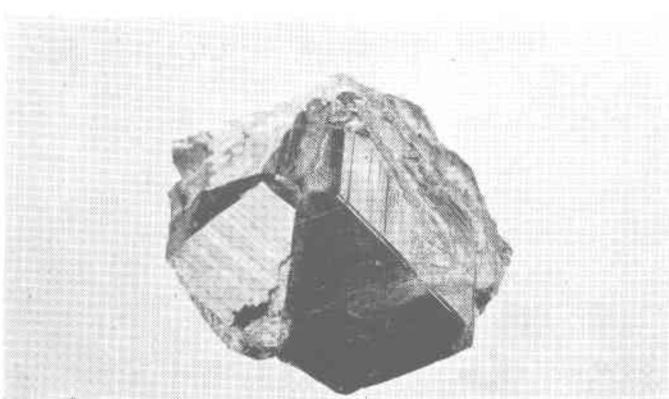


59B. Specimen of bladed blue kyanite in radiating aggregates from a quartz vein 1 mile northeast of Baywood.



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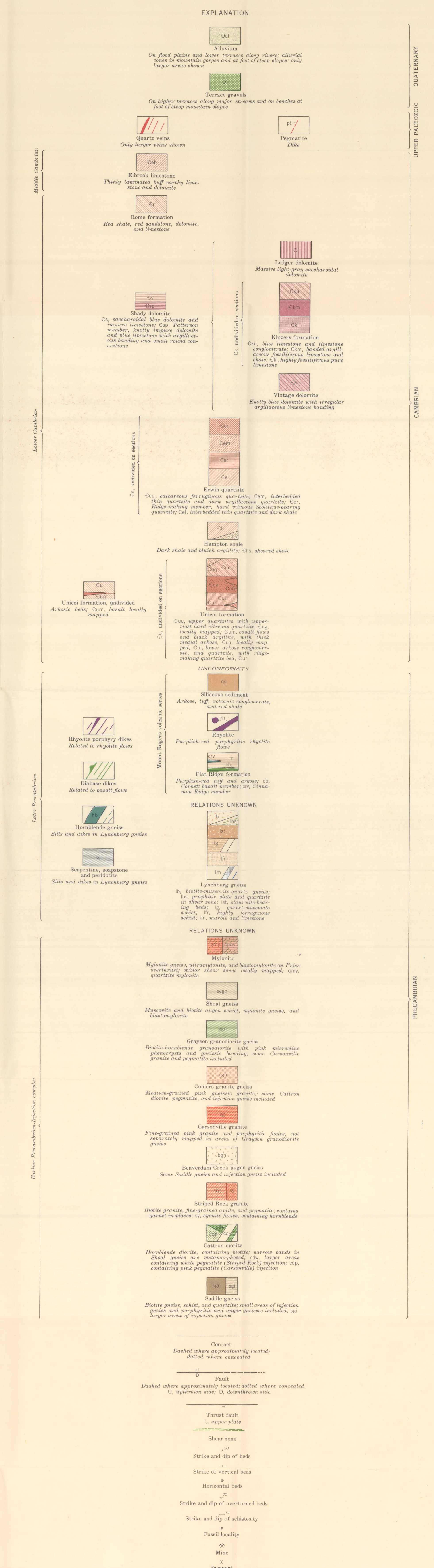
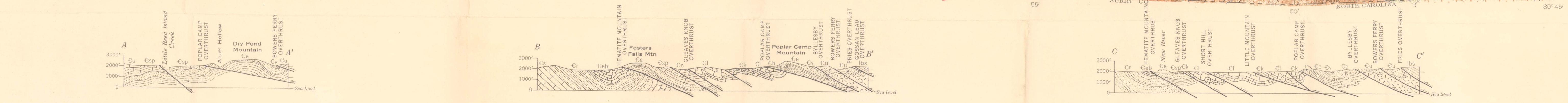
VIRGINIA DEPARTMENT OF CONSERVATION AND DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver, Commissioner of Mineral Resources
and State Geologist

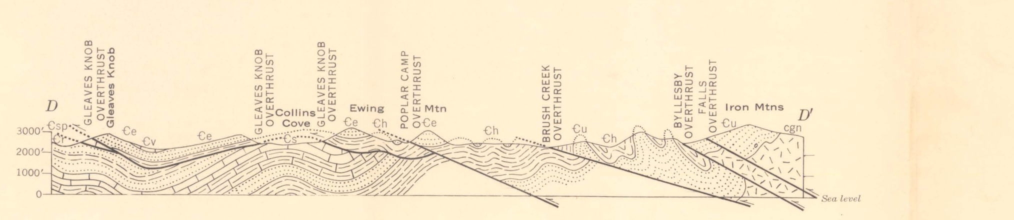
PREPARED IN COOPERATION WITH THE
UNITED STATES GEOLOGICAL SURVEY



MINERALS IN QUARTZ VEINS AND PROSPECTS

B	Barite	Q	Quartz
CU	Pyrrhotite	R	Rutile and IL, ilmenite
IR	Iron ore	SN	Stone
K	Kyanite	S	Staurolite
LS	Limestone	SP	Spessartite
M	Magnetite	ST	Soapstone
MN	Manganese oxide	Z	Zinc and lead
P	Pyrite		





Base from U. S. Geological Survey quadrangle maps

Geology by Anna J. Stose and George W. Stose, 1932-39

GEOLOGIC MAP AND STRUCTURE SECTIONS OF THE GOSSAN LEAD DISTRICT AND ADJACENT AREAS IN VIRGINIA

Scale $\frac{1}{62500}$

APPROXIMATE MEAN DECLINATION, 1931

Contour interval 20 feet
Datum is mean sea level

1957

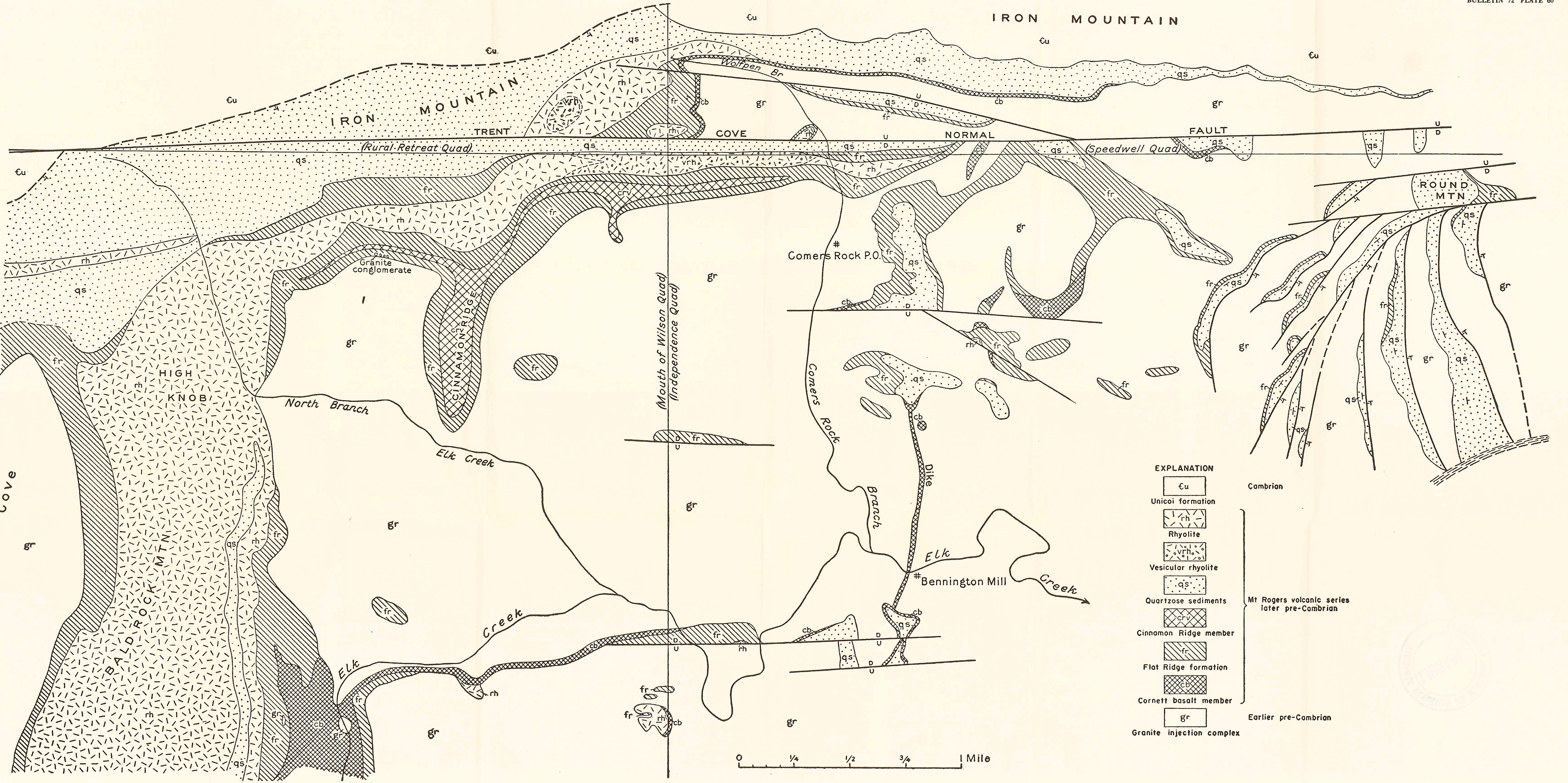
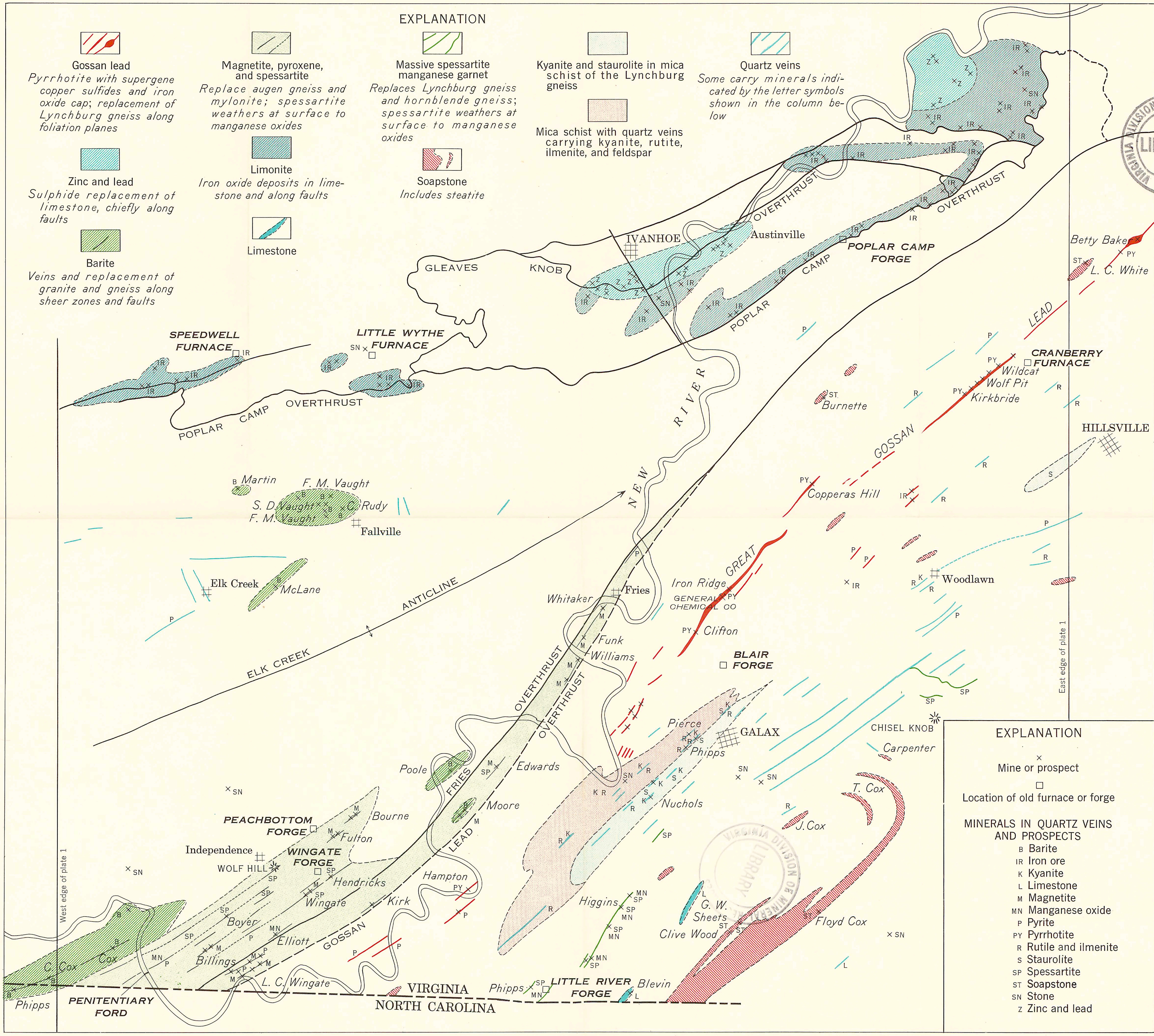


PLATE 60. Detailed map of Mount Rogers volcanic series.



DISTRIBUTION OF MINERAL PRODUCTS IN THE GOSSAN LEAD DISTRICT

1 0 5 Miles