VIRGINIA GEOLOGICAL SURVEY

Outline of the Geology and Mineral Resources of Russell County, Virginia

BULLETIN 49—1938

WOODWARD

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COMMONWEALTH OF VIRGINIA

STATE COMMISSION ON CONSERVATION AND DEVELOPMENT

VIRGINIA GEOLOGICAL SURVEY

ARTHUR BEVAN, *State Geologist*

Bulletin 49
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Outline of the Geology and Mineral Resources of Russell County, Virginia

By

HERBERT P. WOODWARD

UNIVERSITY, VIRGINIA

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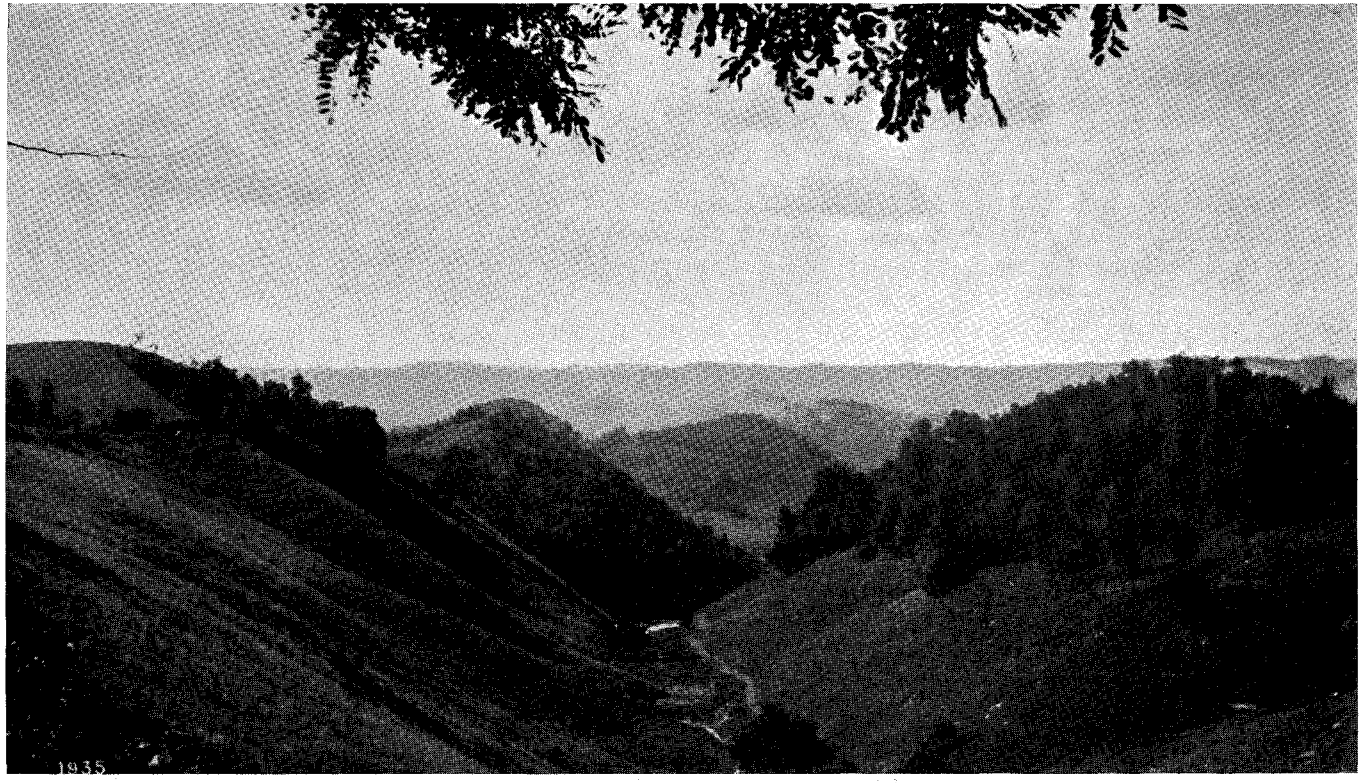

Scenery along Clinch River in northern Russell County. Looking north along State Highway 82 toward the Appalachian Plateau from the crest of Copper Ridge between Lebanon and Cleveland. The deep ravine is typical of many that descend to Clinch River.

Scenery along Clinch River in northern Russell County. Looking north along State Highway 82 toward the Appalachian Plateau from the crest of Copper Ridge between Lebanon and Cleveland. The deep ravine is typical of many that descend to Clinch River.

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LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., March 15, 1938.

To the State Commission on Conservation and Development:

GENTLEMEN:

I have the honor to transmit and to recommend for publication as Bulletin 49 of the Virginia Geological Survey series of reports the manuscript and illustrations of an *Outline of the Geology and Mineral Resources of Russell County, Virginia,* by Dr. Herbert P. Woodward, Department of Geology, University of Newark, Newark, N. J.

This report is the second in the county series of reports. It has been prepared especially for the residents of Russell County and adjacent areas so as to make readily available reliable up-to-date information about the most commonly observed features of the local geology, physical geography, and mineral resources. Emphasis is placed upon the characteristics and origin of the physical features and the occurrence and economic importance of the rock and mineral deposits and the water resources. The field work in Russell County by the author was done in the summer of 1935.

It is hoped that this report will be particularly useful in the schools of Russell and adjacent counties and that it will be of value to all who are interested in the natural resources of Russell County.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:

State Commission on Conservation and Development,
Richmond, Virginia, March 16, 1938.
R. A. GILLIAM, *Executive Secretary and Treasurer.*

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Outline of the Geology and Mineral Resources of Russell County, Virginia

By Herbert P. Woodward

INTRODUCTION

This report has been prepared with special emphasis on the geographic features and economic possibilities of Russell County. It is a nontechnical account of the land and the underlying rocks, their past and present uses, and their future usefulness. Descriptions that are solely of scientific importance and items of significance chiefly to the professional geologist have been eliminated or reduced to their simplest form. It is hoped that this bulletin will be of service particularly in the local schools and to the residents of southwest Virginia, and that accurate information about the mineral resources of the county will aid in their proper development.

The accompanying map of Russell County (Pl. 1) indicates the outcrops of the more common types of rock that may be recognized without technical study. Most geologic maps show the areal distribution of geologic or stratigraphic units that are readily recognized by the professional geologist but are generally unfamiliar to the nontechnical reader. The present map disregards the strict geologic classifications and delimits the surface outcrops of such familiar materials as limestone, shale, and sandstone. Existing geologic maps of the area, which were revised and modified during field studies by the writer in 1935, form the base from which the present outcrop map of the county was prepared.

Acknowledgments

The author is indebted to many sources for material. Valuable information and courteous cooperation were given by the residents of Russell County during the field work. In the preparation of the accompanying map, data have been freely drawn from geologic maps prepared by Dr. Charles Butts and Dr. Marius R. Campbell, of the United States Geological Survey. Publications of Mr. Leland B. Tate, formerly of Lebanon and of Southwestern Virginia, Inc., have furnished useful information. Mr. Lee Long, vice-president, and Mr. George T. Stevens, chief engi-

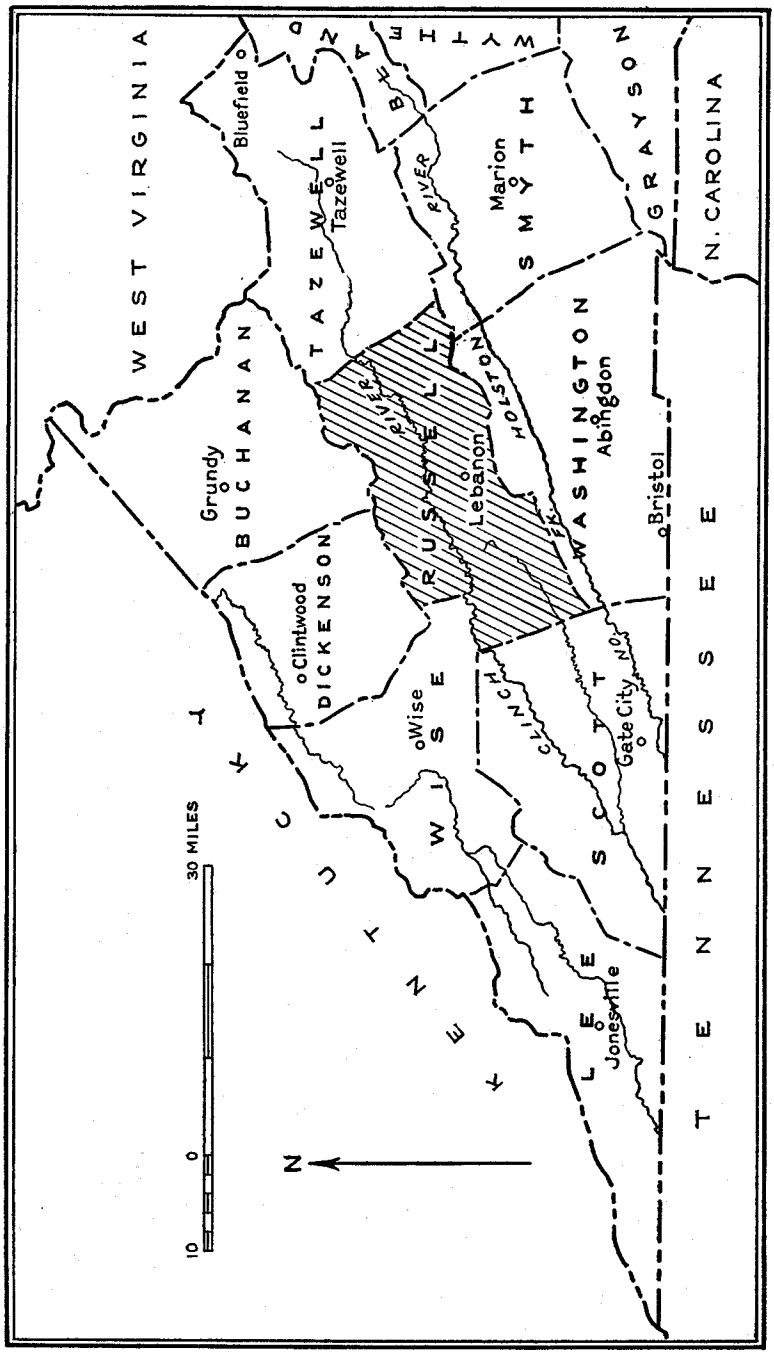


FIGURE 1. Index map of southwest Virginia showing the location of Russell County.

neer, of the Clinchfield Coal Corporation, have kindly supplied information and photographs that are elsewhere acknowledged in this report. Other mining companies of Russell County have furnished data that are individually acknowledged. Judge W. C. Hargis, of Lebanon; Mr. T. C. Boyd, of Dickensonville; and Mr. Lathan Powers, of Fort Blackmore, Scott County, were helpful in supplying information about mineral prospects. Mr. Robert L. Bates, of Iowa City, Iowa, acting as assistant and junior associate, has materially contributed to the field work, especially in the area near Big A Mountain, where he was conducting an independent geologic study in cooperation with the Virginia Geological Survey. The editing of the manuscript was done by the staff of the Virginia Geological Survey.

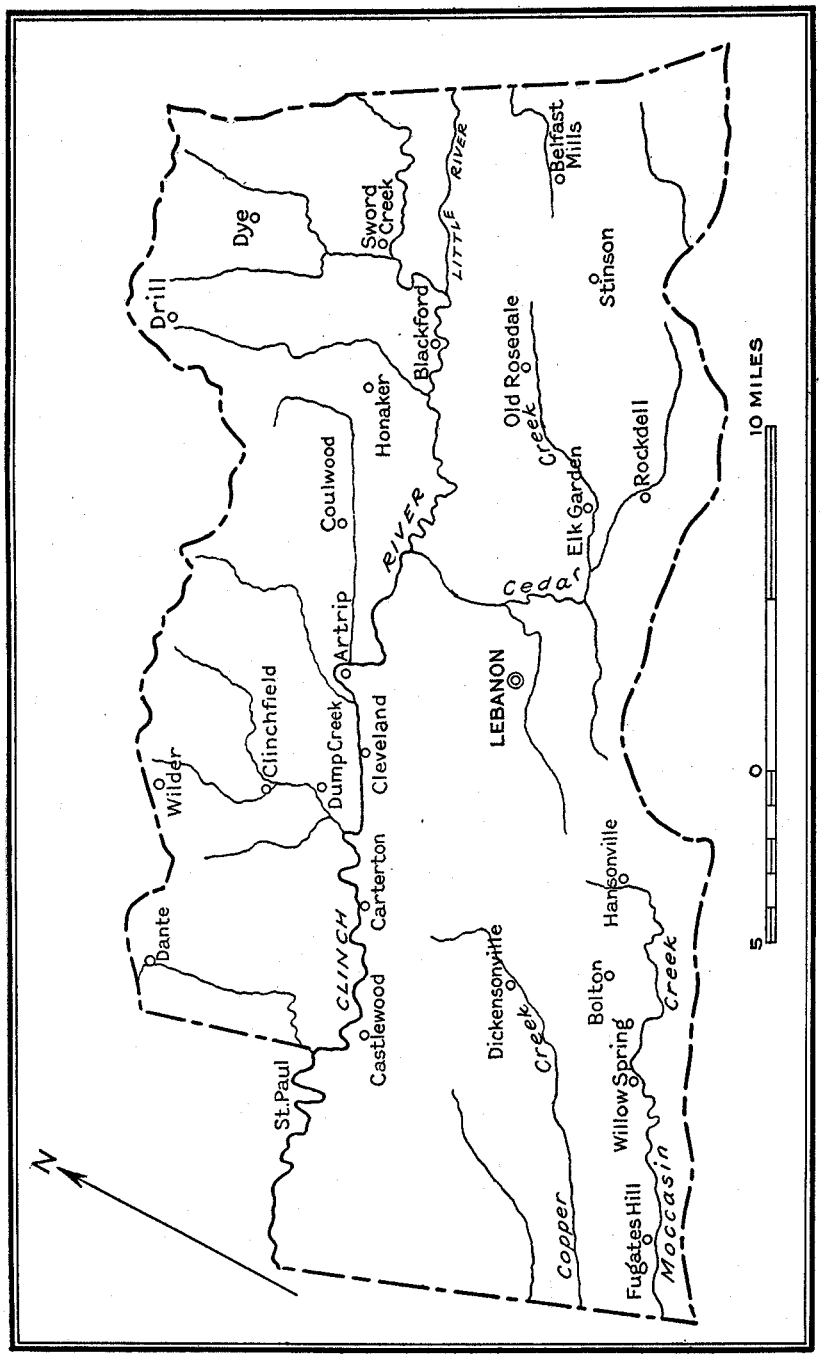


FIGURE 2. Sketch map of Russell County showing the principal geographic features.

GEOGRAPHY

GENERAL FEATURES

Russell County is in southwestern Virginia, and Lebanon, its county seat, is almost equally distant from the Tennessee, Kentucky, and West Virginia boundaries. (See Fig. 1.) The county is roughly rectangular. Its longest dimension, which is 34 miles, extends northeastward in a direction parallel to the main ridges of the region. Its width is about 15 miles. (See Fig. 2.) Russell County, with an area of 496 square miles (317,440 acres), ranks 29th in size among the 100 counties of Virginia. Clinch Mountain (Pl. 3, B) forms the southeastern boundary and a short section of Clinch River and the crests of Big A Mountain (Pl. 5, A) and Sandy Ridge form the northwestern boundary. The county is bounded at the northeast and southwest by surveyor's lines.

About 78 per cent of the county has been cleared of timber. More than 150,000 acres is now in pasture, of which at least two-thirds is in bluegrass (Pl. 8, B) and about 50,000 acres is crop land. About 54,000 acres is underlain by workable coal beds. Claims for mineral lands amounting to 35,000 acres were on record in 1925.

The population of Russell County in 1930 was approximately 26,000, of whom 25,178 were white and 779 were colored. Native-born inhabitants comprise 99.5 per cent of the total. The density of population is almost 53 persons to the square mile.

The county is divided into 7 political, or magisterial, units and contains 27 postal communities. Lebanon is near the center of the county at latitude 36° 56′ and longitude 82° 05′. (See Fig. 2.) About 500 persons live in the town. An equal number live outside the town limits but within 1 mile of the courthouse. Dante has a fluctuating population which is estimated to be about 2,000 at present. It is a coal-mining town, owned and controlled by the Clinchfield Coal Corporation, on Lick Creek in the extreme northwest corner of the county. Honaker, population 700, and Cleveland, population 400, are near Clinch River on the Norfolk & Western Railway. Other communities are Castlewood, Elk Garden, Blackford, Sword Creek, and Drill. Wilder, formerly an important coal-mining town, has been abandoned since 1930.

The county is served by the Clinch Valley division of the Norfolk & Western Railway and by the Clinchfield Railway. The former connects Norton, Virginia, with Bluefield, West Virginia, and crosses Russell County along Clinch River. It has three short branch lines within the county, namely, from Honaker to

Drill, from Honaker to Blackford, and from Sword Creek northward for 3 miles. The Clinchfield Railway crosses the northwest part of Russell County for a distance of about 15 miles, passing through Dante. It also operates a branch line from Carbo, on Clinch River, to Wilder. There is about 95 miles of railroad track within the county.

U. S. Highway 19, known as the "Trail of the Lonesome Pine," enters Russell County from Tazewell County, passes through Lebanon, and leaves the county through Little Moccasin Gap, in Clinch Mountain. Virginia State Highway 64 extends from Lebanon to Norton, Wise County. State Highway 80 extends from Old Rosedale through Blackford and Honaker to Council, in Buchanan County, and beyond; State Highway 82 connects Cleveland with Lebanon; and State Highway 70 connects Dante and points to the northwest with St. Paul and other points in Wise County. All the main highways are hard-surfaced. Other roads, commonly in good repair, extend from Lebanon and from Hansonville to Gate City, from Elk Garden to Abingdon, and from Castlewood to Fort Blackmore, in Scott County. There are more than 550 miles of public roads within the county, and travel is comparatively easy throughout the area.

CLIMATE

Russell County is favored with a pleasant climate, because of its relatively high average altitude. Its mean annual temperature is 54° F., and extreme temperatures above 93° or below 0° are rare. The average annual rainfall is 49 inches, and the average annual snowfall 9 inches. An average of 170 rainy days occur each year, and a growing season of 180 days is expectable. Killing spring frosts are rare after April 20, and severe autumn frosts seldom occur before October 30. Although a wide range in altitude—from 1,350 to 4,700 feet above sea level—produces considerable local variation in climate, the area as a whole is well adapted for profitable agriculture.

RELIEF AND DRAINAGE

Russell County occupies a section of the southern Appalachian Highlands[1] (Fig. 1) and is aligned in a northeasterly direction with the trend of the mountains. The south edge of the county lies along the crest of Clinch Mountain, which stands from 3,000 to 4,500 feet above sea level. (See Pls. 3, A and 3, B.) The

[1] This area is in the geologic provinces known as the Valley and Ridge province and the Appalachian Plateaus.

mountain extends from Tennessee into Virginia as a narrow ridge and holds this character to Little Moccasin Gap, 9 miles south-southwest of Lebanon. Northeast of this place the mountain broadens into a wide plateau, 3,700 feet above sea level, in Washington County due south of Lebanon, and an irregularly branching ridge in the extreme eastern part of Russell County. (See Pl. 5, B.) The mountain is locally crossed by a secondary road from Fugates Hill to Mendota, by U. S. Highway 19 through Little Moccasin Gap, and by State Highway 80 through Hayter Gap. An old road through Mutters Gap is now difficult to follow as a result of severe forest fires near the headwaters of Tumbling Run.

Immediately north of Clinch Mountain is a long, narrow valley that is occupied at the southwest by Moccasin Creek, near Lebanon by the headwaters of Cedar Creek, and at the north by Indian Creek. In the southwestern part of the county this valley is bounded on the north by the irregular upland of Moccasin Ridge, which rises 500 to 600 feet above the basin of Moccasin Creek and separates it from the basin of Copper Creek, on the north. The headwaters of Copper Creek rise in a broad valley that occupies the central portion of the county near Lebanon (Pl. 8, B), and narrows toward the northeast to merge into the valley of Indian Creek. Moccasin Ridge merges imperceptibly into a row of low ridges on the valley floor between Dickensonville and Lebanon.

Copper Ridge, a broad dissected upland, enters Russell County northwest of Copper Creek, where it is more than 7 miles wide, and descends steeply on the northwest to Clinch River. (See Pl. 2.) The ridge gradually narrows toward the northeast until its width north of Lebanon is less than 2 miles. It is crossed by Clinch River between Lebanon and Honaker. Its continuation between Blackford and Tazewell County is known as Kent Ridge. The steep northwest flank of Copper Ridge is difficult to ascend, but from the valley floor at Lebanon the land rises gradually to the crest of the ridge. A short distance above Blackford, Clinch River is joined by its main tributary, Maiden Spring, or Little, River. In the east-central part of the county, between the valley occupied by the headwaters of Cedar Creek and the main Clinch Valley, there are two short linear ridges known as Elk Garden and House and Barn mountains, that stand conspicuously above the surrounding valleys.

The northwest boundary of the county is formed chiefly by the crests of Sandy Ridge and Big A Mountain (Pl. 5, A), from which the land slopes irregularly southeastward to Clinch River.

Although the crests of the mountains are invariably underlain by resistant rock, rapid weathering and slumping of rock debris normally prevent the bedrock from cropping out in conspicuous ledges. This is not true on House and Barn Mountain, where a resistant sandstone forms the crest of the ridge. The sandstone has few weak zones for erosional attack, and as a result almost vertical cliffs have developed where the rock has broken along vertical joints. Immense rectangular blocks of sandstone, some of which are completely detached from the main outcrop, cap the mountain summit. Two of these, somewhat resembling a house and barn when viewed from the Lebanon-Tazewell highway, have suggested the name of the ridge.

Minor rows of ridges and conical hills (Pl. 3, C) complicate the geography of the county and help to produce a distinct system of northeastward-trending valleys and intervening ridges. The local topography is strikingly linear and forms a pattern that has affected the location of roads and the settlement of the county.

The chief river of Russell County is the Clinch, which follows a meandering course along the greatest length of the county, and forms part of the boundary between Russell and Wise counties. (See Fig. 2.) Its main tributaries, Maiden Spring (Little) River and Cedar Creek, enter it from the east and south, respectively. Sword, Lewis, Chaney, and Lick creeks are smaller tributaries that descend from Sandy Ridge. About 78 per cent of Russell County drains directly into Clinch River, which is 1,350 feet above sea level at the extreme western edge of the county.

About 19 per cent of Russell County drains into Moccasin and Copper creeks, which rise in the central part of the county and flow southwestward into Scott County. Copper Creek enters Clinch River near Clinchport; Moccasin Creek flows through Big Moccasin Gap to join Holston River south of Gate City, in Scott County. Tumbling Creek, which is tributary to the North Fork of Holston River, rises in Mutters Gap and descends in a narrow gorge in the southeastern corner of the county. It drains about 3 per cent of the county.

The local drainage reaches Tennessee River through Clinch and Holston rivers and ultimately makes its way into the Mississippi.

SOIL AND VEGETATION

Three of the four leading industries of Russell County—agriculture, livestock production, and lumbering—are almost wholly dependent upon soil and vegetation; only coal mining proceeds without regard for soil.

Except for river-bottom and other stream-laid material, almost all natural soil in Russell County is the product of the weathering and decay of the bedrock directly beneath the surface. Although there is a wide variety of rock types in the county, yet for practical purposes the soil types may be restricted to three main kinds, for the end products of the decay of various rock types tend to resemble one another.

Probably the most important soil type is the so-called limestone or bluegrass soil which occupies most of the area between Clinch Mountain and Clinch River. This soil has resulted from the weathering of limestone, limy shale, and dolomite and is fairly deep, has excellent fertility, and is commonly sod-producing. The attractiveness of this soil led to the early settlement of the county by the hunters, who overstayed their hunting seasons to cultivate desirable tracts on the valley slopes. The soil is normally a red clay loam which grades downward into a red clay. It supports a good stand of either timber or blue grass and can be readily cultivated for the ordinary staple farm products. (See Pls. 4, C and 8.) Where the underlying rocks are impure or contain chert the soil is less productive, and along the crests of Moccasin and Copper ridges there are many belts where such impurities impede cultivation and furnish large quantities of fragments to the soil.

An interesting subtype of this soil is found in a belt of moderate width and extent from Point Truth past Mason's Store to Dickensonville. It is developed upon a green shaly rock and is locally known as "blue soil." Although the true color is dark chocolate-brown, a freshly plowed field shows a distinctly bluish or purplish cast that gradually disappears upon exposure. This soil is extremely dense and plows with difficulty. It is not very deep but is exceptionally tight and forms large clods. Below the surface it is smooth and moist, but at the surface it quickly dries out. It is readily recognized, and is sharply separated from adjoining limestone soils. Although many of its characteristics are undesirable, they are more than offset by an unusual fertility. Clover thrives exceptionally well in this soil and, where examined in a number of fields, stood several inches higher in the "blue soil" than on the adjacent limestone ground. The soil is limited to small patches in a belt that is only a few miles long.

The second main soil type is that produced by the disintegration of underlying shale. (See Pl. 5, C.) Although the largest area of shale soil is found along the northwestern slope of Clinch Mountain, there are many small linear belts between the various limestone belts in the central part of the county. Like the adjacent limestone soils, the shale soil supports a good stand of blue-

grass and furnishes ideal pasture land, although many areas are too steep for profitable agriculture. (See Pls. 4, A, and 6, B.) The soil is reddish brown, is fairly deep, and is not normally subject to wash. It contains minute rock splinters and is but slightly less fertile than the true bluegrass limestone soil.

A third soil type is developed upon the coal-bearing sandstone and shale of the area north of Clinch River. It is loose, sandy, and relatively sterile. It does not support bluegrass, and its steep slopes become quickly gullied and scoured in the absence of the thick sod that protects the limestone soils under similiar conditions. Rock outcrops are common on the steeper slopes.

When the Indians moved into Russell County, it was well wooded and a desirable hunting ground. The ridges were largely in chestnut and chestnut oak, and their slopes were crowded with white and red oaks, chestnut, hickory, maple, and with some black oak, walnut, and other hardwood species of lesser importance. In the ravines along the smaller streams and the coves grew yellow poplar, white oak, and an occasional hemlock and sugar maple. On the lower stream slopes and on the level floors of the larger valleys, hemlock was abundant with rhododendron forming dense thickets under the trees.

With the settling of the first colonists, or "long hunters," the more level areas were cleared of forests and were tilled. Gradually a thick stand of bluegrass began to encroach upon the cultivated fields. At first it was considered a pest, but soon its nourishing value for stock suggested grazing as a pioneer industry. More and more of the land was cleared for bluegrass pasture and the forests dwindled until at present nearly 80 per cent of the county is devoted to farms or pasturage. Since its organization the county has always ranked high in volume of stock produced.

Wherever slopes too steep for cultivation or too rocky for bluegrass have been cleared of timber, erosion of soil and impoverishment of the land have been the results. With the settlement of the coal areas north of Clinch River, trees were destroyed and steep stony slopes were unwisely tilled. When the soil was eventually washed away, the itinerant farmer moved to another location, and a scraggly growth of barren timber grew up in the abandoned fields. In the more prosperous limestone areas many of the large stock ranges were tenanted by unskilled farmers, who moved their fields every few years after largely destroying the value of the land by unscientific farming. (See Pls. 4, A, and 6, B.) Thus there has developed an unfortunately large percent-

age of submarginal land,[2] which has temporarily lost its usefulness either for pasturage or for cultivation. Recently, through the agencies of the Civilian Conservation Corps and the Tennessee Valley Authority, modern scientific methods of reclamation have been undertaken, but at least a generation will pass before most of this land regains much of its former value.

Corn, wheat, and oats have long been the county's chief crops, and burley tobacco, potatoes, and apples are other common products. Well-located and properly managed farms are unusually prosperous. Much of the county is a rolling range that is exhibited to good advantage to the tourist who follows the main roads. (See Pl. 8, B.)

[2] This term is applied to lands whereon the farmer's normal efforts to maintain a living fail to give him a margin of profit.

HUMAN HISTORY

Russell County takes its name from one of its most distinguished early settlers, General William Russell, a veteran Indian fighter, Revolutionary soldier and brother-in-law of Patrick Henry.[3]

The present county was originally part of the "County of Orange," which, before 1738, when the act establishing Augusta County was passed, included all land between the Blue Ridge and the Mississippi River—that is, extended indefinitely west. When this vast territory was formally organized as Augusta County in 1745, the portion including the present Russell County was known as "West Augusta." In 1769 West Augusta became Botetourt County, from which in 1772 a section was detached to form Fincastle County. The process of partition continued in 1776 with the division of Fincastle into three counties, one of which was known as Washington County. Ten years later a portion of Washington County was organized into a separate political unit and called Russell County.

As the Russell County of 1786 included much of southwestern Virginia northwest of Clinch Mountain, as well as a small part of the present West Virginia, its area may have exceeded 3,000 square mlies. In 1792 it relinquished a portion of its territory to form Lee County; another portion was lost in 1799 to the newly formed Tazewell County; and further subdivisions of its area occurred in 1814, 1855, and 1858, with the formation of Scott, Wise and Buchanan counties, respectively. The loss of many square miles to Dickenson County in 1880 reduced the county to its present size.

Although the remoteness of Russell County from the more densely settled Piedmont and Tidewater areas retarded its colonial development, numerous families of pioneers and hunters passed through or tarried in the region during the early decades of the 18th century. They found the drainage basins of Clinch and Holston (Indian) rivers to be fine hunting grounds, although occupied by Indians. As the Indians were not sympathetic to colonial settlement, open hostilities marked the period between 1754 and 1764 until a truce was arranged between the Indians and the English in the treaty of Lochaber, and territory marked by John Donelson's line—mainly the land west of Clinch Mountain—was mutually set aside for hunting only and was closed for settlement. Many of the white hunters decided to remain in the restricted

[3] A fuller statement of the early history of Russell County, prepared by Dr. Daniel Trigg, is included in "An economic and social survey of Russell County," by L. B. Tate, published in volume 16 (no. 1) of the University of Virginia Record, Extension Series, 1931.

area, and communities sprang up in the hunting grounds in violation of the treaty.

The first of these settlements in Russell County was in Castle's Woods, on Clinch River near the present site of Castlewood. Other "long hunters" settled on Moccasin, Copper, and Sword creeks, in Glade Hollow near the present site of Lebanon, and at Elk Garden. As the settlements grew more prosperous, strategic points were fortified, including Fort Blackmore, Fort Russell, Glade Hollow Fort, and Elk Garden Fort. The trails that connected these posts were used alike by the ambitious settlers and the indignant Indians, and along many of them open warfare ensued. Daniel Boone and William Russell each lost a son in the Indian attacks, which gradually increased in intensity and culminated in Cresap's (or Dunmore's) War in 1774. Owing to the concerted stand of the settlers the Indians temporarily ceased to harass the isolated but stanchly supported settlements.

A mill was erected in Castle's Woods in 1774, and an increasing number of settlers began to occupy the local area. In retaliation both Ohio and Cherokee Indians resumed their depredations in 1776, and for nearly 20 years forays against the settlers continued under the leadership of Dragging Canoe and the renegade Benge. The overwhelming number of frontiersmen, however, gradually reduced the Indian attacks to a minimum, and by 1796 this element of peril was almost entirely removed.

In 1786 the region now included in Russell County was severed from Washington County, and early in 1787 the first court of Russell County sat near Castlewood. As a result of a gift of land near the present site of Dickensonville, the former county seat of government was removed late in 1787 to that locality. With the formation of Lee, Tazewell, and Scott counties, each of which absorbed part of Russell County, the seat was moved to a tract of land, along a tributary of Cedar Creek, that had been donated to the county. For the new site, then abounding in cedars, the name Lebanon was appropriate, and in 1819 the town was laid out. (See Fig. 2.)

A post office was established at Dickensonville in 1821, and other small settlements began to thrive at Elk Garden, Castlewood, and New Garden. The pioneer trail from Russell's Fort through Little Moccasin Gap to Abingdon connected with the old Fincastle Road from the north and became the chief highway of the county. In 1889-90 the first railroad, the Norfolk & Western, entered the county, and the towns of Cleveland and Honaker were founded along it. The development of coal lands near Turkey Foot, on Lick Creek, led to the establishment of Dante in 1902.

PHYSIOGRAPHY

PHYSIOGRAPHIC PROVINCES

The Blue Ridge upland of Virginia, whose crest can be seen on a clear day from Clinch Mountain, forms an important geomorphic province in southwest Virginia. Within it lie the rugged mountains of the Tennessee-Carolina boundary, including the Unaka Range and its continuation in Virginia. Farther north and west is a wide territory, the Valley and Ridge province, in which long mountain ridges alternate with elongate parallel valleys. All these features comprise the remnants of a very ancient mountain system.

A broad continuous lowland along the west foot of the Blue Ridge plateau has long been known as the Great Valley. In Virginia it is called the Valley of Virginia; in Tennessee, the Tennessee Valley. Long ago, when the pioneers settled in southwestern Virginia, a small part of this lowland was known as Abb's Valley; now, the southwestern section of the Valley of Virginia in Washington and Smyth counties is called the Abingdon Valley. The floor of Abingdon Valley stands between 2,100 and 2,200 feet above sea level, or 3,500 feet below Mount Rogers, the highest summit of the Blue Ridge in Virginia.

Clinch Mountain, one of the longest and most persistent of the Appalachian ridges (Pls. 3, B and 5, B), forms the northwestern boundary of Abingdon Valley and the southeastern boundary of Russell County. Hence all of the county is west of the Great Valley and occupies the western part of the Valley and Ridge province. Clinch Mountain, Moccasin and Copper Ridges, Elk Garden, House and Barn, Big A, and Stone mountains are the most conspicuous ridges. The valleys of Copper, Moccasin, and Indian creeks, and Clinch River are prominent lowlands. (See Pl. 4, C.)

Dickenson and Buchanan counties, northwest of Russell County (Fig. 1), lie in the Appalachian Plateaus province, which extends partly into Russell County, where, except for the small areas of Big A and Stone mountains, it slopes directly down to Clinch River.

EROSION LEVELS

It seems obvious that the surface features of Russell County have resulted from work by streams. Indeed, stream erosion is the dominant factor in shaping the surface of most areas. An important but passive factor in land sculpture is the character of the underlying rocks, for the rate and results of erosion are dependent in large measure upon the resistance of the material that is being eroded. All the present surface features of the county have resulted from erosion and weathering operating upon rocks of different hardness.

The ascent to the summits of Big A (Pl. 5, A), Stone, and House and Barn mountains is rewarded with excellent views of Russell County, in which one of the most striking elements of the landscape is the long even crest of Clinch Mountain. (See Pl. 3, B.) From a similar vantage point on Clinch Mountain an observer can look across the central part of Russell County to the crest of Sandy Ridge, along the northern and western horizon. The crests of these summits stand at approximately the same elevation, and if it were possible to fill the valleys to the level of the ridges, a broad, gently undulatory plain would be produced. Such a surface existed here in the geologic past. It was produced during a long epoch of active erosion, when the land stood much nearer sea level than at present and when the drainage basins of the streams were worn down nearly to a uniform level. Then the surface was a lowland feature; now its remnants are found only on the crests of the high mountains, where they have escaped obliteration by subsequent erosion. An appropriate name for this old erosion surface is the "Upland level."[4] Probably the most striking remnant is the great meadow at the head of Brumley Creek, which occupies nearly 8 square miles of Clinch Mountain due south of Lebanon and stands about 3,800 feet above sea level. Probably it was widespread throughout the Appalachian region, for other remnants, similar to that on Clinch Mountain, are common to all parts of the region.

Although the rocks beneath Sandy Ridge and the Appalachian Plateaus are flat-lying, those which underlie most of Russell County, including Clinch Mountain, are tilted on edge. Evidently the former lowland plain which is now the Upland level must have been cut across the edges of the upturned rocks, and thus it must have been crossed by parallel belts of rock that dipped steeply below the surface. Inasmuch as different rock types behave differently under erosion, it is probable that the belts of softer rock formed low swales and the belts of harder rock low ridges. Any uplift of such a surface would rejuvenate the streams and cause a second cycle of stream erosion to cut deeply into the softer rocks, thereby destroying the previous surface save on the summits of the more resistant rocks.

Such a development seems to have followed the formation of the Upland surface in Russell County. As the region was gradually elevated, erosion attacked and ultimately removed large masses of material from the rocks which were relatively soft. How long it took for this erosion to be accomplished is now impossible to determine, but it must have been very long in terms of human history—probably many millions of years. At any rate, it was sufficiently long to remove all trace of the Upland

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

level except the few remnants now preserved on the local mountain summits. The erosion has never stopped, but there is some evidence that for a long period it progressed very slowly. This evidence is furnished by terraces, or benches, considerably below the Upland level, yet well above the present stream bottoms. The broad area between Clinch River and Copper Ridge in the western portion of the county, the flats near Lebanon, and the terraces along Copper and Moccasin creeks (Pl. 4, C) suggest that the period of downcutting was interrupted by a stage of valley widening, in which the streams broadened rather than lowered their valley floors. Such a change in stream activity would result from a halt in the uplift of the region and would produce benches, or local erosion levels, along all the larger streams. From their position on the floors of the old broad valleys, these levels are now known as the "Valley-floor levels."[5] As all the present streams are now incised below the Valley-floor levels, the downcutting must have been renewed, and the trenches occupied by the present streams must be the product of this renewal of erosional activity.

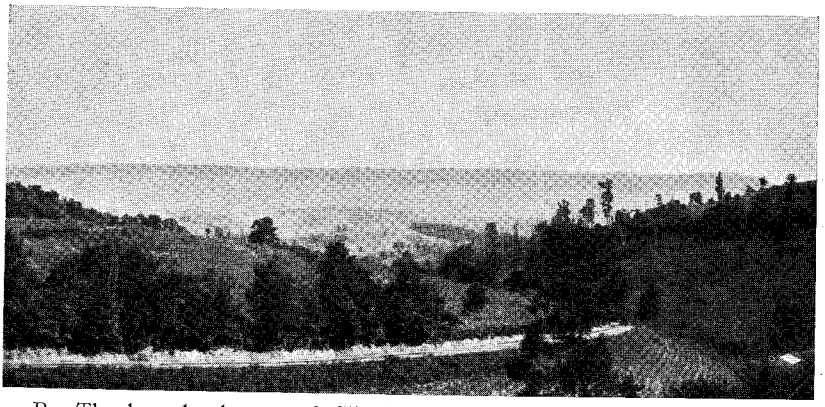
Thus it is possible to recognize two erosion levels in Russell County. The Upland level, 2,500 to 4,000 feet above sea level, is the older, and its remnants now occur only on the crests of the highest mountains. The Valley-floor level is much lower and is represented by flat areas at about 1,700 to 2,000 feet above sea level. Present streams now lie from 200 to 400 feet below the Valley-floor level. Although the formation and dissection of these two erosion levels represent the major elements of the geography of Russell County, the levels themselves are relatively inconspicuous and would escape casual observation.

SURFACE DRAINAGE

The drainage pattern of Russell County is a product of the development of the two major erosion levels. The main streams of the county occupy valleys that are conspicuously parallel and trend northeastward between mountain ridges and minor rows of hills. For both valleys and ridges the northeasterly trend is inherited from the belts of upturned rocks that were beveled by the Upland level. The original trend of these folded rock belts was toward the northeast. The trend of the main streams has been maintained as the valleys grew deeper and as the ridges, by comparison, grew higher. As most of the tributary streams flow down the slopes of the parallel ridges, the general pattern of the drainage is more or less rectangular, with parallel main members and smaller branches that enter at right angles. This drainage pattern, which is known as "trellis drainage," is the common type in the Valley and Ridge province.

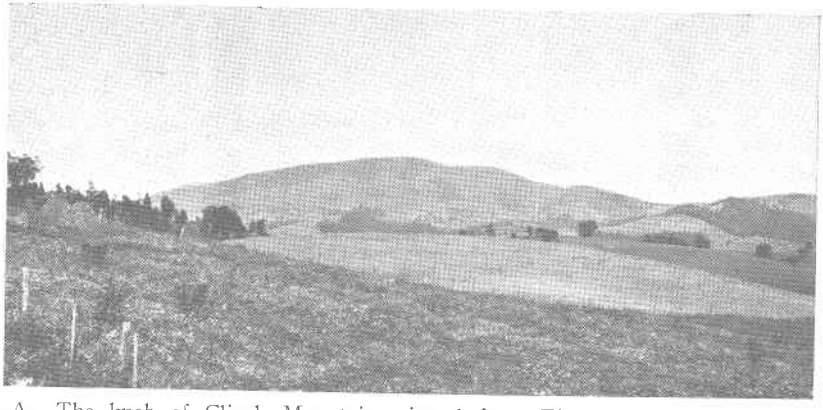
[5] Stose, G. W., and others, op. cit., p. 39.

A. The knob of Clinch Mountain, viewed from Elway across the famous Russell County pasture land. The knob is 4,223 feet above sea level.



B. The long level crest of Clinch Mountain from Copper Ridge, north of Lebanon.

C. Hummocky knobs upon Cambrian shale southeast of Cleveland. Although partly cleared, the slopes are too steep for profitable agriculture.



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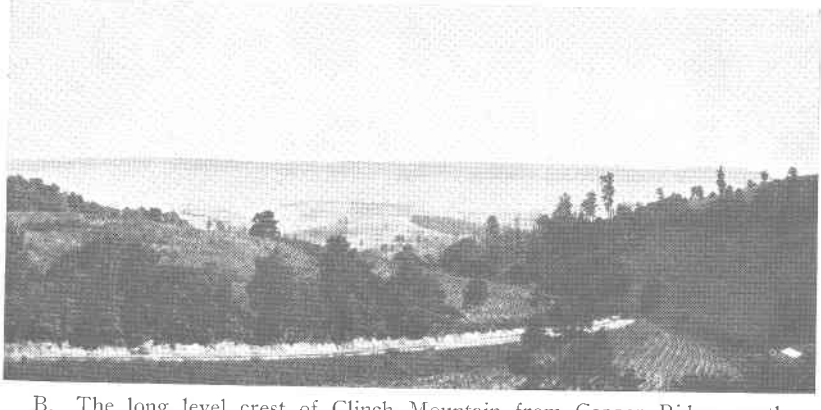

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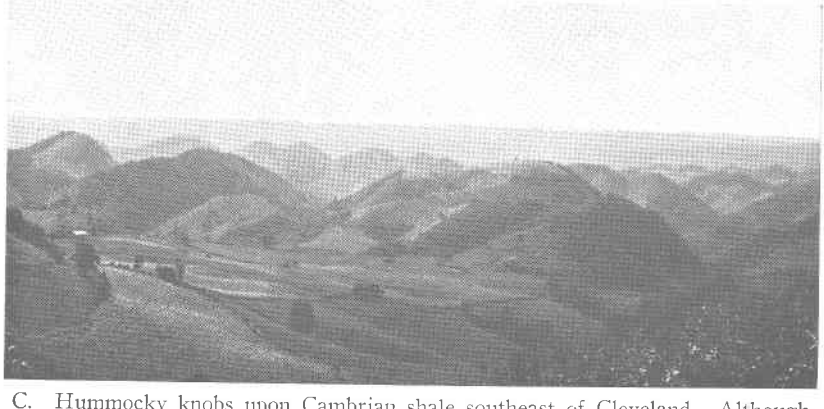
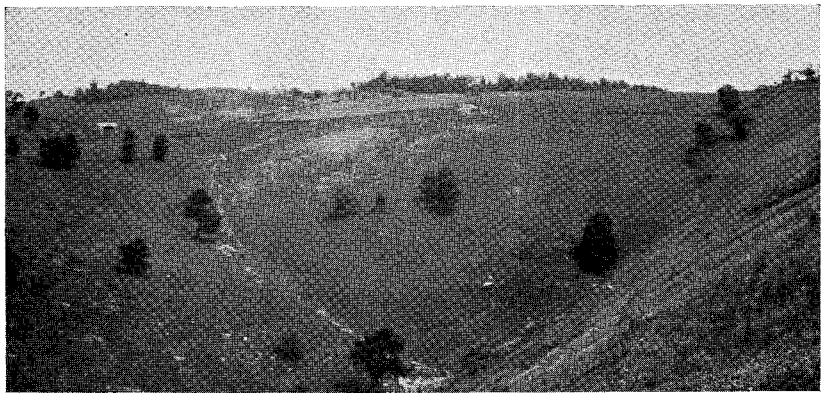


C. Hummocky knobs upon Cambrian shale southeast of Cleveland. Although partly cleared, the slopes are too steep for profitable agriculture.



A. Steep shale slopes along the northern edge of Copper Ridge near Cleveland.

B. Bare ledges of limestone near Gardner, indicating improper soil cultivation. The tree in the middle background is a lone survivor of the original forest.

C. Valley-floor levels along Moccasin Creek near Fugates Hill, as seen from the north slope of Clinch Mountain.

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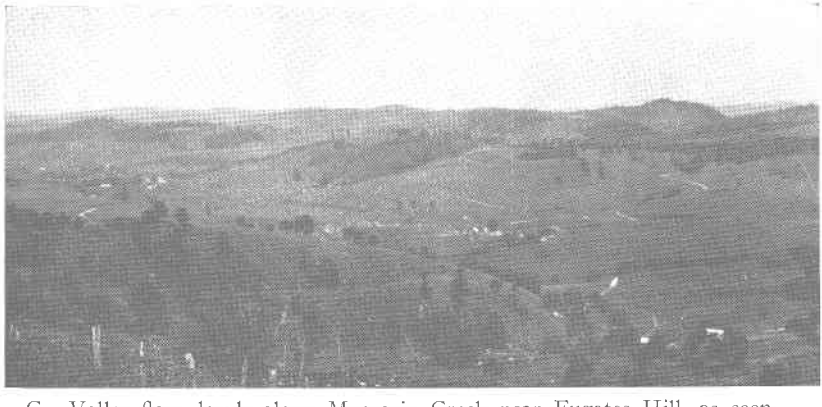


C. Valley-floor levels along Moccasin Creek near Fugates Hill, as seen from the north slope of Clinch Mountain.

Only Clinch River fails to fit regularly into the trellis pattern. This failure is due chiefly to its winding course, for the general direction of its valley is parallel to the main valleys formed by other streams. The Clinch, which is now the largest stream of the region, has probably always been the master stream, for it was present on the Upland surface before any of its existing tributaries had developed. On that old surface it flowed quietly southwestward and, like other normal streams with a low gradient, adopted a meandering course. When uplift of the region increased its current, the stream began to erode its channel into the soft rock underlying its valley. Once incised into solid rock, the sinuous course on the Upland level has been perpetuated as a dominant characteristic of the stream, even though the surface upon which it was originally developed has been almost completely destroyed.

In the area of coal-bearing rocks north of Clinch River (Fig. 5) there is little or no trace of any trellis pattern, and the streams unite in a treelike pattern that is known as "dendritic drainage." This is the typical pattern where there are no alternate more or less parallel belts of soft and hard rocks such as occur in areas of folded strata.

UNDERGROUND DRAINAGE

That all the local drainage is not carried at the surface is well known to residents of the county. Depressions out of which no streams flow are common, as are caves, sink holes, and springs. These features are restricted to the belts of limestone and dolomite (Pl. 1) and are due to the solubility of those calcareous rocks. Fractures and crevices in the bedrock make easy channels for surface water to enter. If the rock is soluble, the crevices will be enlarged and the flow of water increased. The larger volume of water accomplishes additional solution, together with a certain amount of erosion, and permanent lines of underground drainage result. This drainage generally makes its way to the surface again, and if the outlet furnishes a steady stream of water, a spring is formed. Water may seep directly downward into a channel below and thus a funnel-shaped depression may develop on the surface. If the roof of the underground channel collapses, a sink hole will be formed. In some places the rapid downcutting of a surface stream will intersect a subsurface channel, which then becomes visible as a cave. Many such features are exhibited in Russell County, especially in the limestone area immediately north of Lebanon, between Dickensonville and Blackford.

VALLEYS

The attractive Lebanon Valley (Pl. 4, C) and the valleys of Copper and Moccasin creeks stand several hundred feet above Clinch and Hol-

ston rivers. Lebanon Valley is adjacent to both Clinch and Holston valleys. Its high level is shown by the descent from Hansonville through Little Moccasin Gap to Holston, or that from Lebanon to Cleveland—in each place a vertical drop of 700 feet in a short horizontal distance. The difference in level is explained by the fact that Lebanon Valley is drained by the headwaters of Moccasin and Copper creeks, both of which flow nearly 30 miles beyond the county before they reach the level of their master streams, the Holston and Clinch rivers, respectively.

CONICAL HILLS

Possibly the most conspicuous minor item of the topography is the abundance of small conical hills in parallel rows along the flanks of Copper and Moccasin ridges. Good examples of these knobs occur directly south of Lebanon and along Clinch River between Carterton and Nash Ford. (See Pl. 3, C.) Almost all the hills are underlain or capped by shale, and their rows lie between parallel belts of limestone. Although shale and limestone are eroded readily, the limestone is soluble whereas the shale is not. As a result of this solubility the limestone belts are lower topographically than those of the insoluble shales, which have gradually grown in relief as sharp ridges, dissected into knobs by the streams that cross the shale belt. Weathering and the slump of loose rock from their slopes tend to give the shale hills a rounded profile. Many of the hills have been cleared for pasturage or cultivated for crops, but their slopes are nearly everywhere too steep for pasture and much too steep for successful cultivation.

TUMBLING CREEK GORGE

Possibly the most beautiful scenery in Russell County is the gorge of Tumbling Creek, which descends into Washington County north of Hazel Springs. The gorge is almost inaccessible from the Russell County side, is nearly 2,000 feet deep, and is occupied by a mountain stream that tumbles over falls and rapids to reach the level of Poor Valley. A peculiar sequence of events has taken place at the head of this stream in Mutters Gap, which is floored by soft shale overlain by a residual soil that originally supported a dense forest with correspondingly thick underbrush. Recent forest fires have removed not only the underbrush but also much of the standing timber, thereby inciting rapid soil erosion by the active streams on both sides of the gap. This erosion and rain wash have entirely denuded the gap of its soil. The charred stumps of the larger trees were originally deeply rooted, but with the removal of the soil their bare unburned roots, washed clean of dirt, now stand 2 or 3 feet above the present floor of the gap and form a tangle through which it is extremely difficult to travel.

GEOLOGIC FORMATIONS

GENERAL STATEMENT

The earth's surface is everywhere underlain by solid rock, or bedrock, which may be covered by soil or other debris. Here and there it is exposed in bare rock cliffs and ledges. (See Pl. 4, B.) Only one of the three major groups of bedrock occurs in Russell County. The rocks are entirely of sedimentary origin, having been formed during ancient epochs of erosion and weathering and subsequently deposited as loose sediments that have become consolidated into bedrock. (See Pl. 7, A.) Igneous rocks, which were formerly molten, and metamorphic rocks, produced by intense heat and great pressure, occur only at great depths in the county.

Both coarse- and fine-grained fragmental sedimentary rocks occur in Russell County. The coarse pebbly varieties are conglomerates; the fine-grained varieties composed mainly of sand are sandstones. Thin-bedded mudrocks, or shales, are common. There are two types of dominantly calcareous or limy rocks, including limestone, which is chiefly a calcium carbonate rock ($CaCO_3$), and dolomite, a calcium-magnesium carbonate rock [$CaMg(CO_3)_2$]. Many gradational varieties, such as limy shales, shaly sandstones, and impure limestones, can be recognized.

From a study of the rocks all over the earth, geologists have divided all of geologic time, during which these rocks were formed, into five major eras. They are the Archeozoic, Proterozoic, Paleozoic, Mesozoic, and Cenozoic eras. The first two comprise pre-Cambrian time, for they antedate the first period of the Paleozoic which is called the Cambrian.[6]

All the bedrock of Russell County belongs to the group of rocks that was deposited during the very ancient Paleozoic era of earth history. All but one of the rock systems of the Paleozoic have local representatives, only Permian rocks being absent. Possibly the Permian rocks were once present but have been removed by erosion. The Paleozoic divisions in Russell County are as follows:

[6] For a discussion of geologic time units, see any standard textbook of geology.

System	Thickness (feet)
Pennsylvanian	5,280+
Mississippian	1,400-1,520+
Devonian	1,175-1,350
Silurian	425+
Ordovician	3,200-3,800
Canadian[a]	1,200±
Ozarkian[a]	1,200±
Cambrian	2,200-2,500

The geologic section of Russell County includes 32 rock units that range from early Cambrian to early Pennsylvanian and aggregate more than 17,000 feet in thickness. The section is unusually complete, and most of the formations are well exposed and may be easily studied. In Table 1 is listed the name, thickness and geologic age of each rock unit. (See also Pl. 1.)

[a] The Canadian as used here corresponds to the lower part of the Ordovician system and the Ozarkian to the upper part of the Cambrian system of most geologists.

TABLE 1.—*Geologic column for Russell County*

AGE	FORMATION	THICKNESS (feet)		MAP UNIT (Plate 1) AND CHARACTER
		North of Clinch River	South of Clinch River	
Pennsylvanian	Wise formation	2,150		Coal-bearing rocks; sandstone and shale
	Gladeville sandstone	80–100		
	Norton formation	1,400		
	Lee formation	1,650		
Mississippian	Pennington shale	1,100		Sandstone and shale
	Gasper limestone	50 –75	*c*	Limestone, thick-bedded, oolitic
	Ste. Genevieve limestone	50 –75		
	St. Louis limestone	50±		Impure limestone
	Price-Pocono sandstone	200		Sandstone and shale
	Big Stone Gap shale	4 –16		

TABLE 1.—*Geologic column for Russell County*—Continued

AGE	FORMATION	THICKNESS (feet)		MAP UNIT (Plate 1) AND CHARACTER
		North of Clinch River	South of Clinch River	
Devonian	Brallier shale	1,000	1,250	Shale
	"Romney" shale	50		
	Onondaga limestone	75	0–100	Impure limestone
	Helderberg limestone	50		
Silurian	Clinton formation	300	300	Sandstone and shale
	Clinch sandstone	125	125	Sandstone, massive
Ordovician	Juniata shale	300	300	Sandstone and shale
	Martinsburg shale	1,600	1,800	Shale
	Moccasin-Lowville formation	600	500–700	Impure limestone
	Ottosee limestone	0–400	400–450	
	Holston limestone	0–300	250–300	Pure limestone
	Lenoir limestone	0– 50	50– 75	
	Mosheim limestone	0– 50	25– 50	
	Murfreesboro limestone	0–125	125	Impure limestone

Canadian[a]	Bellefonte dolomite equivalent Nittany dolomite equivalent	undifferentiated	1,200	1,200	Dolomite, pure
Ozarkian[b]	Copper Ridge dolomite		1,200	1,200	Dolomite, impure, cherty
Cambrian	Nolichucky shale		400	400–500	Shale and limestone
	Honaker dolomite	Maryville limestone	550	550	Limestone, slightly magnesian
		Rogersville shale	0–100	0–100	Shale
		Rutledge limestone	250	250	Limestone, slightly magnesian
	Rome formation		1,000	1,100	Shale
			16,541	10,475	

[a] Lower Ordovician of most geologists.
[b] Upper Cambrian of most geologists.
[c] Present in Sinkhole Valley.

Plate 1 shows the local formations arranged on the basis of their rock type—that is, all the sandstones are grouped together, all the limestones are shown in a second group, and other rocks are classified according to their varietal types. This classification represents the most simple and practical arrangement of the local rocks, and is also used on the accompanying geologic map (Pl. 1), where the area of outcrop of each rock type is indicated. In the paragraphs which follow, a brief description is given of the several rock formations in each geologic system.

CAMBRIAN

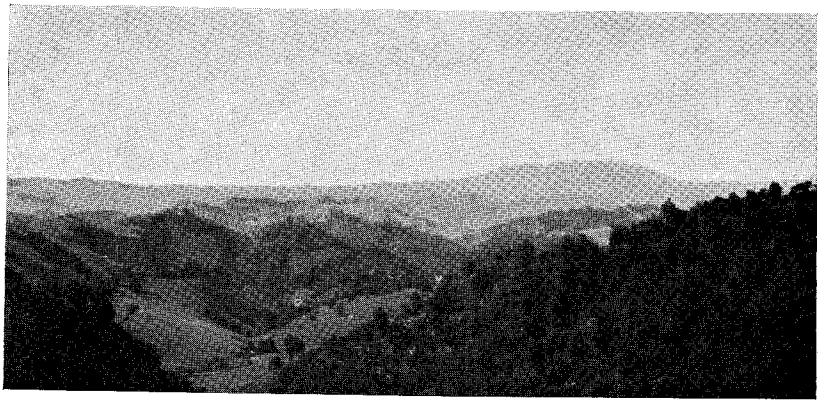
The oldest exposed bedrock of Russell County consists of sediments that were deposited during the Cambrian period. The age of these rocks in terms of years is difficult to determine, although it is probable that they are not less than 500,000,000 years old. They attain a maximum total thickness of about 2,500 feet in Russell County and may be subdivided into five formational units.

The Cambrian system begins with the shaly Rome formation (Pl. 5, B), which is everywhere cut off by faults, or breaks in the strata, so that its lower portion and the basement upon which it rests are not visible at the surface. Rome shales are overlain by the Honaker dolomite, which, east of St. Paul, appears to grade laterally into the magnesian Rutledge limestone, the Rogersville shale,[7] and the Maryville magnesian limestone. Both the Maryville and Honaker dolomites are overlain by the gray Nolichucky shale, which has a thickness of about 500 feet. The Rome, Rogersville, and Nolichucky shales contain trilobites, the fragments of which are common in limestone lenses.

The Cambrian shales crop out in narrow belts along the lower slopes of Copper and Moccasin ridges and in the valley of Clinch River. (See Pl. 3, C.) They are comparatively stiff shales that do not produce an especially fertile soil. They contain interbedded lenses of limestone, which are separated from the adjacent shale beds by sharp contacts. As these shales occur along the flanks of ridges between belts of calcareous rocks, their outcrop is marked by rows of sharp-pointed conical hills that are striking features of the local landscape. (See Pl. 6, A.)

Classified as magnesian limestones, the Maryville and Rutledge limestones grade directly into the Honaker dolomite. They crop out in Russell County only in the area from Castlewood westward. The rocks are similar in appearance to the limy beds of the Honaker, yet are somewhat more calcareous than true dolomites. Both formations are dark colored and fine textured and are separated from one another and from other adjacent limestones by shales.

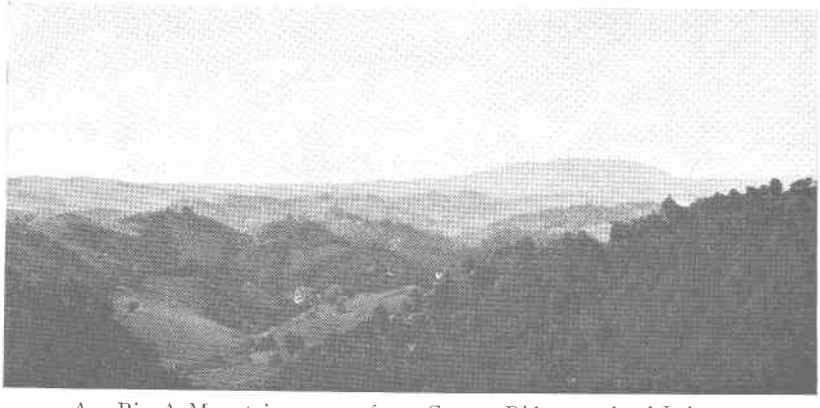
[7] It is possible, however, that the Rogersville shale has no equivalent in the Honaker.



A. Big A Mountain as seen from Copper Ridge north of Lebanon.

B. The rugged crest of Clinch Mountain north of Hansonville. It is formed by the resistant Clinch sandstone. Holston limestone occurs in the foreground.

C. Cleared Martinsburg shale slopes along the northern flank of Elk Garden Mountain, south of Blackford. The steep slopes retain their soil even after cultivation.



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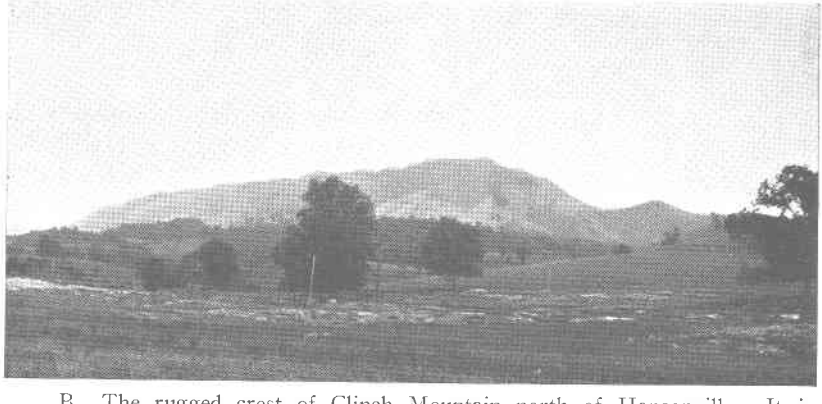
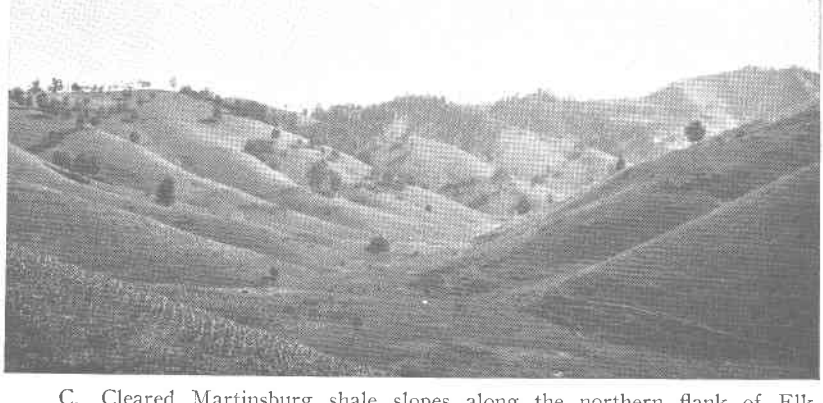
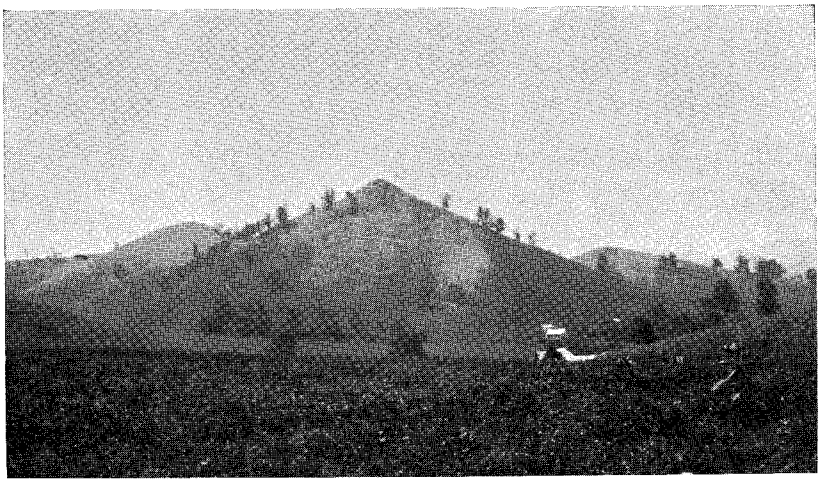


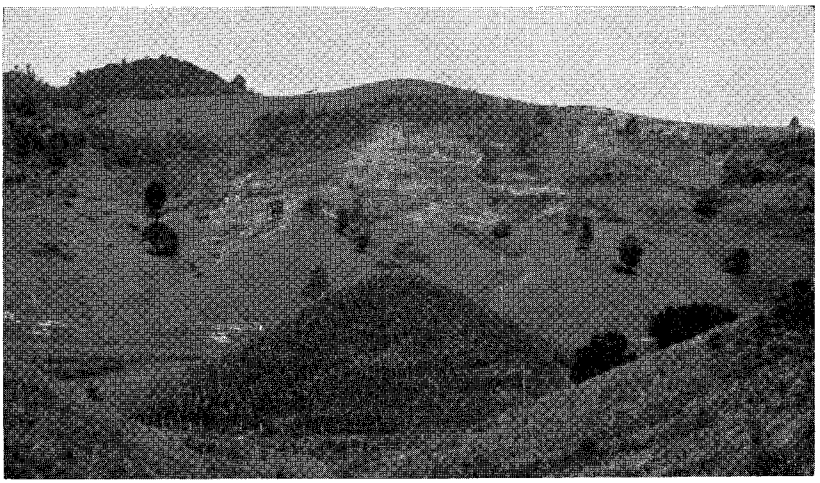
B. The rugged crest of Clinch Mountain north of Hansonville. It is formed by the resistant Clinch sandstone. Holston limestone occurs in the foreground.



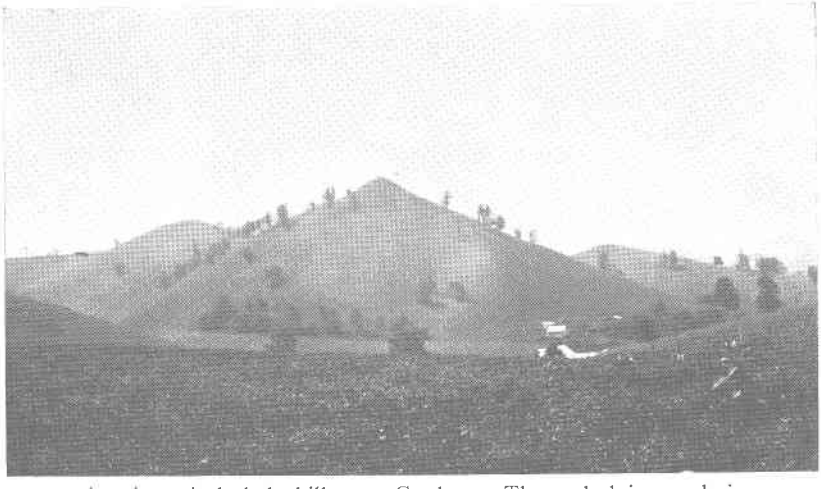
C. Cleared Martinsburg shale slopes along the northern flank of Elk Garden Mountain, south of Blackford. The steep slopes retain their soil even after cultivation.



A. A conical shale hill near Gardner. The underlying rock is the Rome formation.



B. A cultivated shale knob near Blackford. Under cultivation, the steep slopes of the knob will become stripped of arable soil.



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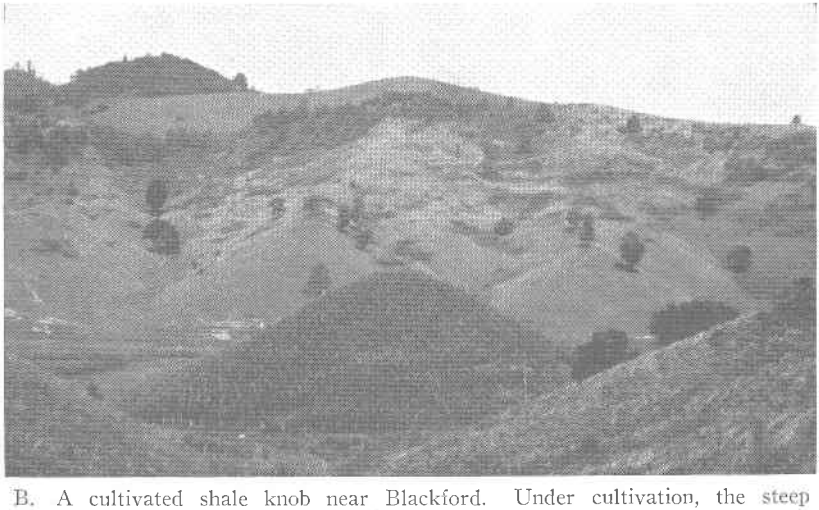


B. A cultivated shale knob near Blackford. Under cultivation, the steep slopes of the knob will become stripped of arable soil.

OZARKIAN AND CANADIAN

Rocks of Ozarkian and Canadian age are widely distributed in Russell County, where they attain a maximum total thickness of about 2,400 feet. (See Table 1.) All of them are dolomites that were formed next after the deposition of the Cambrian rocks. They include, in ascending order, the Copper Ridge dolomite and a dolomite mostly equivalent to the Nittany and Bellefonte dolomites of Pennsylvania. No equivalents of the Chepultepec and Stonehenge formations, which occur south of Clinch Mountain, appear to be present.

The dolomites of Russell County crop out in three long belts that extend nearly the entire length of the county and underlie a large part of it. (See Pl. 1.) One of these belts lies along the southern flank of Moccasin Ridge, where it includes the entire slope from the summit of the ridge to Moccasin Creek. This belt extends northeastward along the headwaters of Cedar and Indian creeks. A second belt occupies a similar position along Copper Ridge and extends northeastward along the valley of Little River. A third area lies along the northwest foot of Copper Ridge and extends from St. Paul through Honaker and Sword Creek.

The Ozarkian and Canadian dolomites are almost entirely thick-bedded rocks. They have been tilted from an original horizontal position into various inclined attitudes. (See Pl. 7, B.) They are very dense and break more commonly with curved surfaces than with jagged or splintery edges. Gray colors predominate, but upon weathering the rock surfaces assume a drab color in which a faint brownish hue is apparent. Some of the light-colored beds are coarse grained; a few are sugary in texture.

Dolomite is somewhat less soluble than limestone and resists erosion slightly more; hence, dolomite outcrops are hillier and more irregular than limestone outcrops. In Russell County, chert, a flintlike material, is associated with some of the dolomite beds. Both Copper and Moccasin ridges are covered with irregular, jagged masses of white to gray chert that hinder cultivation of the soil and add to the resistance which the underlying beds offer to erosion. Some of the chert masses are cavernous, and many are stained with iron. In a few places nodules of brown iron occur with the chert in such quantity as to delude the casual observer with the impression that a large body of iron ore must be present.

Two varietal types may be recognized among the dolomites of Russell County. The more prevalent type is represented by the Nittany equivalent and Copper Ridge formations, from which chert is a conspicuous product. The second type is represented by the Bellefonte

dolomite equivalent which contains some pinkish rock that generally yields less and smaller chert fragments, although in places chert is abundant as, for example, on the summit and down the slope toward Bolton southwest of Hansonville. The Bellefonte outcrop is narrow and is parallel to the belts of the more cherty dolomite that follow Copper and Moccasin ridges.

Very few fossils can be found in any of the Ozarkian and Canadian rocks. The cross section of a coiled, snail-like shell may be observed on the smoothed surface of a few dolomite ledges, and impressions or casts of similar shells occur in some of the chert masses. A persistent characteristic of the Copper Ridge dolomite is thin lenses of brown-weathering porous sandstone. The sandstone is more conspicuous when weathered for its original light color is similar to that of the dolomite.

Dolomite soils are deep, brownish red, and fertile. They support a good stand of bluegrass and cover the large pasture areas of the county. (See Pl. 8.) Only where the slopes are very steep or where too much chert occurs are they unfavorable for cultivation. The dolomite makes an excellent stone for road metal or rough construction, and the purer varieties, such as the Bellefonte dolomite, may be considered for more decorative uses.

Because under ordinary circumstances it is not advisable to attempt to burn dolomite for agricultural lime, the outcrops of dolomite shown on the accompanying geologic map (Pl. 1) should be studied with care when supplies of agricultural lime are needed. It is true, of course, that usable limestone beds occur within the dolomites, but they are not persistent and at a given locality may be entirely lacking. The simplest test for dolomite is to use a weak solution of hydrochloric acid (HCl), which may be obtained at a drug store. A drop of this solution will bubble on the fresh surface of limestone. On dolomite no reaction will occur, although powdered dolomite will effervesce mildly, especially if the acid is heated.

ORDOVICIAN

The Ordovician system has a considerable representation in Russell County, where its pure limestones form a potentially valuable reserve of lime and cement materials. Not less than 3,500 feet of the rocks here belongs to the Ordovician system, of which about the lower 1,000 is almost entirely limestone. (See Table 1.)

Limestone is commonly a medium- to thick-bedded, gray to bluish-gray, fine-grained and rather dense rock. With admixture of clay, limestones grade into calcareous shales that are soft and slabby and weather readily. Some limestones are black, a few are brown and red, some are granular and others are distinctly crystalline. The latter

are sometimes called "marble," for they can be polished and used like marble for interior decoration. Limestone is derived from consolidated limy mud or shell fragments. Because its chief constituent is calcium carbonate, limestone is easily soluble and, in humid climates, is readily eroded and weathered. Its outcrop is commonly on low ground, and it is likely to contain channels, or cavernous openings, produced through solution by underground water. Its soil is prevailingly fertile (See Pl. 8, A) and in the Appalachian region is dark red.

The oldest Ordovician formation in Russell County is the Murfreesboro limestone, which directly overlies the Bellefonte dolomite and consists of a distinctive series of red and green mudrocks and gray-green sugary magnesian limestones. Its conglomeratic basal member contains pebbles of the underlying Bellefonte dolomite. From its excellent exposures at Blackford, the local beds are known as the Blackford facies[8] of the Murfreesboro. They are overlain, in ascending order, by the Mosheim, Lenoir, Holston, and Ottosee formations, which contain a large percentage of pure limestone beds. Most of the local Ordovician limestones are dark colored but weather to lighter shades of buff, gray, and gray-brown. With the exception of the Holston limestone, which is coarsely crystalline, they are prevailingly fine grained. The Mosheim limestone is very dense and almost glassy in texture. Where pure, the Ordovician limestones are medium bedded and contain individual beds 2 to 3 feet thick. The impure types are thin bedded and grade into shales. Little or no chert is associated with the limestones. They are commonly fossiliferous and contain many types of small bivalved shells of brachiopods and the lacelike fronds of bryozoa. Small cylindrical stems of crinoids are also common.

The Mosheim, Lenoir, and Holston limestones crop out in three narrow belts parallel to and adjoining the outcrop of the Murfreesboro limestone. The northernmost belt lies about 1 mile north of Copper Creek and extends northeastward through the valley of Sinking Creek, crossing Clinch River near Blackford and continuing along Little River. A second belt appears at Cedar Creek, 3 miles northeast of Lebanon, and extends into Tazewell County, where it is followed, near Indian Creek, by U. S. Highway 19. A third belt follows the valley of Moccasin Creek to Hansonville, passing through Elk Garden, Say, and Belfast Mills to enter Tazewell County near Repass.

The Mosheim limestone, which directly overlies the Murfreesboro formation, is an extremely pure, light-gray to dove-colored rock that is suited to supply lime. It is about 50 feet thick. It is overlain by the Lenoir limestone, which consists of black knobby impure beds that are interstratified with thin dark-colored calcareous shales. The thickness

[8] Butts, Charles, personal communication, 1935.

ranges from 50 to 75 feet. The Holston limestone, which overlies the Lenoir, is a coarsely crystalline rock that contains light-gray, pink, and chocolate-brown lenses. It has potential value for agricultural lime, cement material, and, in places, building stone. (See Pl. 5, B.) Its thickness is about 300 feet, of which nearly one-half consists of pure limestone. These three limestones constitute one of the most important natural resources in the county. (See pp. 72-77.)

The Holston limestone is overlain by the shaly Ottosee and Moccasin (Lowville) formations, which are widely distributed along the flanks of Clinch, Stone, Big A, Elk Garden, and House and Barn mountains, as well as between Copper Creek and Copper Ridge. The Ottosee is an assemblage of limestones and limy shales that attains a maximum thickness of about 450 feet. Some of its calcareous members are as pure as those of the underlying Holston, and in places the shaly material is of a quality suitable for cement rock. The Moccasin is a miscellaneous series of limestones and mudrocks, of little or no potential economic value. Both red and blue Moccasin beds are present, the red mudrocks alternating with yellowish shales that contain many fossil mud cracks. The equivalent bluish limestones of Lowville age are well displayed near the county line in Little Moccasin Gap. The thickness of the Moccasin formation ranges between 500 and 700 feet.

The thick Martinsburg shale (Pl. 5, C), which overlies the Moccasin formation, crops out along the slopes of Clinch, Big A, Elk Garden, and House and Barn mountains in belts from 1 to 3 miles wide. The formation consists of shaly beds that are exposed from the foot of the ridges to the hard ledges of sandstone along their summits. Near the base of the mountains the shales are highly calcareous and many beds of limestone (Trenton facies) are present. (See Pl. 9, A.) Toward the middle of the slopes the formation becomes more shaly and yellow (Eden facies) and contains fewer lenses of limestone. Near the mountain summits the shales become more sandy, and beds of true sandstone increase in abundance (Maysville facies). Martinsburg soil is more fertile than the soil of any other local shale, and although it is situated on steep slopes, it has been productive where cultivated and supports bluegrass where cleared. (See Pl. 6, B.) The Martinsburg shale is excellently exposed in Hayter Gap, where it is about 1,600 feet thick.

Red sandstones and mudrocks of nonmarine origin overlie the Martinsburg and constitute the youngest Ordovician formation. This sequence, known as the Juniata shale, attains a thickness of about 300 feet. Unlike the Martinsburg shale, which contains many fossils, the Juniata is largely unfossiliferous.

SILURIAN

The Silurian system is represented locally by the Clinch sandstone and the Clinton formation, which have a combined thickness of about 425 feet. (See Table 1.) The base of the system is a conspicuous geologic horizon, for the massive ledges of Clinch sandstone form a striking contrast to the underlying soft red mudrocks of the Juniata formation.

The Clinch sandstone (Pl. 5, B), which is the one pure sandstone in the county, forms the crests of Clinch, Elk Garden, House and Barn, Big A, and Stone mountains and occurs nowhere else in the area. It is about 125 feet thick, massively bedded, ranges in color from white to gray, and varies in texture from rather coarse grained to conglomeratic. Bold ledges are formed along the mountain summits, from which many loose fragments are detached to cover the upper mountain slopes. It is well exposed in Little Moccasin Gap, where "Flat Rock," now the Douglas Memorial, is a huge slab of Clinch sandstone. Specimens of the only fossil common to this formation—a peculiar marking, probably a worm trail—may be seen in "Flat Rock." To the resistant character of the Clinch sandstone is due the greater height of the mountains which it caps.

The Clinton formation is relatively inconspicuous in comparison with the Clinch sandstone, upon which it rests. It is a series of green and red shales with interbedded sandstones that reaches a maximum thickness of about 300 feet. Near the middle and at the top of the formation are dark-red sandstones which resemble the iron ore that occurs at this horizon elsewhere in the southern Appalachian region but is absent in Russell County. Unless they are present near the head of Weaver Creek, no equivalents of the Wills Creek and Tonoloway formations, also of Silurian age, occur within the county, although they are well developed in adjacent areas.

DEVONIAN

About 1,200 feet of Devonian rocks occur in Russell County, but only the Brallier shale (Table 1) is widely exposed. The Helderberg group, the lowest division of the Devonian system, is exposed only at the head of Weaver Creek, where a few ledges of dark-colored platy fossiliferous limestone possibly represent the Becraft limestone. The Onondaga limestone and chert occur in a few almost inaccessible outcrops along the crest of Clinch Mountain, at the extreme southeast corner of the county.

The Devonian is best represented north of Clinch River, where a considerable thickness of shale and shaly sandstone of Middle and Late

Devonian age crop out in the Dump Creek region. The main mass of these shales is of a gray-green color which, on weathering becomes stained yellow-brown by iron oxide or black by manganese oxide. Thin layers of fine-grained sandstone are common. The term "Romney" is provisionally used for the lower black shales. The main portion of the upper beds belongs to the Brallier shale. A few feet of medium-bedded sandstone occupies the approximate horizon of the Chemung formation near Coomb's School on Weaver Creek, where it is overlain by a thin bed of black shale that is probably the equivalent of the Big Stone Gap shale, of early Mississippian age. Evidences of deposition in shallow water, such as ripple marks, rain prints and rill marks, are common. Tiny glistening flakes of mica are also prominent in the shales.

The relatively weak resistance of the rock to erosion has resulted in low ground along the shale areas, and a comparatively poor soil has kept these areas from intensive cultivation.

Few if any economic products have been derived from the Devonian rocks of Russell County, but the possibility of obtaining brick clay from the Devonian shales is suggested by their use for that purpose in Tazewell County. The soil derived from the Devonian shales is shallow and full of small fragments of shale and sandstone and affords a poor foothold for common crops and supports only a meager stand of timber. Roads built of the shale are smooth and generally superior to roads surfaced with other local materials.

MISSISSIPPIAN

The Mississippian system is locally represented in a small area near Dump Creek, where about 1,800 feet of sedimentary rocks have been separated into six formations. (See Table 1.)

The earliest Mississippian formation is the Big Stone Gap shale, an inconspicuous black shale. The formation may be recognized by its phosphatic oval shells. It is overlain by 200 feet of sandstone and shale belonging to the Price formation, which are not essentially different in character and topographic expression from the Upper Devonian rocks. Next above occurs the dark-colored cherty St. Louis limestone, which crops out in a narrow belt between Dump and Weaver creeks. It carries fossils of colonial corals that weather readily out of the limestone and may be picked up in the thin residual soil on hill slopes. The maximum local thickness of the St. Louis limestone does not exceed 50 feet.

Gray oölitic limestones, identified as the Ste. Genevieve and Gasper formations, occur above the St. Louis limestone on the low ridge between Cleveland and Dump Creek known as Sinkhole Valley. Lacelike bryozoa and the budlike blastoid, *Pentremites,* are characteristic

fossils. Along the southern edge of Buffalo Mountain a thin wedge of Glen Dean limestone appears immediately below the Pennington shale, but it is largely concealed by the edge of an overthrust fault block. No beds of Warsaw age are present in the county. The combined outcrop of the Gasper and Ste. Genevieve limestones is marked by sinkholes. The total exposed thickness of the two formations is less than 200 feet.

The Pennington shale is 1,100 feet thick and is the uppermost Mississippian formation in Russell County. It consists of red, green, and yellow shales that contain many interbedded sandstones. The sandstones are less pure than the Clinch sandstone and are neither so tightly cemented nor so resistant to weathering and erosion as the Clinch. An exception is the hard sandstone that crosses the county line at the head of Weaver Creek and caps Sandy Ridge between Russell and Dickenson counties.

PENNSYLVANIAN

Coal-bearing sandstones and shales of Pennsylvanian (Pottsville) age occupy the greater portion of Russell County northwest of Clinch River and, with negligible exceptions, occur entirely north of the river. (See Fig. 5.) Included in this system are the Wise, Gladeville, Norton, and Lee formations, which are composed mainly of coarse-grained fragmental sediments. No limestones or other calcareous rocks are associated with them. (See Table 1.) Approximately half of the volume of the local Pennsylvanian rocks is composed of shale and conglomerate in the proportion of about 4 or 5 to 1. The group consists of a miscellaneous assortment of beds that range in thickness from a few inches to several feet. Probably the most prevalent type of sedimentary rock is an impure gray to brown sandstone composed of grains of quartz, with smaller amounts of mica, feldspar, and other minerals. Although this rock is easily weathered and eroded, its soil is neither thick nor productive. The sandstone grades into a drab to brown shale that weathers into a sterile clay soil. A few beds of sandstone are coarse grained, and some conglomeratic beds, which contain well-rounded grains of quartz, are present. None of the beds is tightly cemented. Some of the sandstones are cross-bedded. Nearly all the rocks are stained with iron, and some of them contain nodules of iron along the bedding planes. The sandstones of the Lee formation, which are more resistant than those of the other coal-bearing rocks, form imposing cliffs along Clinch River near Burtons Ford.

Plant fossils occur commonly in the beds above and below the coal seams. Most of the fossils are broken segments, and almost all of them are highly carbonized. It is possible to identify stems and strap-like leaves of several types of coal-forming plants, although it is rare to

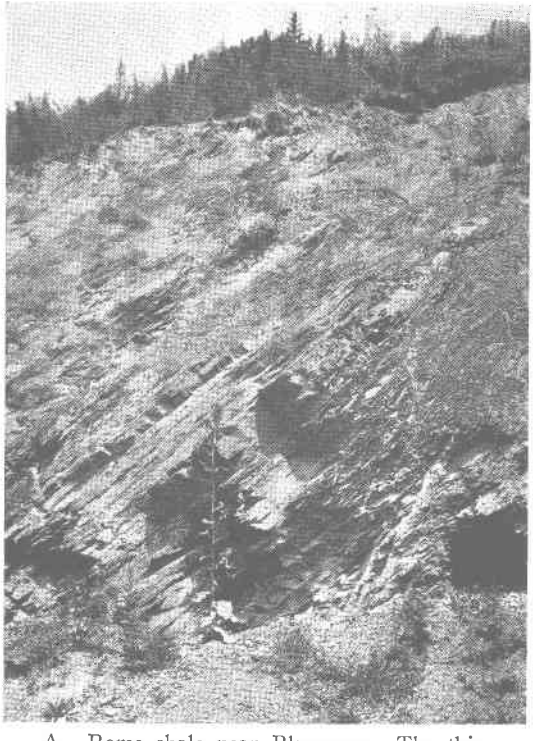
find an entire plant. Here and there a tree trunk, now flattened through pressure, is found preserved in sandy or shaly beds near the coal seams.

Beds of bituminous coal (Fig. 6), ranging in thickness from a fraction of an inch to several feet, occur throughout the rocks, although only a few are of minable quality and thickness. (See Pl. 10.) Because of their geographic persistence and economic importance, these coal beds are described on pages 52-55.

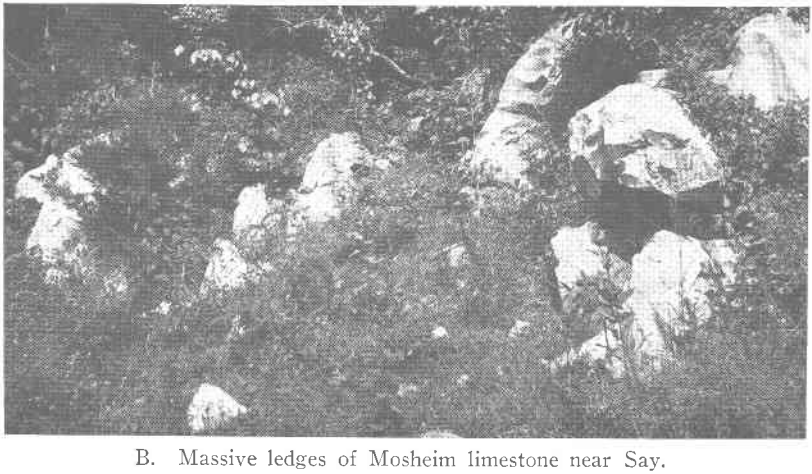
Most of the workable coals occur in the Norton formation; only a few scattered seams have been found in the Wise formation. The full succession of coal-bearing rocks is well exposed along U. S. Highway 84, which leads north from Raven, in Tazewell County. Other good exposures occur near Dante and between Dump Creek and Wilder. The Gladeville sandstone, which forms the crest of Sandy Ridge, is of some economic importance for, when wet, it can be sawed into blocks that can be used for building stone. The soil developed on Pennsylvanian rocks is meager and unproductive, although it normally supports a thin growth of timber.

A. Rome shale near Bluegrass. The thin slabby beds are well shown.

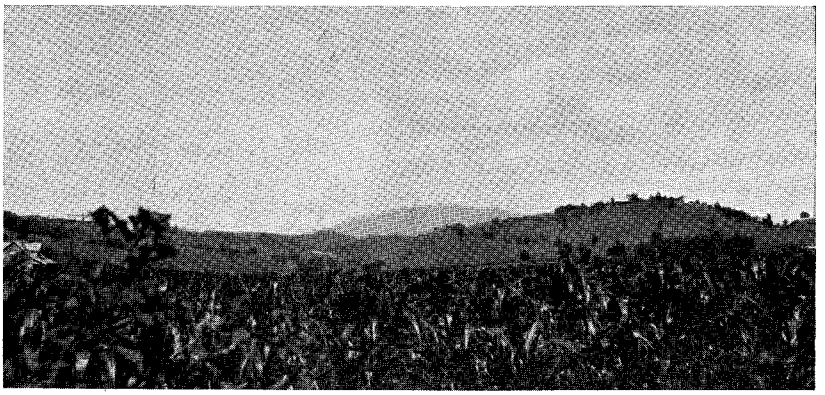
B. Massive ledges of Mosheim limestone near Say.



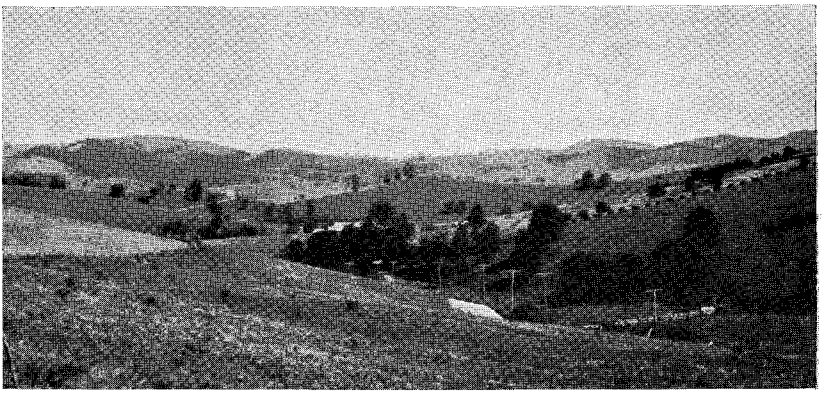
A. Rome shale near Bluegrass. The thin slabby beds are well shown.



B. Massive ledges of Mosheim limestone near Say.



A. Fertile limestone area near Elway. Clinch Mountain rises along the horizon.



B. The broad rolling Lebanon Valley. It is developed on limestone and dolomite. Looking east from Lebanon.

A. Fertile limestone area near Elway. Clinch Mountain rises along the horizon.

B. The broad rolling Lebanon Valley. It is developed on limestone and dolomite. Looking east from Lebanon.

GEOLOGIC STRUCTURE

GENERAL STATEMENT

Most sedimentary rocks are deposited in a horizontal position, which they normally retain except where they have been subsequently disturbed. Where involved in earth movement, they may become folded, crumpled, and fractured. The resultant structure reveals the nature of the deforming process.

The results of deformation in sedimentary rocks are of two types: Folds, including anticlines, or upfolds, and synclines, or downfolds; and faults, which are displacements along fractures. All the structural features of the rocks of Russell County have resulted from pressure. The folds range from the crumplings that are found in a fragment of rock to anticlines or synclines many miles across. (See Pl. 9, A.) The faults are of the overthrust type, in which one rock mass has been pushed laterally over another mass during an epoch of compression. Some of the faults represent tremendous displacements over long lateral areas; a few of them may be traced for many miles. (See Pl. 9, B.) Apparently the pressure that produced the local structures was exerted from the southeast, for the prevailing dip, or slope, of the faults is southeast and the folds are overturned to the northwest. Hence the belts of rock extend northeastward across the county. Figure 3 shows the main elements of the structure of Russell County.

FOLDS

The most common type of fold in Russell County is a syncline whose northeastern part, or limb, is exposed, but whose southeastern part has been broken and overridden by a fault block. The most conspicuous syncline occupies the southeast part of Russell County and the northwest half of Washington County. As its axis passes near Greendale, in Washington County, the fold is called the Greendale syncline. This structural basin includes all the rocks from the Rome formation, exposed along Copper Creek, to the Pennington shale, exposed near Greendale. All the beds dip to the southeast. (See Pl. 5, B.) Although the syncline is broken along its southeastern margin by a fault, and only its northern portion lies in Russell County, nevertheless it dominates the geologic structure of the southern half of the county.

Copper Ridge and its northeastern extension, Kent Ridge, are similarly developed upon another fold, which may be called the Copper Ridge syncline. This fold is bounded by faults, and its southeastern rim, like that of the Greendale syncline, has been obliterated by an overthrust fault block. The Copper Ridge syncline occupies the area

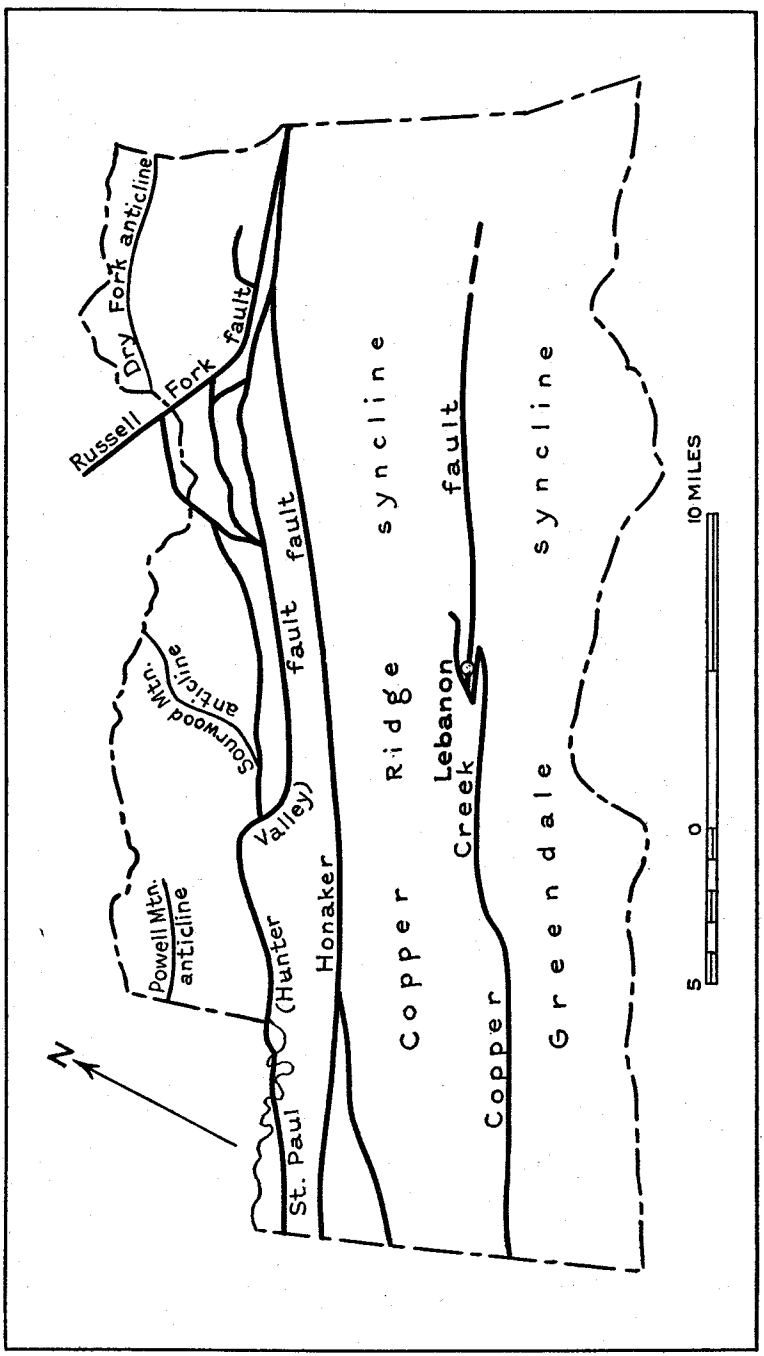


FIGURE 3. Sketch map of Russell County showing the main elements of the geologic structure.

from Copper Creek to Clinch River; in Tazewell County it merges into the Greendale syncline to form a large irregular fold. Elk Garden and House and Barn mountains lie along the axis of this syncline and are formed by canoe-shaped blocks of Clinch sandstone resting upon Ordovician (Martinsburg and Juniata) shales.

A narrow complex synclinal fold occurs between Clinch River and the Russell County coal fields. The rock of this belt has been crowded between two overthrust faults and thus is the most highly disturbed rock in the county. The structure is synclinal, but a tangle of minor folds, together with many cross or branching faults, has obscured it. The fold includes Big A[9] and Stone mountains, both of which are bounded by faults. (See Pl. 10.)

North of this complex block is the Russell County coal field, in which the rocks are approximately horizontal except along the southern margin of the field, where they have been upturned as a result of overthrusting. (See pp. 55-56.)

FAULTS

There are four prominent overthrust faults in Russell County, all of which have resulted from lateral compression and belong to the group of faults that characterize the Appalachian region.

The southernmost fault is the Copper Creek fault,[10] which is between the Greendale and Copper Ridge synclines. It follows the valley of Copper Creek from Scott County to a point near Lebanon, whence, after making an S-turn, it continues northeastward to die out in the limestone area near Belfast Mills. A second displacement, known as the Honaker fault,[11] appears in northeastern Scott County and follows Clinch River for most of its course through Russell County, bounding the Copper Ridge syncline on the northwest.

The St. Paul fault, which is also known as the Hunter Valley fault, enters Russell County from the northeast corner of Scott County and bounds the coal field on the south. The trace, or outcrop, of this fault is somewhat irregular, and it merges into, or is cut by, the Russell Fork fault[12] east of Big A Mountain. Several smaller displacements branch from the St. Paul fault between St. Paul and Honaker, where they produce a complicated pattern that involves much of the Big A Mountain area.

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[9] See Bates, R. L., The Big A Mountain area, Virginia: Virginia Geol. Survey Bull. 46-M, pp. 167-204, 1936.

[10] Stevenson, J. J., Notes on the geological structure of Tazewell, Russell, Wise, Smyth, and Washington counties, Virginia: Am. Philos. Soc. Proc., vol. 22, pp. 114-161, 1885.

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

[12] Giles, A. W., The geology and coal resources of Dickenson County, Virginia: Virginia Geol. Survey Bull. 21, pp. 51-67, 1921.

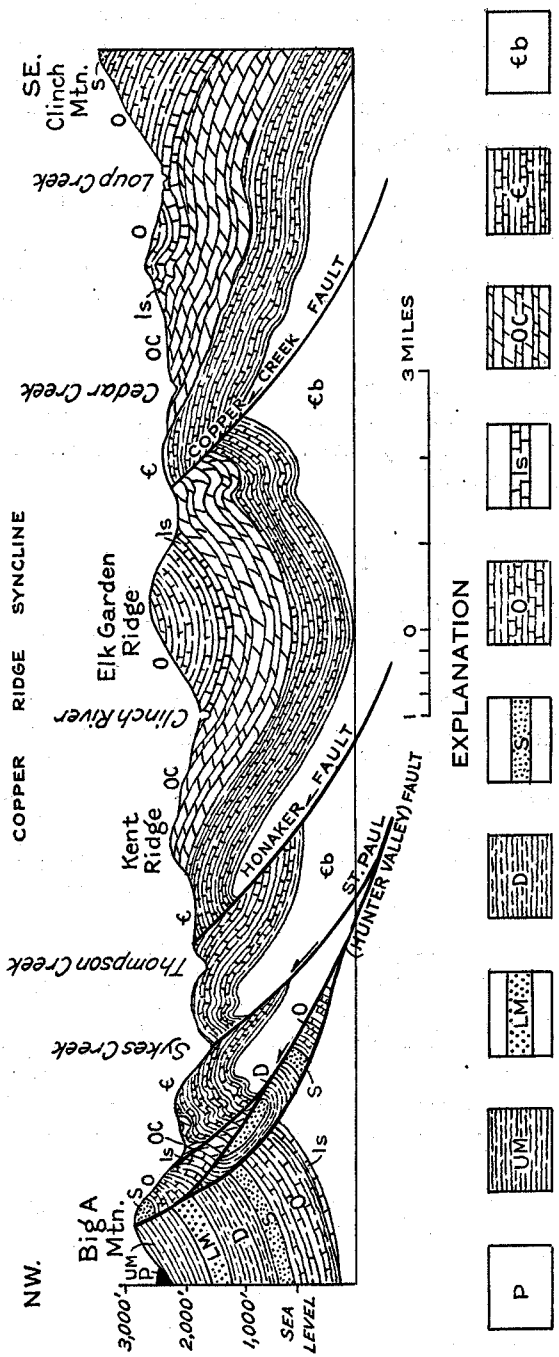


FIGURE 4. Generalized structural section across Russell County. P, Pennsylvanian coal-bearing rocks; UM, Upper Mississippian shales; LM, Lower Mississippian sandstones and limestones; D, Devonian shales; S, Silurian sandstones; O, Ordovician shaly limestones; ls, Ordovician pure limestones; OC, Ozarkian and Canadian dolomites; €, Cambrian shales and limestones; €b, basal Cambrian sandstones (not exposed).

The Russell Fork fault[13] bounds Big A Mountain on the east. Unlike most of the faults of southwestern Virginia, it trends northwestward. Its outcrop extends between the St. Paul and Honaker faults at the southeast and the Pine Mountain fault, in Kentucky, at the northwest. Although the Russell Fork fault is of much geologic significance, it has little or no geographic expression and is of small economic importance.

Figure 3 indicates the main elements of the structure of Russell County, and Figure 4 is a generalized cross section which indicates the subsurface arrangement of the rocks. Almost all the rocks dip toward the southeast at steep angles; only the flat-lying sedimentary beds of the coal field are exceptions to this general rule. Both the faults and the folds are relatively inconspicuous, and an areal geologic map, on which all individual stratigraphic units are represented, would be necessary to indicate their effects upon the individual rock members in the county.

[13] Wentworth, C. K., Russell Fork fault of Southwest Virginia: Jour. Geology, vol. 29, no. 4, pp. 351-369, 1921.

GEOLOGIC HISTORY

GENERAL STATEMENT

The geologic history of a region is read from its rocks and its topography, for some phase of the history is recorded in each layer of the bedrock and each feature of the landscape. When all these features have been carefully studied, and when their individual records have been interpreted in the light of known processes, the geologist can reconstruct the events of the ancient past with almost as much precision as the historian can recount the stages of ancient human history. For any area the geologic events of greatest antiquity are recorded in the bedrock; later events are interpreted from the landscape features.

Geologic history is measured in vast periods of time. Recorded human history is a matter of several thousand years, but geologic history involves hundreds of millions of years. The reader must appreciate this immensity of time before he can properly understand the events of the geologic past. To facilitate the understanding of the long history of the earth and for convenience of reference, geologists have separated geologic time into several primary divisions, known as eras. During these eras similar geologic processes were in uniform or regularly progressive operation, and some distinctive life groups were dominant. Three eras have been distinguished in well-recorded geologic time: Paleozoic era, or time of ancient life; Mesozoic era, or time of medieval life; and Cenozoic era, or time of recent life. Each era is separable into periods that represent smaller time units in the rocks of which a distinctive set of geographic or biologic conditions can be recognized.

Most of the bedrock of Russell County was deposited during the Paleozoic era, during which the area was submerged by marine waters, in which the sediments accumulated that are now consolidated into the rocks of the area. The beginning of a long period of elevatory movements involving the formation of the Appalachian Mountains brought the Paleozoic era to an end and ushered in the Mesozoic era, which in this region was an era of land sculpture and long-continued erosion. Erosion and weathering have produced the details of the present landscape during the Cenozoic era.

A convenient presentation of the geologic history of Russell County is one that treats the Mesozoic and Cenozoic eras as a time of erosion and separates the Paleozoic era into two units—an earlier time (Cambrian to Pennsylvanian, inclusive) of rock deposition and a later time (Permian) of mountain uplift. Such a treatment has many advantages for the layman and at the same time does not destroy the more precise arrangement which the geologist prefers. The following paragraphs discuss the local geologic history in this convenient pattern.

ORIGIN OF THE ROCKS

Since many of the rocks of Russell County now contain fossil shells of ancient sea animals, the early topography of North America must have permitted bodies of sea water to occupy an area that is now far inland.

At the beginning of the Cambrian period the site of the present Appalachian Highlands was occupied by a long, narrow trough and strait, which extended from the Gulf of St. Lawrence region toward the Gulf of Mexico. This trough, now called the Appalachian geosyncline,[14] ranged in width from a few miles at its north end to at least 100 miles in the present region of southwestern Virginia. To the east of the geosyncline lay a rugged borderland that is known to geologists as Appalachia; to the west lay the continental mainland, which was then a broad, low area partly flooded at times by sea water. The geosyncline was occupied by sea water, and it was nowhere more than a few hundred feet deep. A shallow interior sea, which intermittently flooded the southern part of the continental interior, at times entered the geosyncline across the present areas of Kentucky and Tennessee; at other times the interior sea was absent or for some other reason failed to reach the geosyncline.

The eastern borderland of Appalachia separated the Appalachian geosyncline from the open Atlantic Ocean. From this upland swift-flowing rivers heavily laden with debris, emptied their burdens into the Atlantic on the east and the geosyncline on the west. There is no available record of the sediments poured into the Atlantic, for they are now far below sea level, but those deposited in the geosyncline form the sedimentary rocks that underlie the Appalachian region.

The continental interior was a vast country of low relief, which was undergoing slow erosion. At various times sea water from the geosyncline spread across its central portion and into the shallow waters of the interior sea. Marine animals of many kinds, including corals and various shelled animals, lived in profusion when the sea was extended, and furnished abundant organic debris to the accumulating mud that covered its floor. Calcareous material from the central sea occasionally spread eastward into the geosyncline, where it became interbedded with the coarse sedimentary debris brought down by the active streams of Appalachia. Other calcareous material was deposited in the geosynclinal seas at times when no connection apparently existed with the interior seas. The deposits of the geosyncline, now hardened and consolidated, form the rocks which underlie Russell County. The

[14] The term "geosyncline" is applied to a large region that has a general synclinal structure, though it may be modified by many minor anticlines.

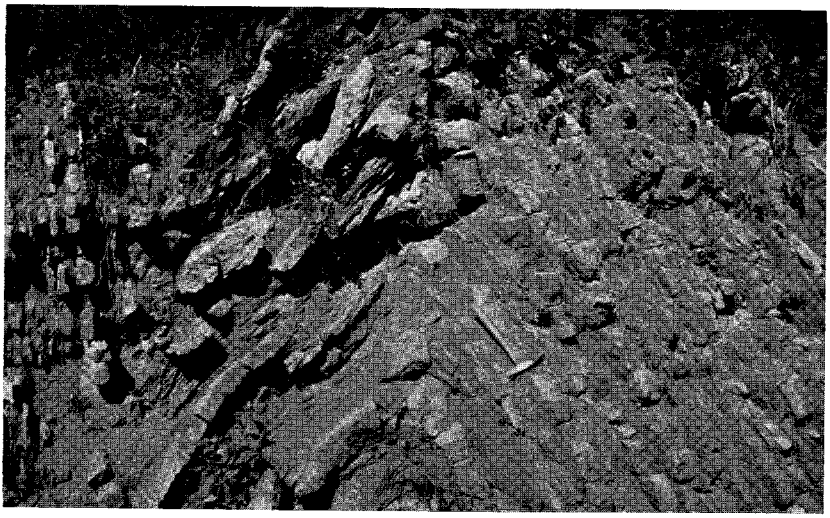
succession of sandstone, shale, limestone and dolomite reveals the details of the Paleozoic history of the region.

The initial sediments of the Paleozoic era were coarse gravel and sand, now consolidated into sandstone and quartzite. They are exposed in the foothills of the Blue Ridge region but are deeply buried in Russell County. They are covered by finer silt and mud that represented the waste from lower lands and now constitute the Rome formation, which is the oldest exposed bedrock of Russell County. Later in the Cambrian period the supply of mud and silt diminished, and a succession of waters carrying limy mud formed the Honaker dolomite and its equivalents, the Rutledge limestone, Rogersville shale, and Maryville limestone. A recurrence of mud deposition at the end of Cambrian time produced the Nolichucky shale, uppermost and latest of the Cambrian rocks.

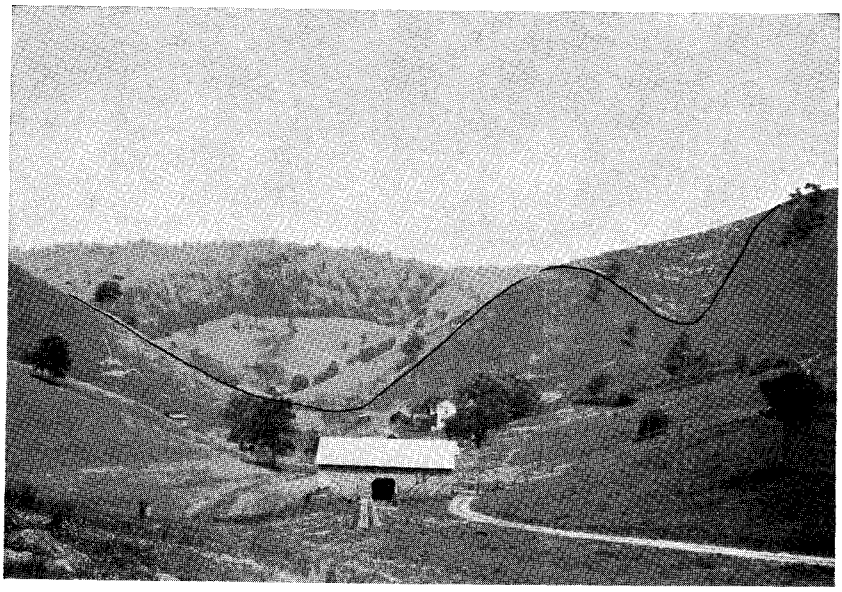
The erosion of Appalachia during the long Cambrian period, which lasted perhaps for 100,000,000 years, reduced it so that little or no debris was furnished during the succeeding Ozarkian and Canadian periods. Consequently, thick calcareous beds, almost wholly devoid of fragmental debris, collected in the marine waters in the geosyncline. These deposits, now the Copper Ridge and Nittany dolomites, contain a few shells of marine animals—mostly gastropods or snails—that testify to the presence of life during the periods. Possibly the original deposit was pure limestone, which subsequently became altered in part to dolomite; or possibly the magnesian content of the dolomite was present from the time of its deposition.

During the Ordovician period, many beds of pure limy mud and ooze (Mosheim, Holston, and Ottosee limestones) were deposited with beds of dark-colored calcareous muds (Lenoir limestone) and impure limestone and mudrock (Moccasin formation). The prevalence of the impure limestone indicates that the Ordovician seas were again becoming muddy, probably as a result of the uplift of Appalachia. As the period progressed the quantity of fragmental debris increased, and the deposits of late Ordovician time (Martinsburg and Juniata shales) clearly indicate a growing activity on the part of the rivers that drained the west slopes of Appalachia. An abundance of fossils of many kinds throughout the Ordovician strata shows that the life of the period was greatly expanded and that marked evolutionary changes were in progress.

Convincing evidence that Appalachia was rising in respect to sea level is afforded by the initial Silurian rocks, which consist of coarse gravel and sand (Clinch and Clinton formations). Only vigorous rivers, on steep slopes, could produce the debris which settled in the geosyncline during early Silurian time. It is likely that the borderland was again reduced by Silurian streams, for the latter part of the Silurian and the

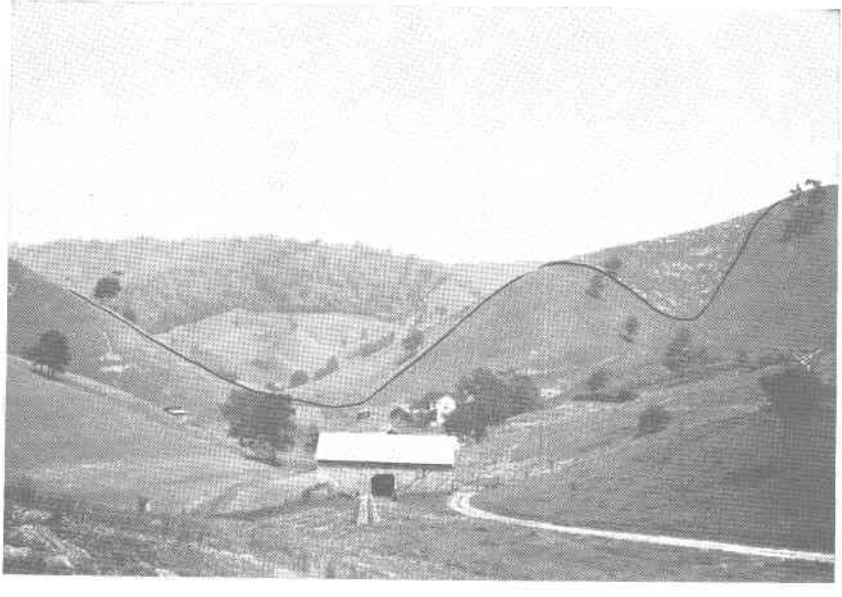


A. Folds in the Martinsburg shale along the northern slope of Elk Garden Mountain, south of Blackford.

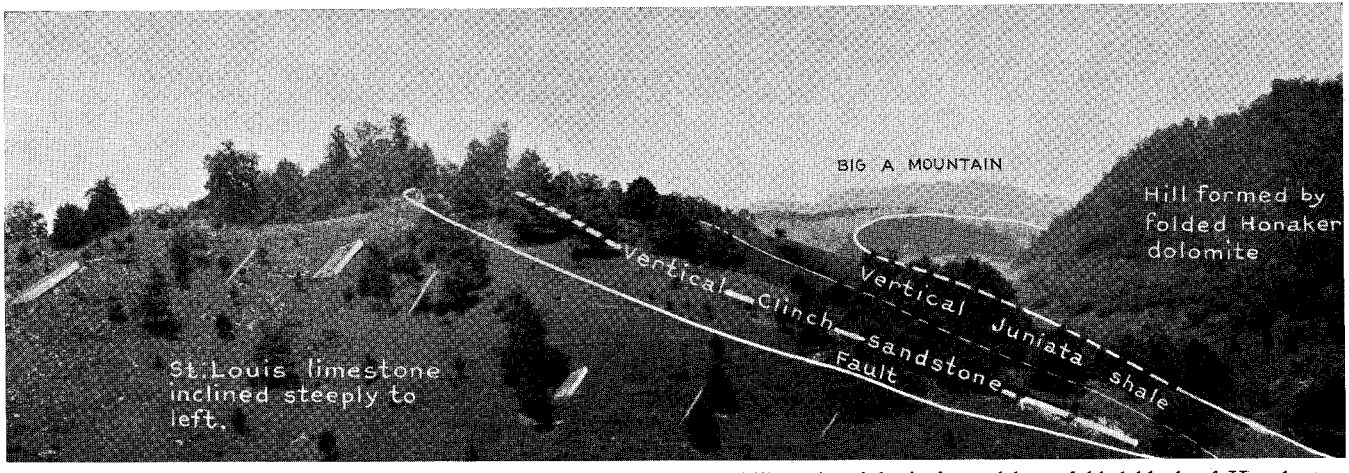


B. Fault between Nolichucky shale (in foreground) and Lenoir limestone. The outcrop of the fault is indicated by the black line from which the fault surface slopes below ground toward the observer, passing below the central foreground. Looking north near Fullers Corners, west of Honaker.

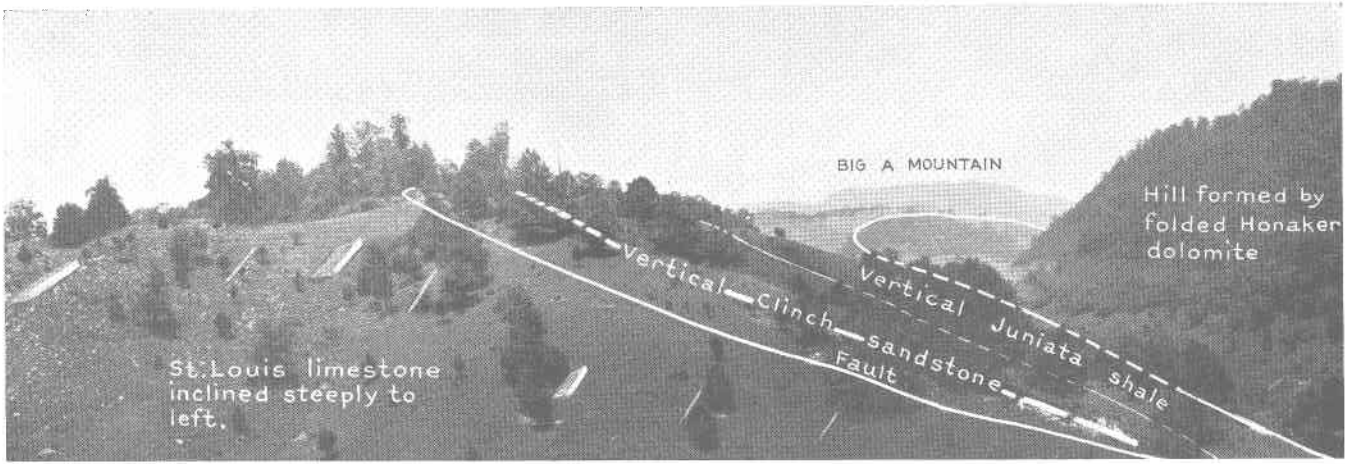
A. Folds in the Martinsburg shale along the northern slope of Elk Garden Mountain, south of Blackford.



B. Fault between Nolichucky shale (in foreground) and Lenoir limestone. The outcrop of the fault is indicated by the black line from which the fault surface slopes below ground toward the observer, passing below the central foreground. Looking north near Fullers Corners, west of Honaker.



Panoramic view looking north toward Big A Mountain. The steep hill at the right is formed by a folded block of Honaker dolomite that has been overthrust from the east (right) upon Juniata shale.



Panoramic view looking north toward Big A Mountain. The steep hill at the right is formed by a folded block of Honaker dolomite that has been overthrust from the east (right) upon Juniata shale.

early part of the Devonian were epochs of limy deposits (Tonoloway and Helderberg) during which very little mud accumulated in the waters of the geosyncline.

By the middle of the Devonian period the inland sea of the geosyncline had given way to broad alluvial flood plains, which advanced westward from a borderland that seems to have partly regained its former higher altitude. Ripple marks, rain prints, and other indications of shallow-water deposition are common to the various members of these flood-plain deposits and indicate that the marine sediments of the "Romney," Brallier and associated formations intergraded with alluvial materials during a shoaling of the Paleozoic seas. Plant fossils testify that vegetation had taken root on land and in the swamps along the shores.

As the earliest Mississippian sediments were coarse, it may be inferred that Appalachia again underwent an uplift during which active erosion brought down the sands of the Price-Pocono formation. The time of uplift must have been relatively short, for a succession of limestones (Warsaw, St. Louis, Ste. Genevieve, and Gasper) was laid down in either an expanded or a deepened geosyncline, which was then receiving little coarse fragmental material. Invertebrate life of many kinds abounded in the Mississippian seas, and distinctive fossils characterize all of the formations. Near the end of Mississippian time the geosyncline received a thick deposit of sand and mud (Pennington shale). At the end of the period the marine water was entirely displaced from the strait, thereby bringing the era of marine sedimentation to a close.

Although pre-Pennsylvanian time involved a few hundred million years, it was not until its end that the geosyncline became entirely filled with sediment. Despite the continual addition of fragmental debris from the slopes of Appalachia and the constant shallowness of the strait, for some reason its ability to receive more material was not substantially diminished. This fact suggests that its floor must have progressively sunk as sediment was deposited upon it, for only by this process could such a thick sequence of sediments have been deposited and at all times in marine waters that remained relatively shallow. In an exactly analogous manner the borderland Appalachia must have gradually risen in spite of the persistent attacks of erosion and the constant removal of material. It is thus necessary to conjecture a narrow elongate basin whose floor progressively sank as more and more sediment was loaded upon it, and a borderland that retained or renewed its general level in spite of the continual removal of eroded material from it. Both the geosyncline and the borderland appear to be distinct crustal features of the earth's surface, each behaving as distinct units under the surface transfer of material.

MOUNTAIN BUILDING

Events greatly different from those of the early and middle parts of the Paleozoic era characterized the Pennsylvanian and Permian periods. The geosyncline became shallower, owing to the growth of wide alluvial fans that were built by streams flowing westward from Appalachia. Coal swamps began to appear along the margin of the continental interior, occupying a border belt of partly submerged land. There is also evidence of growing crustal unrest or climatic changes, for the coal swamps were intermittently flooded and drained many times during successive epochs of the Pennsylvanian period. The unstability may have resulted from the overloading of the geosyncline with an enormous mass of sediment. Even if it is granted that the earth's crust has considerable elasticity, it must be realized that the floor of the basin had been sinking for more than 300,000,000 years, and that as it had subsided at least 40,000 feet, the limit of its compressive endurance may have been reached. At any rate, events of an entirely different nature began to occur.

A persistent compressive force began to thrust northwestward against the sedimentary rocks recently deposited in the geosyncline. This irresistible pressure gradually folded the rocks into a great series of anticlines and synclines that may be compared to giant waves. Some of the anticlines were compressed beyond their breaking point, and great wedges or slices of rock were thrust forward as the pressure continued. These fault blocks overrode the adjacent synclines to the northwest and largely obliterated the anticlinal folds from which the faults themselves had been formed. Not only in Russell County, but throughout the Appalachian province, the irresistible force of crustal movement folded, crumpled, and uplifted the Paleozoic rocks to such an extent that the term "Appalachian Revolution" has been generally used as an appropriate name for the process and epoch.

Lateral compression of sufficient force to fracture great masses of rock is an immensely powerful agent. Whatever its origin, the geosyncline and the borderland were obliterated as distinct geographic features. The geosyncline was uplifted into a lofty range of folded ridges; the borderland was compressed into a piedmont area that flanked the ancestral Appalachian Mountains. The earth movements were very gradual. It is probable that had man lived during the epoch, he would have failed to detect any change in his physical surroundings. However, a gradual uplift of 1 inch in 100 years amounts to nearly 2 miles in 10 million years. Soon after the uplift, the wind and the rain had begun their attack on the newly formed mountains.

LAND SCULPTURE

At the beginning of the Mesozoic era the dominant geologic process was erosion, and there were radical changes in the geography of the continent. The Appalachian geosyncline had disappeared, and its site was occupied by the ancient Appalachian Mountains. The old borderland of Appalachia formed an eastern piedmont apron to these mountains. As the interior sea and the Paleozoic strait had vanished, the Atlantic Ocean, which lay several hundred miles to the east of southwestern Virginia, was the nearest body of sea water. Probably the earth's crust was again in equilibrium, for it remained in a stationary position for a long time.

Gradually the leveling forces of erosion began to smooth out the irregularities of the land, and the mountain summits were worn down as the streams changed from young and vigorous to larger and more mature rivers. An erosional attack that lasted through the Mesozoic era produced a broad almost featureless plain, upon which the master streams developed meandering courses. Such an extensive surface is called a peneplane. The plain in Virginia sloped gradually eastward toward the sea, for sediments were carried far eastward by the larger streams, to build a broad coastal plain skirting the Atlantic seaboard.

The era of erosion was terminated by a renewed uplift of the entire Appalachian region. It is possible that the removal of the eroded material lightened this portion of the earth's crust and aided it to rise, and that as the debris was carried far away, there was no corresponding subsidence of any adjacent area. Due to the uplift of the widespread peneplane, mature streams were invigorated by an increase in their gradients and they again became active erosional agents. Probably the slow vertical uplift amounted to more than 2,500 feet. The previously developed peneplane had beveled both hard and soft rock belts alike, but the rejuvenated streams eroded the belts of softer rocks more rapidly, thus gradually producing a pattern of parallel valleys and low ridges on the uplifted surface. As erosion continued, the upturned edges of the harder rocks became higher and higher above the intervening belts of weak rock. Thus, a new generation of hills and ridges appeared, to form the first and highest ridges of the present Appalachian Mountains.

With but slight interruptions the reduction of the surface continued beyond the Mesozoic era into the early part (Tertiary) of the Cenozoic era. For a considerable time during the Tertiary period the uplift ceased; hence the streams were checked in their down cutting and they widened rather than deepened their valleys. This temporary condition was ended by renewed uplift, during and after which the rivers resumed their dissection of the land, a process from which they have not

again been diverted. The remnants of the first peneplane, known as the Upland level, have been largely destroyed and occur only upon the summits of the highest ridges. Even the benches produced during the temporary halt in uplift have been deeply scored by the present streams, which have sunk their channels several hundred feet below the Valley-floor peneplane. The general process of destruction of the earlier surfaces has produced the present scenic features of Russell County.

Probably the present epoch of erosion will continue uninterrupted for a long time. Possibly even the existing high ridges will ultimately be reduced to a low level. The most significant fact is that the present is merely a stage in the never-ending evolution of the earth, and that the present features are continually undergoing changes.

MINERAL RESOURCES

GENERAL STATEMENT

The mineral resources of an area consist of rocks and minerals of economic value. Their occurrence, abundance, quality, and origin are problems for the geologist; the determination of their value in terms of accessibility, cost of operation, selling price, and market falls within the field of the economist. To a large degree the demand for a material and its abundance determine its selling price. The value of most mineral resources depends upon a favorable difference between the price which the prepared product commands and the cost of mining and preparing it. For most materials this difference is slight, and such factors as ease of transportation, competition, and nearness to the market may determine the balance between profitable operation and financial failure. The time element is equally important, for discoveries of new minerals, development of new methods of preparation, and changes in general economic conditions may suddenly alter the entire financial structure under which a product has been successfully mined. As a matter of fact, it is the economic background which primarily controls the commercial possibilities of most mineral resources. Most of such economically valuable minerals and rocks as those of Russell County are abundant.

The mineral resources of the county fall naturally into four classes: Those which are now being utilized or which merit commercial exploitation; those which have probable future value; those which were formerly developed but cannot now be operated at a profit; and those of no known past, present, or future value.

Foremost among the materials now being developed is coal, of which there are abundant supplies and for which there is promise of continuous profitable operation. It is not likely that the county will leave the ranks of coal-producing areas for some time. Lime and cement materials, which are abundantly distributed in the county, deserve more attention than they have yet received, and it is probable that, under favorable economic conditions, they can be brought into the field of successful operation. Ample supplies of building and construction stone are available when they are needed. From abundant local resources of brick and pottery clay and clay shale, material can be found to warrant cautious development, and favorable economic factors might justify large-scale operation. Abundant water power and ample supplies of water for domestic use are available to the operator who can find proper conditions of demand and markets.

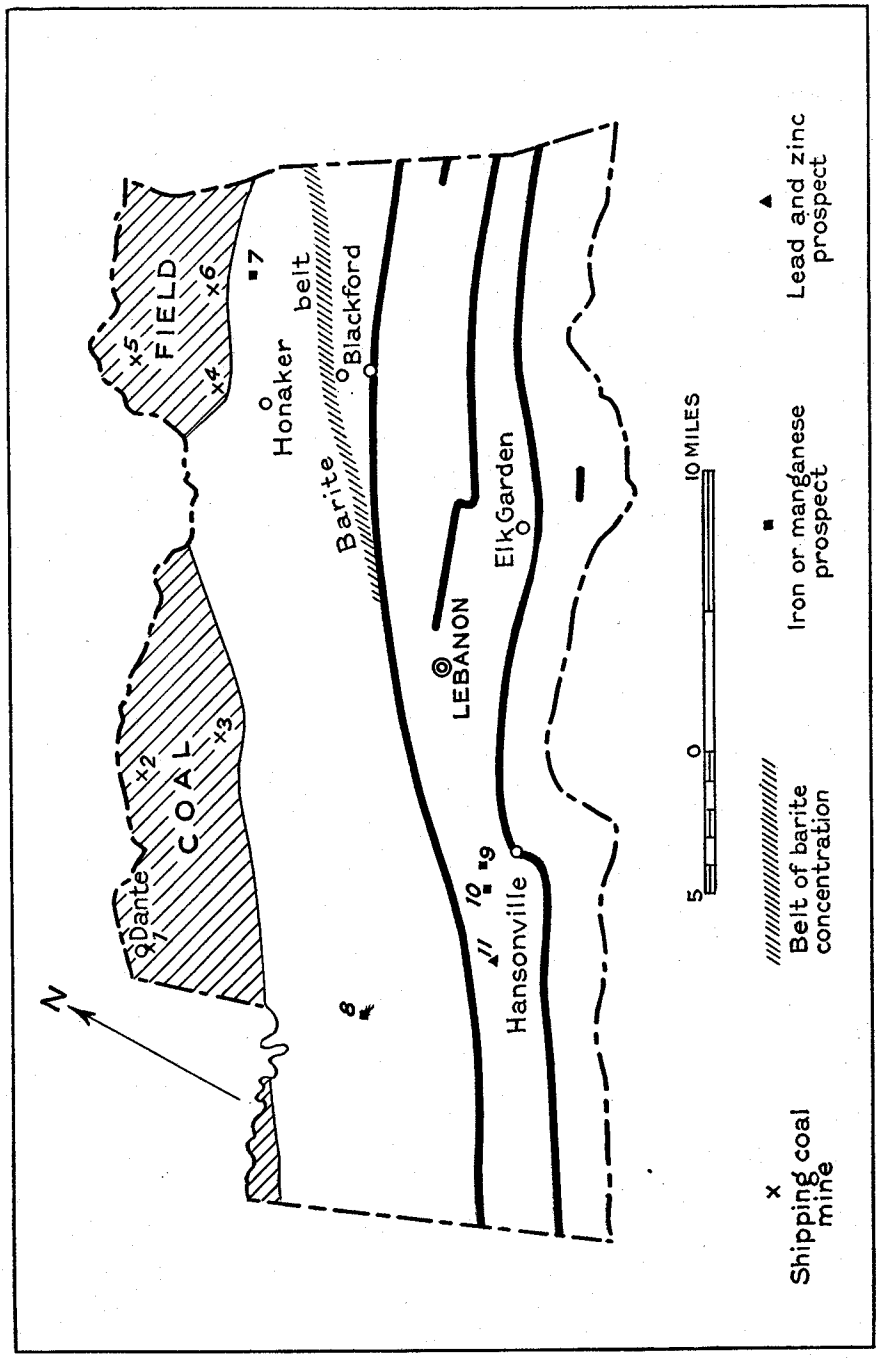


FIGURE 5. Sketch map of Russell County, showing the local coal field, the main belts of pure limestone, and the important mineral localities. 1, Clinchfield Coal Corporation, Dante; 2, Clinchfield Coal Corporation, Wilder; 3, Dixie Beaver Coal Company, Clinchfield; 4, Candlewax Coal Company, Candlewax; 5, New Garden Coal Company, Drill; 6, Sword Creek Mining Company, Sword Creek; 7, Whitt prospect; 8, Hall prospect; 9, Helbert prospect; 10, Fortner prospect; 11, Osborne mine. Limestone belts are solid black.

As materials for possible future development, local supplies of iron, manganese, lead, and zinc deserve attention. Under present conditions they have little value, but in the normal course of increasing future demands, or under extraordinary conditions of forced need, deposits of these minerals may warrant more development than can now be anticipated. It is possible that deep wells properly placed might tap a reserve of gas in Russell County that is at present unknown. Although the county has not yet been thoroughly tested, the probabilities of such a discovery seem remote.

At one time the county was a successful producer of barite, or barytes. Now most of the usable supplies have been exhausted, and it is doubtful if the remaining occurrences can ever be successfully exploited.

Although it is hazardous to make definite predictions, it may be stated with all confidence that commercial quantities of oil, gold, silver, or copper do not occur in Russell County, and that the most valuable mineral resources are those already mentioned. There is, of course, a possibility that other minerals may be discovered, or that new uses will be found for those already known; but the chances are remote and unpredictable.

Table 2 shows the mineral production of Russell County from 1895 to 1935, inclusive. Figure 9 indicates the chief mineral localities within the area, and Figure 5 shows the location of the coal-producing area and the belts of pure limestone.

TABLE 2.—*Mineral production of Russell County*[a]

Mineral	Period	Quantity (short tons)	Value
Coal	1902–33	[b]40,485,561	[b]$69,804,533
Limestone	1911–35	236,034	253,274
Barite	1895–1905	[c]11,000	[c]37,500
Lime	1911–35	4,345	16,050
Iron	Small production; no statistics available.		
Manganese			
Lead and zinc			

[a] Data from files of the Virginia Geological Survey, U. S. Geological Survey, and U. S. Bureau of Mines.
[b] Includes small production from adjacent areas during 1902-10.
[c] Estimated.

Coal, oil, and gas are the three common natural fuels. They occur under somewhat similar geologic conditions, and all are of

organic origin. Coal is formed from plants that grew in swamps where their partly decomposed remains—roots, leaves, spores, branches, and trunks—accumulated beneath quiet or stagnant water. The fibers of the plants were pressed flat, carbonized, and hardened through long ages of burial into sedimentary rocks.

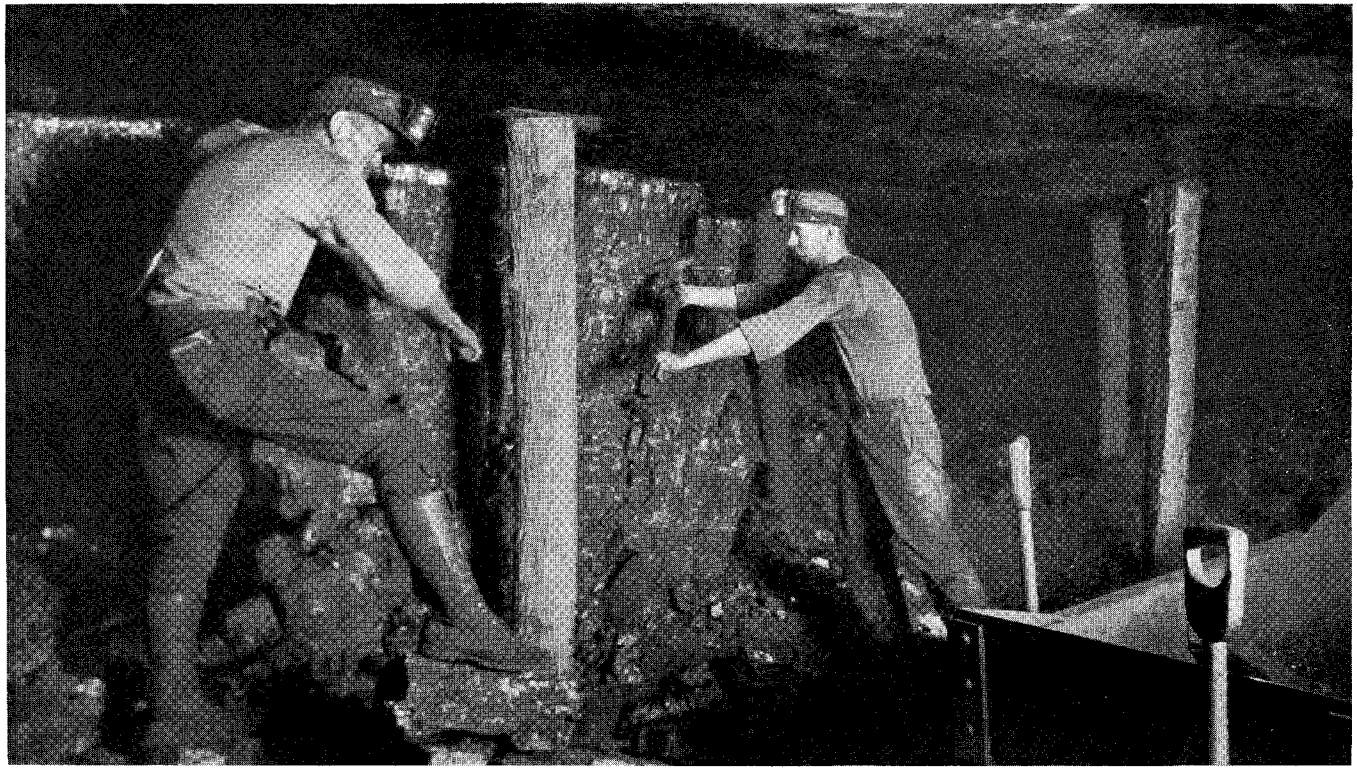
Although gas and oil may occur in coal fields, commercial quantities are seldom if ever contained in the same rocks with the coal, for they are invariably associated with rocks of marine origin and commonly occur at horizons below the coal-bearing sediments. As both oil and gas are volatile, they tend to escape from the rocks in which they were formed and rise, where possible, to the surface. Only where they are trapped beneath impervious rocks do they remain in the ground, and rocks that have been crushed or fractured contain too many lanes of escape to act as reservoirs of either oil or gas.

COAL

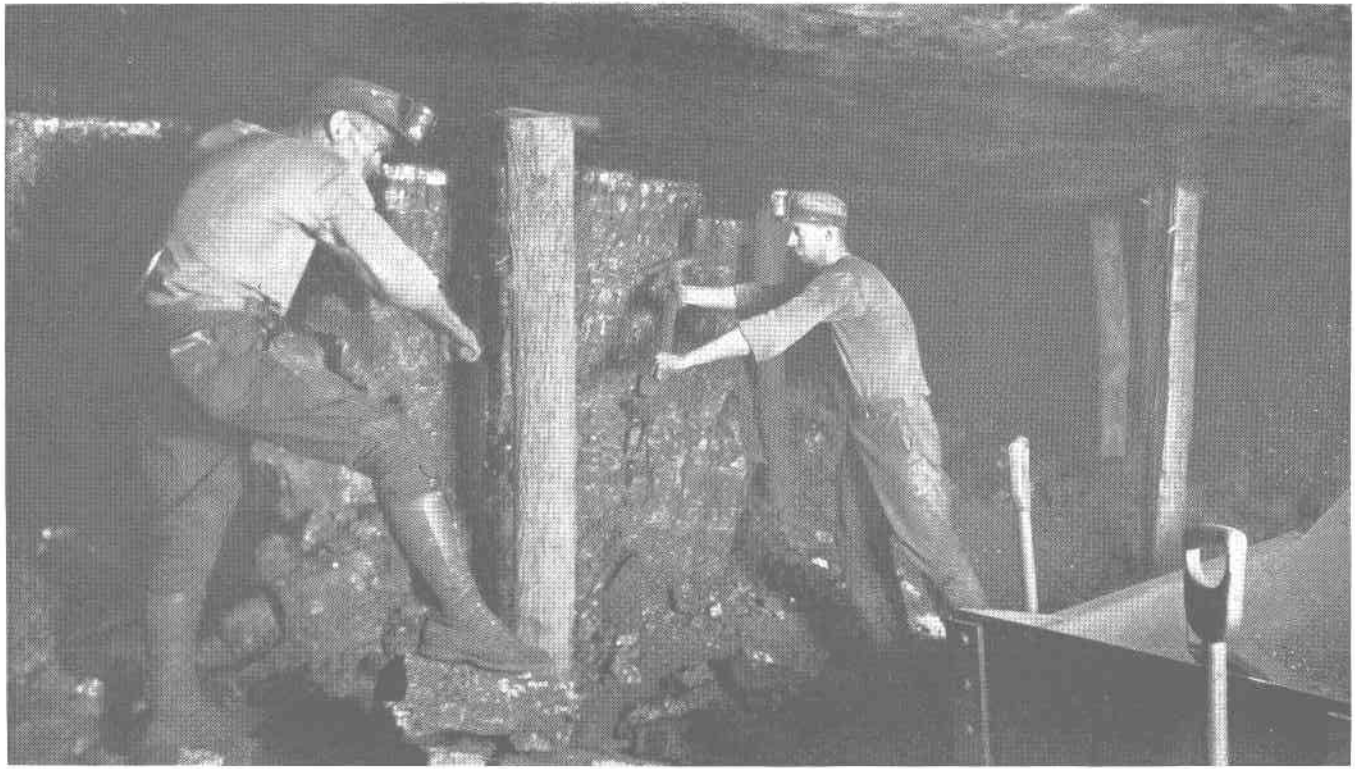
Almost all of the Russell County coal field lies north of Clinch River in the rugged area of the Appalachian Plateaus which has been thoroughly dissected by streams. (See Fig. 5.) The entire field drains into Clinch River and is separated by Big A Mountain into two main portions, a larger western area and a smaller area east of the mountain. West of Big A Mountain the field includes the Burtons Ford, Lick Creek, Dump Creek (including Chaney and Hurricane Forks), and Weaver Creek districts. East of Big A Mountain, there are two basins drained by Lewis and Sword creeks. The coal field occupies seventeen per cent of the total area of the county, or about eighty-four square miles. Including Big A Mountain it is about twenty-nine miles long in a northeasterly direction and four and one-half miles wide from northwest to southeast. The altitude ranges from 1,500 to 3,000 feet.

MINING ACTIVITIES

Coal in Russell County furnished fuel for farms and domestic use during the last century. Together with adjacent areas in Dickenson and Buchanan counties, the local field was worked in a small way after the War between the States, but the first important development was in 1904, when mines were opened by the Clinchfield Coal Corporation at Dante, formerly known as Turkey Foot. Thereafter the industry gained momentum, and additional mines were opened by the same company at Laurel and Wilder, while other companies and local operators began de-



In a mine of the Clinchfield Coal Corporation at Dante, showing the level floor and roof, the horizontal Upper Banner coal seam, and the method of timbering the mine roof. (Photograph courtesy of the Clinchfield Coal Corporation.)



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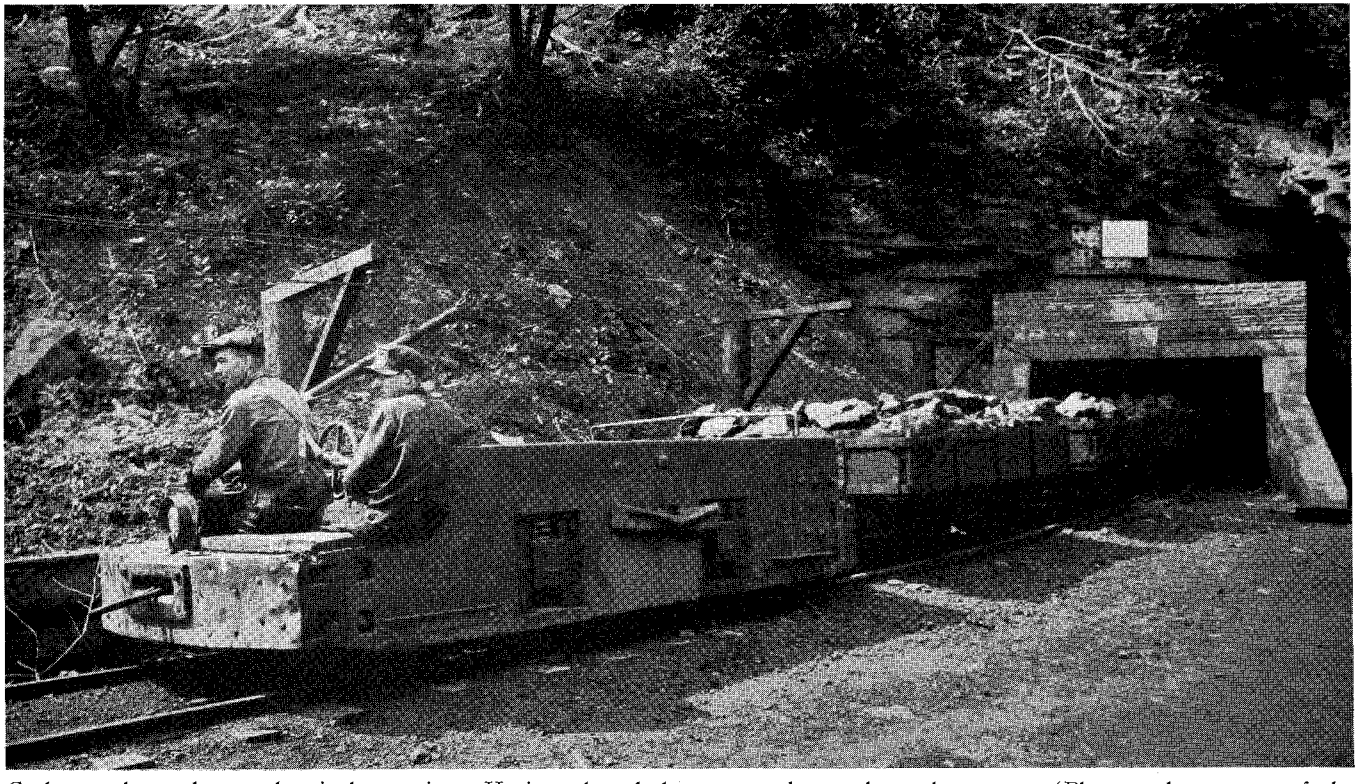
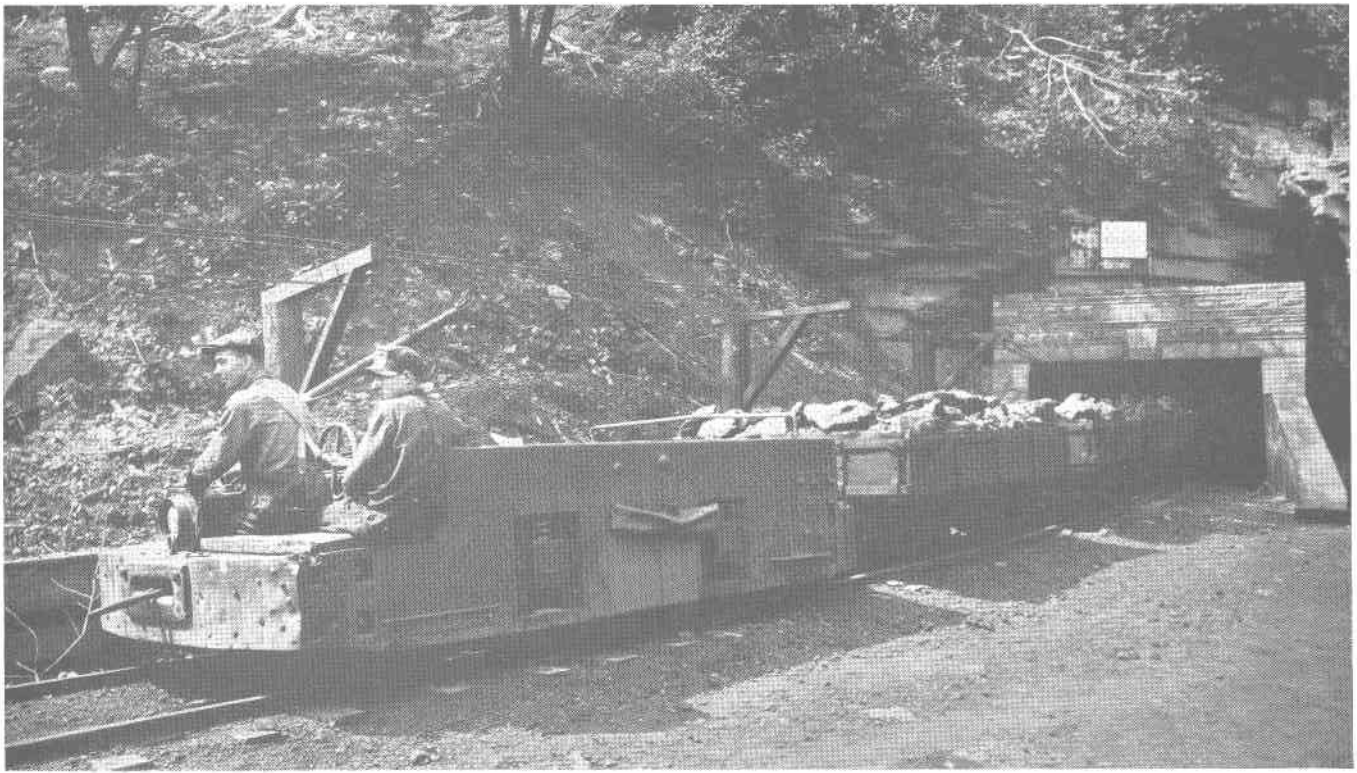


Coal cars drawn by an electric locomotive. Horizontal rock layers are shown above the entry. (Photograph courtesy of the Clinchfield Coal Corporation.)



Coal cars drawn by an electric locomotive. Horizontal rock layers are shown above the entry. (Photograph courtesy of the Clinchfield Coal Corporation.)

velopment elsewhere in the county. The total annual production first reached 1,000,000 tons in 1911, and has attained more than 2,000,000 tons annually in several subsequent years. The total production of the county during 34 years of commercial operation is approximately 40,000,000 tons. (See Table 3 and Fig. 8.)

TABLE 3.—*Coal production of Russell County, 1902-35, in short tons*[a]

1902	[b]7,831	1920	2,122,891
1903	[b]9,255	1921	1,543,862
1904	[c]177,133	1922	2,070,574
1905	[d]323,073	1923	2,066,057
1906	[d]302,896	1924	1,602,073
1907	[e]448,515	1925	1,854,514
1908	[e]255,693	1926	1,863,968
1909	[e]482,132	1927	1,518,557
1910	[e]790,066	1928	1,260,086
1911	[f]1,107,056	1929	1,414,677
1912	[f]1,292,365	1930	1,254,795
1913	[f]1,512,356	1931	1,008,773
1914	1,236,114	1932	674,069
1915	1,493,421	1933	752,798
1916	1,950,036	1934	771,531
1917	2,000,540	1935	660,424
1918	1,998,144		
1919	1,801,607		39,627,882

[a] Data compiled by the Virginia Geological Survey, U. S. Geological Survey, and U. S. Bureau of Mines.
[b] Includes Pulaski County.
[c] Includes Montgomery and Pulaski counties.
[d] Includes Lee, Montgomery, and Pulaski counties.
[e] Includes Lee and Montgomery counties.
[f] Includes Henrico, Montgomery and Pulaski counties.

The Norfolk & Western Railway and the Clinchfield Railway, including several spur lines to the coal mines, bring the field within convenient reach of markets both along the Atlantic Coast and in the Middle West. A few improved roads traverse the more open stream valleys to the larger mines, and other roads make possible truck or wagon hauling for local distribution.

At present (1935) the most important operations are the Clinchfield Coal Corporation, with offices at Dante; Dixie Beaver Coal Co., with offices at Clinchfield; Candlewax Smokeless Coal Co., with offices at Candlewax (formerly Della); New Garden Coal Co., with offices at Drill; and the Sword Creek Mining Co., with offices at Sword Creek. In addition to these larger operations, there are several small private developments where coal is extracted and distributed by truck. The companies listed above make use of the railroad facilities; the truck mines, which are

logical successors to the "wagon mines" of the previous generation, distribute coal to nearby communities that include Lebanon and Gate City, in Virginia, and Bristol, Kingsport, and Johnson City, in Tennessee.

Practically all the coal is extracted through drift mines in which the main entry is horizontal (Pl. 12). There are a few slope mines with inclined entries but no mines with vertical shafts. The common method of mining is to open a number of small "rooms" which are usually driven at right angles from the main or side entries. (See Pl. 11.) The rooms are each several hundred feet long and are supported by pillars of coal that are ultimately "robbed out" when the rooms are abandoned. Where it is practical, the mouth of the mine drift is located at a low point in the seam and all entries are driven upgrade. This method allows mine water to flow by gravity from rooms and entries, thus avoiding the pumping that is necessary where the opening does not permit natural drainage from the mine. In the more extensive workings air currents are forced through the passages by centrifugal fans, although there is little gas in any of the Russell County mines.

Most of the coal cars are hauled by locomotives of the overhead-trolley type. Storage-battery locomotives are used in some mines, and mules or ponies have not been entirely abandoned. At all mines where electric current is available, electric lights are located along the permanent halls, and machine drills are used to cut the face of the coal which is then blasted down and loaded on the mine cars. (See Pl. 13.) In the smaller workings the mining is done entirely by hand. Some of the truck mines are operated by a single miner, who dislodges the coal, loads the mine car, and hauls or guides it to a home-made tipple, where he loads his own truck. Most of the Russell County coal is distributed as "run-of-the-mine" without sorting or sizing. Coal from this field can be used or made available for all purposes required by the market.

CHARACTERISTICS

The coal of Russell County[15] is high-grade bituminous. It is clean, hard, moderately tough, and well adapted for domestic use, steaming, or coking. The average specific gravity is about 1.29. As the coal has two cleavage surfaces at right angles to each other and the bedding of the rock (Pl. 11), the seams yield a moderate proportion of "lump coal" on mining. Computed on an

[15] See also Wentworth, C. K., The geology and coal resources of Russell County, Virginia: Virginia Geol. Survey Bull. 22, 1922.

ash-free basis, most Russell County coals show about sixty per cent of fixed carbon; on an air-dried basis they are ranked as moderately high-volatile coals and generally carry less than eight per cent of ash. They have a low moisture content and little sulphur. Proximate analyses of coals in Russell County are given in Table 4.

TABLE 4.—*Proximate analyses of the coals of Russell County*[a]

(Analyses represent coal as received at testing laboratory.)

	Bed	Location	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	British thermal units
1	Upper	Dante	2.1	36.0	55.2	6.76	0.57	14,028
2	Banner	Wilder	3.4	35.0	55.9	5.71	0.55	14,080
3	Lower	Dante	1.9	35.9	55.9	6.46	0.68	14,110
4	Banner	Wilder	2.7	33.8	57.7	5.78	0.83	14,250
5		Dante	2.5	29.6	52.4	15.50	1.80	11,835
6	Kennedy	Drill	3.3	32.1	58.6	5.98	0.96	13,960
7		Della	2.0	36.1	52.6	9.33	0.83	13,450
8	Aily	Dante	2.6	32.2	60.8	4.40	0.91	14,160
9	Raven	Red Ash	2.9	32.0	59.4	5.73	0.63	14,230
10	Jawbone	Virginia City	1.5	31.4	49.8	17.33	1.25	12,190
11		St. Paul	2.6	29.6	51.8	16.14	0.86	12,235
12	Tiller	Hurricane Fork	2.2	31.9	59.4	6.50	0.46	14,110
13	Burtons Ford	Burtons Ford	3.6	32.1	60.5	3.82	0.47	14,230
	Average		2.6	32.9	56.2	8.42	0.83	13,605

[a] Wentworth, C. K., The geology and coal resources of Russell County, Virginia: Virginia Geol. Survey Bull. 22, pp. 104-133, 1922.

The average of 13 analyses of Russell County coals, as given in the above table, follows:

Moisture	2.6
Volatile matter	32.9
Fixed carbon	56.2
Ash	8.42
Sulphur	0.83
British thermal units	13,605

ASSOCIATED ROCKS

The coal-bearing rocks of Russell County[16] are the Lee and Norton formations at the base of the Pennsylvanian system. The Lee formation, consisting of thick-bedded, ridge-making sandstones and a mass of sandy shale and brown sandstones, ranges from 1,500 to 1,700 feet in thickness. The thick-bedded conglomerate at the top of the formation, known as the "Bee Rock," has a thickness of about 95 to 120 feet. A massive sandstone member occupies about 250 feet at the base of the formation. The resistant "Bald Rock" conglomerate, which occurs 500 feet above the basal sandstone, has a thickness that ranges from 160 to 200 feet.

As the Lee formation is adjacent to the folded rocks of the Clinch Valley along the south edge of the coal field, its beds are rarely horizontal but are generally tilted or even steeply inclined. The Lee contains several workable beds in Tazewell,[17] Wise,[18] and Scott[19] counties, but in Russell County[20] it contains only the Burtons Ford seam, which occurs immediately below the "Bald Rock" conglomerate.

The Norton formation contains most of the valuable coals of Russell County. It averages about 1,400 feet thick and consists of a series of sandstones and shales that are somewhat browner and more impure than those of the underlying Lee formation. Although the Norton formation is more shaly than the Lee formation, it contains two cliff-making sandstones, one of which, known as the McClure sandstone, has a maximum thickness of 180 feet. The McClure immediately underlies the Kennedy coal seam near the middle of the formation. (See Fig. 6.)

COAL SEAMS

There are 7 minable coal beds in Russell County, as well as several others that may have future economic possibilities. The minable beds are the Tiller, Jawbone, Raven, Aily, Kennedy, Lower Banner, and Upper Banner. With the single exception of the Aily seam, each is known to underlie a considerable portion of the field. The thickness of each bed and its position within the Norton formation are given in Figure 6.

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[16] Wentworth, C. K., op. cit., pp. 14-22.

[17] Harnsberger, T. K., The geology and coal resources of the coal-bearing portion of Tazewell County, Virginia: Virginia Geol. Survey Bull. 19, 1919.

[18] Eby, J. B., and others, The geology and mineral resources of Wise County and the coal-bearing portion of Scott County, Virginia: Virginia Geol. Survey Bull. 24, 1923.

[19] Idem.

[20] Wentworth, C. K., The geology and coal resources of Russell County, Virginia: Virginia Geol. Survey Bull. 22, 1922.

Tiller seam.—The Tiller seam occurs between 150 and 250 feet above the "Bee Rock" conglomerate. Although below the water-table in most of the field it lies near the surface at Clinchfield Junction, where it is being worked by the Dixie Beaver Coal Co. The thickness ranges from 24 inches in the Lick Creek basin to 65 inches near Big A Mountain. This seam has been found in some of the prospect drill holes, but the exact thickness and distribution below ground are still uncertain. It is probable that it can be mined over a considerable section of the field.

Jawbone seam.—The Jawbone coal, also known as the Ratliff seam, occurs 60-100 feet above the Tiller seam in the area west of Wilder, where the two seams are separated by a coarse sandstone. This rock disappears east of Wilder and the seams unite to form a bed from 40 to 60 inches thick. The Jawbone coal is exposed at the edge of the field and near the mouths of Road and Hurricane forks of Dump Creek. It is believed that this coal underlies the eastern part of the coal-bearing area and thins westward toward Big A Mountain.

Raven seam.—The Raven seam is exposed in northeastern Russell County and southwestern Tazewell County, where it is extensively mined as the Red Ash seam. It lies between 140 and 180 feet above the Jawbone coal, or between 350 and 530 feet above the Bee Rock conglomerate, and crops out on Cabin Fork of Musick Creek and near Grizzle. Normally it is split by several partings. Most of it occurs below drainage. The thickness ranges from 20 to 48 inches.

Aily seam.—Little is known about the Aily coal which lies about 125 feet above the Raven seam. It is thought that the bed is thin and of local value only.

Kennedy seam.—The Kennedy seam, formerly known as the Widow Kennedy coal, is more extensively exposed than ony other local bed. It is largely above drainage level and its outcrop covers a wide area along the lower and middle slopes of the valleys in the central and eastern districts. It is between 630 and 835 feet above the Bee Rock conglomerate and about 300 feet above the Raven coal. This bed, formerly mined at Dante, has been recently utilized in the eastern region. The thickness normally ranges from 20 to 78 inches, but thins toward Chaney Creek. East of Road Fork the bed is too thin to be of commercial value.

Lower Banner seam.—The Lower Banner coal seam, which is everywhere free from partings, is one of the most valuable coal beds in the county and is mined both at Dante and at Wilder. It is 780 to 1,105 feet above the Lee formation and 150 to 270 feet above the

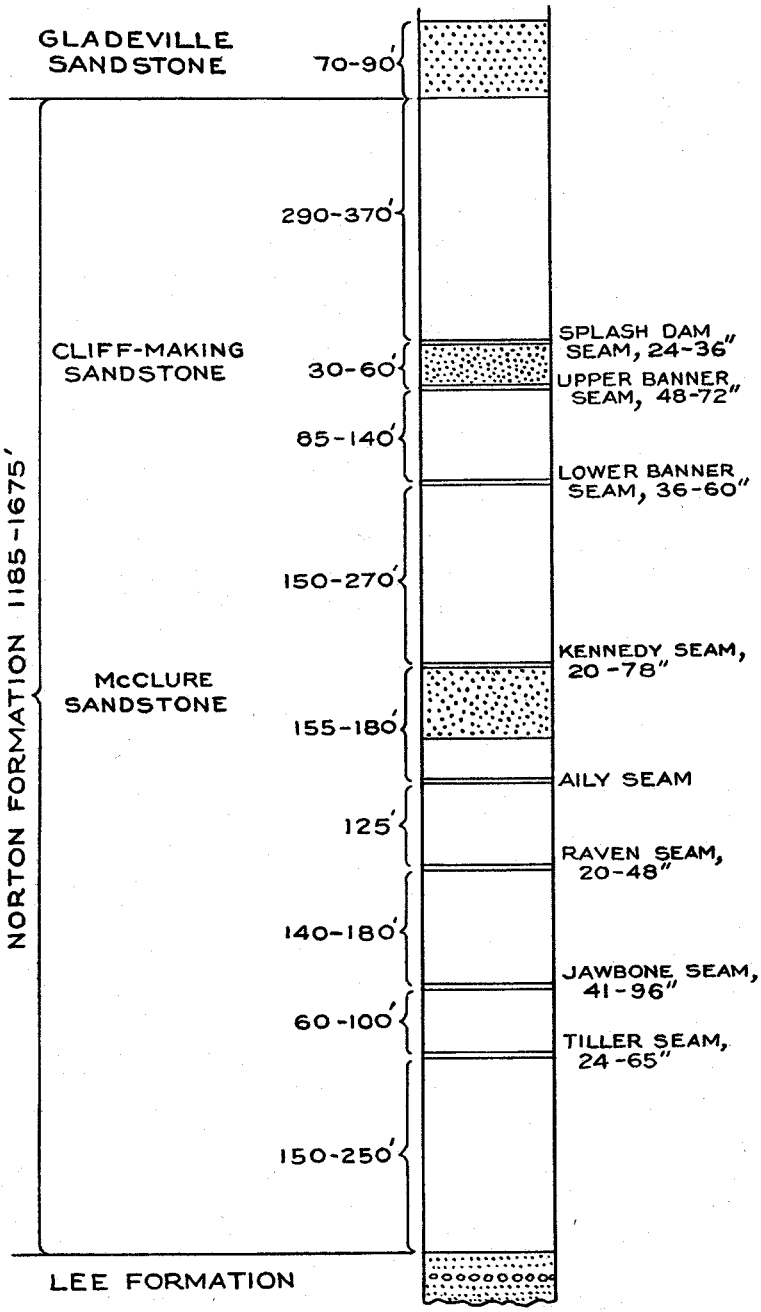


FIGURE 6. Section of coal-bearing rocks in Russell County.

Kennedy seam. The thickness varies between 36 and 60 inches and is minable throughout most of its area of distribution.

Upper Banner seam.—The Upper Banner seam, one of the best-known and most valuable coals of southwestern Virginia, is extensively mined at Dante. It is 85 to 140 feet above the Lower Banner coal and 865 to 1,240 feet above the Bee Rock conglomerate of the Lee formation. The seam is about 20 feet below a prominent cliff-making sandstone and contains in its upper portion a thin persistent sandstone. Throughout most of its area, the bed maintains a thickness that ranges from 4 to 6 feet. (See Pl. 11.)

Other seams.—Although several other seams, including the Splash Dam and Glamorgan coals, are in the higher portions of Sandy Ridge, they are relatively thin and inaccessible and are unlikely to prove of commercial value. The Splash Dam coal is 290 to 370 feet below the top of the Norton formation and immediately above the sandstone cap rock of the Upper Banner seam. It is commonly less than 3 feet thick. The Glamorgan seam is in the Wise formation immediately above the Gladeville sandstone, and is locally split into 3 benches. Each bench is less than 1 foot thick and has no commercial value.

STRUCTURE OF THE COAL FIELDS

The coal-bearing rocks are essentially flat-lying (Pl. 11) except along the southeastern edge of the field, where they have been overturned by the Hunter Valley (St. Paul) fault so that they now dip steeply toward the southeast. As the Lee formation is along the southeastern boundary of the coal field its strata are more disturbed than any of the higher coal-bearing rocks. In the southwestern part of the county the base of the Norton formation is likewise involved in the folding.

East of Big A Mountain the most prominent structural feature is the Dry Fork anticline, a long, gentle arch that extends across the northeastern corner of the county. The axis of this structure which crosses Lewis Creek about 1 mile north of Drill, is parallel to the Buchanan-Russell County boundary. In a belt extending to the county line northwest of the axis of this arch the rocks dip northwestward at a rate of about 500 feet to the mile. In most of the area east of Big A Mountain and southeast of the axis of the fold the dips are southeastward at a rate of about 100 feet to the mile. Since the dips conform closely to the gradients of the streams, outcrops of coal beds occupy fairly constant positions on the valley slopes north and south across the coal field.

West of Big A Mountain the coal measures rise 500 feet in the 1½ miles between Bowen Gap and Rasnake. The rocks continue to rise to the crest of the Sourwood Mountain anticline, whose axis extends southwestward from Dickenson County and reaches the edge of the Russell County field near Grizzle. East of this fold the rocks dip irregularly eastward; west of the axis, they slope westward toward Chaney Fork where several minor folds and basins form local undulations on the main structure.

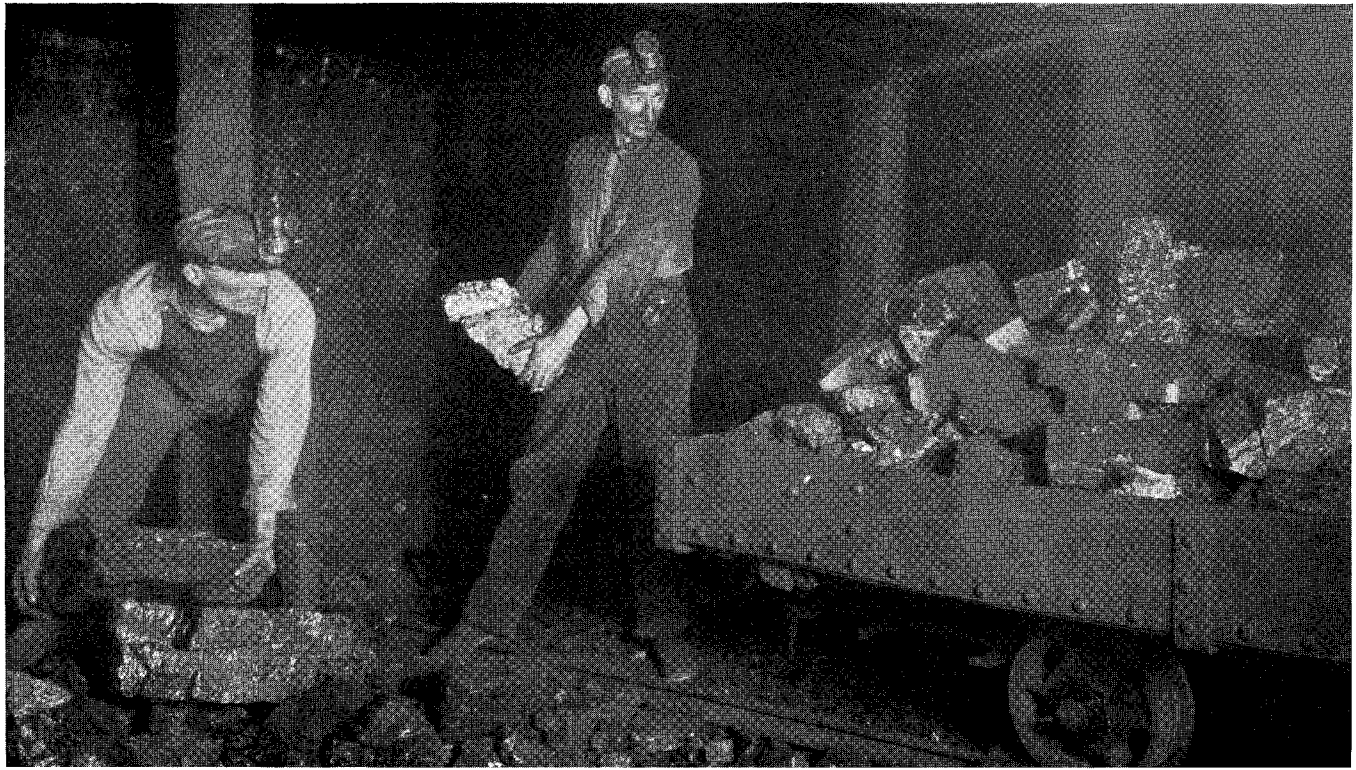
The coal field west of Chaney Fork is on the end of a low anticline that becomes much more pronounced in Wise County, where it forms the Powell Valley anticline. South of the axis of this fold, which crosses Lick Fork south of Dante, all dips are toward the south; north of the axis the rocks are inclined northward.

PRODUCING DISTRICTS

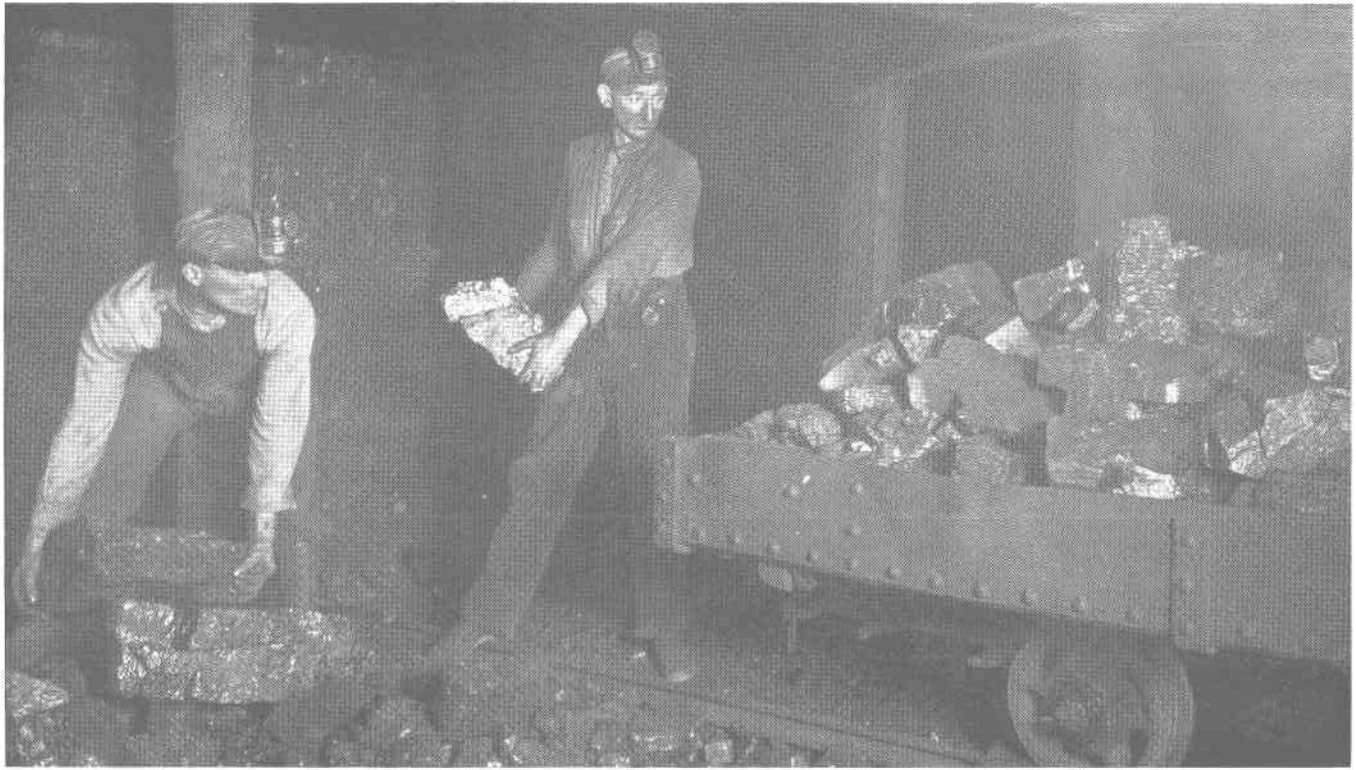
Burtons Ford district.—The Burtons Ford district is south of Clinch River and extends from Burtons Ford to Scott County. The bedrock is crushed, folded, and fractured by movement along the Hunter Valley fault. Burtons Ford seam is the principal coal bed and has been worked from several small mines. The area is inaccessible except by rail, and little active mining has been undertaken. During 1935 the original Burtons Ford mine, formerly operated by the Russell Fork Coal Mining Co., was being cleaned out preliminary to a renewal of mining operations. This district is of special interest to students of geology, because at several places the coal beds can be traced below an overburden of early Paleozoic limestone that has been faulted and thrust over them. At one opening coal (Pennsylvanian) has been mined beneath Cambrian limestone.

Lick Creek district.—The Lick Creek district, which includes the mining town of Dante, is the most extensively operated section of the Russell County field. It contains the Tiller, Jawbone, Raven, Kennedy, and both Banner seams. The chief production has come from the Kennedy and Banner coals.

Most of the development in this district has been undertaken by the Clinchfield Coal Corporation. At present (1935) this corporation is operating mines 2 and 3 in the Upper Banner seam, and mine 52 in the Lower Banner seam at Dante. (See Pls. 11, 12, and 13.) Mine 2, which is the largest in the county, opens in the "middle-foot" branch of Lick Creek. It has 10,000 feet of main hall and connects underground with mine 6 which was originally opened near Wilder. After the two mines were connected in 1930, the entrance and the mining town at Wilder were abandoned, and both mines are now operated from the



Loading coal by hand into cars, after the face of a mine has been cut by machine or by hand. (Photograph courtesy of the Clinchfield Coal Corporation.)



Loading coal by hand into cars, after the face of a mine has been cut by machine or by hand. (Photograph courtesy of the Clinchfield Coal Corporation.)

western entry at Dante. Mine 2 also connects southward with mine 3, which was originally opened in the "right-foot" branch of Lick Creek. The Upper Banner seam is worked in mines 2 and 3 and has an average thickness of about 5 feet. (See Pl. 11.) Both the coal and containing rocks dip 2° N. 35° W. Mine 52, opened in the "right-foot" branch of Lick Creek, follows the Lower Banner bed and extends beneath the active mines in the Upper Banner seam. The local thickness of the Lower Banner seam ranges from 3 to 4½ feet. The Kennedy seam, once extensively mined in this district, is not being worked at present, in part because the available benches have already been robbed out and in part because of its variable character and high ash content. The Tiller, Jawbone, and Raven seams are present, as indicated by drill holes, but have not yet been utilized.

The total production[21] of the Clinchfield Coal Corporation from the mines at Dante for the year ending December, 1934, was as follows:

Seam	Mine Number	Production (Short tons)
Upper Banner	2	312,346
Upper Banner	3	195,034
Lower Banner	52	106,786
		614,166

In July, 1935, the company produced 21,538 tons of coal from the Upper Banner seam and 4,620 tons from the Lower Banner during 12.91 days of operation. In 1934 the Upper Banner coal was mined from 31.19 acres, and the Lower Banner coal from 12.95 acres.

Additional statistics furnished by the Clinchfield Coal Corporation regarding the extent of its operations in Russell County prior to December 31, 1934, are as follows:

	Upper Banner seam Mines 2, 3, 5, and 6 (Acres)	Lower Banner seam Mine 52 (Acres)
Total area owned	9,995.22	5,861.10
Barren area	6,426.54	2,689.67
Coal area	3,568.68	3,170.43
Coal area mined out	1,433.33	214.86
Coal area not minable	190.90	
Coal area still minable	1,934.45	2,953.43

[21] These data were kindly furnished by Mr. George T. Stevens, chief engineer of the Clinchfield Coal Corporation. Other data relating to production in this district, used elsewhere in this report, were also obtained through the courtesy of this corporation.

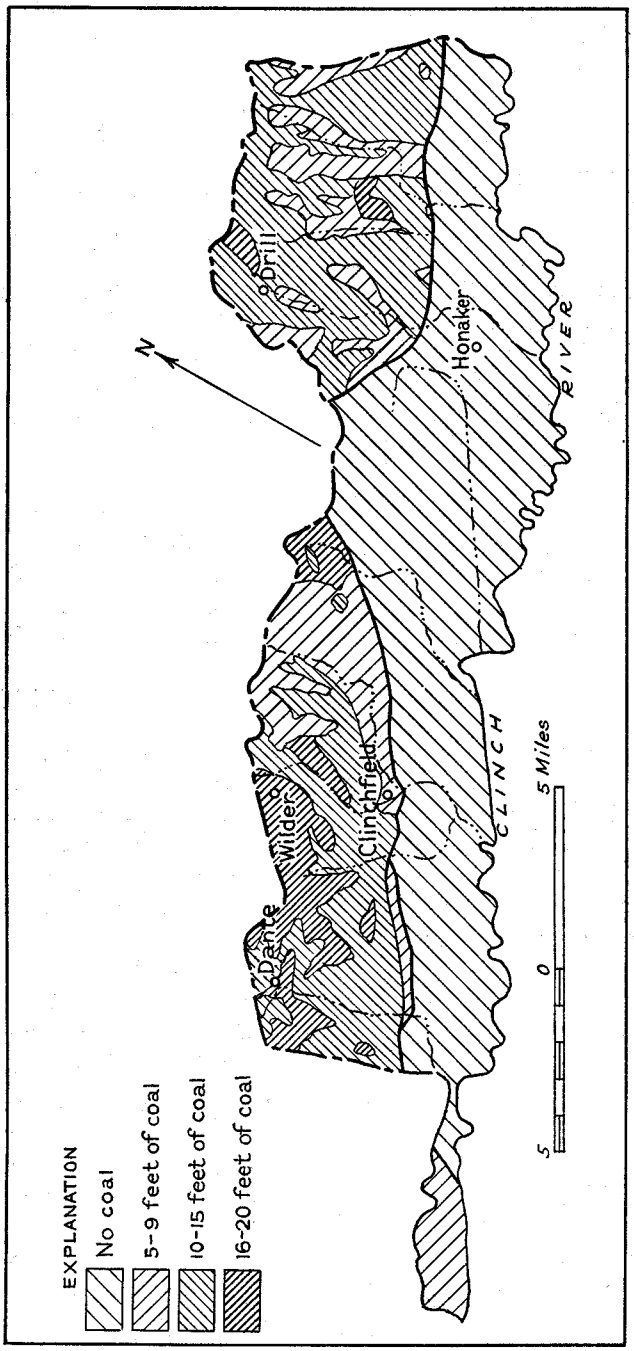


FIGURE 7. Map of the Russell County coal field showing the approximate total thickness of known coal seams. Data from Wentworth, C. K., Geology and coal resources of Russell County, Virginia: Virginia Geol. Survey Bull. 22, pp. 38-48, 1922.

Mines near Hamlin were formerly worked by the Hamlin Coal Co. and the Litton Coal Co. There are few if any truck mines now operating in the district.

Dump Creek district.—The Dump Creek district occupies the greater part of the central basin west of Big A Mountain. The creek has several main branches, including Road and Hurricane forks, which enter from the east, and Chaney Fork and Stonecoal Branch which enter from the west. The Kennedy and both Banner seams have been worked. It is thought that the Tiller, Jawbone, and Raven seams are present in workable thickness. The Kennedy seam, split by several partings, varies in thickness from 2 to 4 feet on Chaney Fork and Stonecoal Branch. The Banner seams crop out at higher levels on the hill slopes and cover smaller areas than the Kennedy seam. The only active working in 1935 was a small truck mine a short distance below the junction of Stonecoal Branch and Chaney Fork.

The Upper and Lower Banner seams were extensively mined in the northern part of the Road Fork basin. This formerly active mining district had camps at Wilder and Laurel. After the connection of mines 2 and 5 of the Clinchfield Coal Corporation, mining activities were transferred from Wilder to the Dante entry. It is thought that both the Tiller and Jawbone seams, which do not crop out in this basin, contain valuable coal reserves, although neither has been fully prospected.

Although the basin of Hurricane Fork of Dump Creek has been worked for a considerable time, most of the production has come from the Tiller (known as Dump Creek seam No. 5) and Jawbone seams. The Tiller has also been mined at Clinchfield P. O., about 1 mile northeast of Clinchfield Junction. The thickness ranges from 45 to 55 inches. The slope mines dip toward the northwest. The Jawbone seam crops out near Grizzle and near Dump Creek School. Both Banner beds, as well as the Kennedy and Raven coals, occur in this basin.

The Dixie Beaver Coal Co., operating on a lease from the Clinchfield Coal Corporation, is active at Clinchfield P. O. In 1935 there were about 45 men engaged in mining operations. The thickness of the coal (Tiller) is about 54 inches, and the total production for the year ending June 30, 1935, was 44,320 tons.[22] The current daily production of the mine is about 250 tons, and the company removed 5.08 acres of coal in 1934. The men work an average of 3 days a week.

Weaver Creek district.—The Weaver Creek district includes the basins of Weaver, Hart, and Musick creeks, and flanks Big A Mountain on the west. The several valuable coals are the Raven (3 to 4 feet thick), Kennedy (about 3 feet thick), and Tiller and Jawbone seams

[22] These data were furnished by Mr. P. H. Smith, Secretary-Treasurer of the Dixie Coal Company.

(not exposed). As the area is rugged and largely inaccessible and as exposures are poor, the coals have not been carefully correlated. The bedrock is greatly broken near the fault that bounds the district on the east and south. One truck mine, operating the Raven coal on Musick Creek at the southeast end of Sourwood Mountain, was active in 1935.

Lewis Creek basin.—The Lewis Creek basin is east of Big A Mountain and structurally separated from it by an overthrust fault. The bedrock is strongly folded and broken. The Kennedy seam occurs locally with a thickness ranging from 3 to 4 feet, and the Raven, Aily and Lower Banner beds are present. Although the Lower Banner seam has been utilized, most of the Lewis Creek production has come from the Kennedy seam. Mining operations have been carried on at Drill and at Candlewax (formerly Della), where shipping mines are now located. The New Garden Coal Co., with offices at Drill, employs about 45 men. It ships coal to order on a short track that connects with the main line of the Norfolk & Western Railway at Putnam. The Candlewax Smokeless Coal Co., with offices at Candlewax, was shipping coal to order in 1935. Several truck mines distribute coal from smaller workings in the basin.

Sword Creek and Little Mill Creek basins.—These basins, in the eastern part of the Russell County coal field (Fig. 5), are underlain by bedrock that dips gently southward. The Kennedy and Lower Banner seams, each with an average thickness of about 3 feet, are the main sources of coal. There are two shipping mines, one operated by the Sword Creek Mining Co. on the west slope of Sword Creek about 3 miles north of Sword Creek Station, and another operated by the Nora Coal Corporation near the mouth of Sulphur Spring Branch. Both mines have rail connection with the Norfolk & Western Railway. Except for State Highway 83, which crosses the basin north of Stone Mountain from Honaker to Raven, the district is without adequate improved roads. As the Kennedy and Raven coals crop out along or near Highway 83, many small mines are so conveniently located that a truck parked along the highway can be loaded directly from their entries. Coal beds along the upper branches of Sword Creek have been poorly prospected.

RESERVES

It has been estimated[23] that there is about 1,000,000,000 tons of coal remaining in Russell County. About 60 per cent of this reserve is west of Big A Mountain. (See Fig. 7.) On the assumption that as much as 70 per cent of the total coal is recoverable, there is an esti-

[23] Wentworth, C. K., op. cit., p. 137.

mated reserve of 700,000,000 tons. Unfortunately, however, much of the coal is too thin or too far below the surface to be profitably worked in competition with the more cheaply mined coal now being produced elsewhere in the Appalachian region. One of the factors that originally retarded local coal development was the inaccessibility of the field to the markets. At present, the two main railways together with their several spur lines have brought ready transportation to each of the major portions of the field, and improved roads are constantly increasing the ease of access. Although there is a present overproduction of bituminous coal, a constantly increasing future demand will eventually force the utilization of coal beds that are now undeveloped. The present production in Russell County (Fig. 8) has decreased from that of the period between 1915 and 1925, but it could be appreciably increased in the near future.

OIL AND GAS

The search for oil and gas in Russell County has been unsuccessful, and it is probable that failure will meet any further attempt. The great age and the disturbed condition of the local rocks exclude all but the coal-bearing strata from consideration as possible reservoirs for oil and gas; and for several reasons the coal strata are thought to be barren of oil and to contain but small supplies of gas.

A study of the producing oil and coal fields of the Appalachian region has shown that there is a constant relation between the presence of oil and the character of nearby coal. When a proximate analysis of coal is computed on a moisture-free and ash-free basis, the amount of fixed carbon present can be determined. It has been observed that wherever oil fields coincide with or are adjacent to coal fields, the fixed-carbon content of the coal is always less than 60 per cent and that no oil occurs near coal which carries more than 63 per cent of fixed carbon. This relationship may be explained by the fact that a high percentage of fixed carbon indicates an involved geologic history in which more thorough rock alteration has occurred than is compatible with the nearby occurrence of oil. In such a region the oil, if ever present, would have become volatilized and would have escaped long ago.

The fixed-carbon content of the Russell County coals, which ranges between 60 and 65 per cent, is well above the maximum amount compatible with the presence of oil, and unless the field is markedly different from the normal fields of the Appalachian region, it may be safely stated that oil in commercial quantities will not be found in the county.

The fixed-carbon ratio does not limit the occurrence of gas, and it is not unreasonable to suspect the presence of gas in the coal-bearing

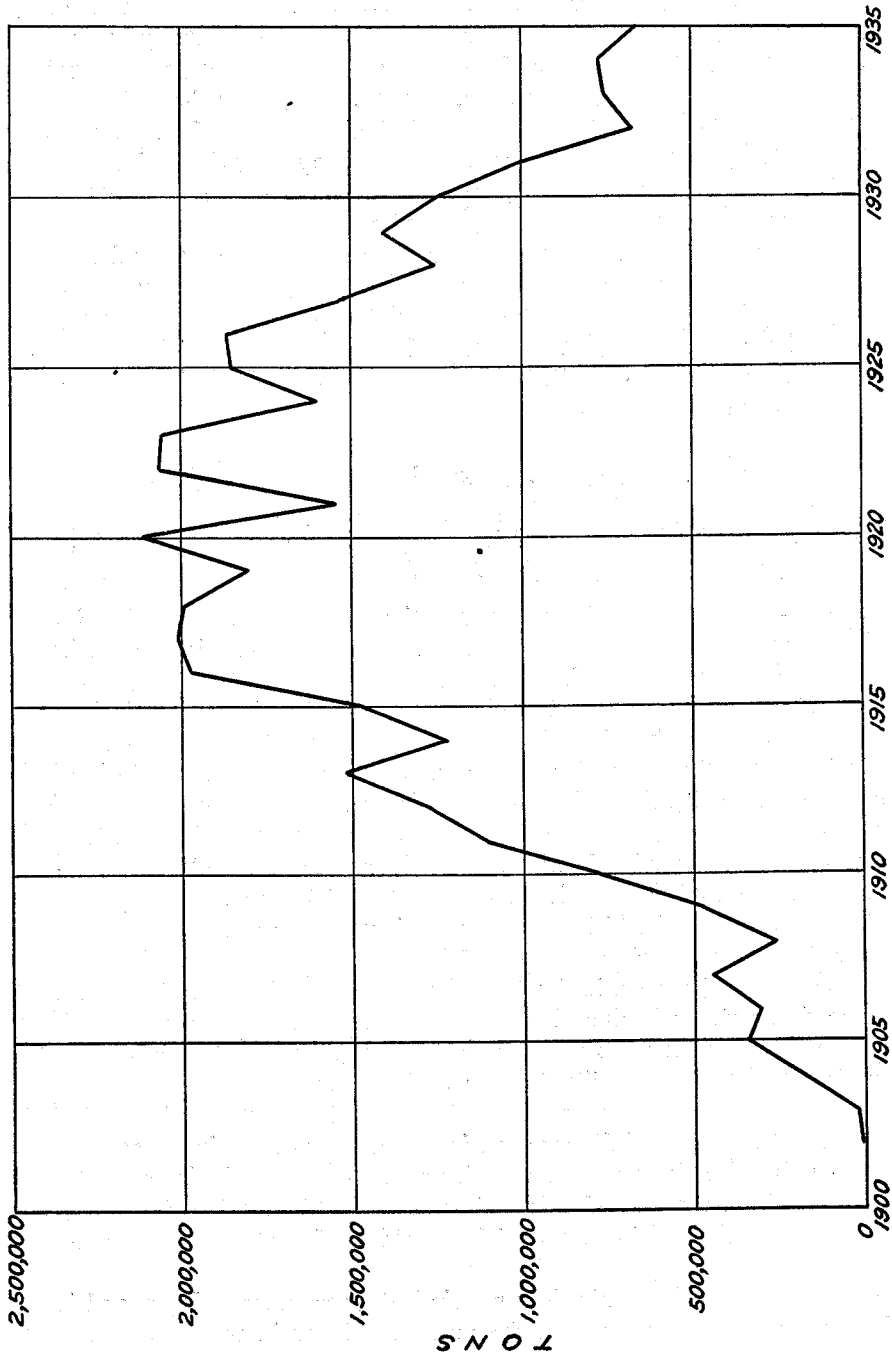


FIGURE 8. Coal production of Russell County, 1902-35. Production for 1902-10 and 1913 includes minor amounts from adjacent counties. (See also Table 3.)

rocks north of Clinch River. As gas rises in whatever rocks contain it, any upward fold, such as an arch or anticline, would tend to trap it, provided that the crest of the fold is formed of impervious rocks. Either the Dry Fork anticline east of Big A Mountain or the Sourwood Mountain anticline west of the mountain may afford such conditions. In 1934 a deep well was drilled near the axis of the Sourwood Mountain arch, on Hurricane Fork of Dump Creek, near the mouth of Grassy Branch. It was located 4 miles due north of Cleveland, 3 miles northeast of Clinchfield Junction, and three-quarters of a mile south of Dump Creek School. It was drilled in the hope of striking either oil or gas and started at a stratigraphic horizon about 100 feet above the Tiller coal seam. It reached a depth of 6,000 feet, but although a little gas was found in coal a short distance below the surface, no commercial quantities of gas or any oil were found. Although this well does not serve as a test of the entire area, its failure has dampened the enthusiasm of prospective operators.

METALS

GENERAL STATEMENT

Iron, manganese, lead, and zinc occur at several places in Russell County. No other metals are present, and the search for copper, silver, or gold will always result in disappointment, despite stories of a local "silver mine" and rumors of a vein of gold.

The slopes of Copper and Moccasin ridges contain areas in which many lumps or nodules of iron and manganese minerals crop out or are plowed up from the soil. As the containing clay becomes washed away, the ore minerals remain behind to suggest the presence of valuable deposits below ground. The suggestion is generally misleading, for although these areas may have an encouraging show, pits dug to the bedrock show a disappointing lack of solid ore minerals.

The geologist is thus faced with the discouraging task of attempting to dissuade the landowner from his belief in rich mineral deposits below ground, and his attempts are sometimes mistaken for poor or prejudiced advice. It is hoped that the following paragraphs, which describe the past, present, and future possibilities of local metal mining, will be of general value to the residents of Russell County.

An abandoned lead and zinc mine and several prospects for iron and manganese are described. None of them is active at present, and only one, the Osborne mine, holds any promise of subsequent development. Figure 5 shows the important mineral localities of Russell County.

IRON AND MANGANESE

General features.—As iron and manganese minerals occur under similar conditions in the Appalachian region, it is customary to describe them together. The chief iron mineral is limonite, a brown iron oxide of medium weight that produces a yellow or yellow-brown stain. The most common manganese minerals are psilomelane, manganite, and pyrolusite. These manganese oxides are dark brown to sooty black and generally occur in irregular or nodular masses. The common ore minerals of iron and manganese are porous earthy materials, rarely crystalline, and frequently admixed with limestone, sandstone, or chert.

Most if not all of the local deposits of iron and manganese (Fig. 5) are found near the surface in the residual soil derived from the decay of the underlying rocks. Some of the deposits may contain veins or stringers of ore minerals that penetrate the bedrock; in others the rocks may be partly replaced by these minerals.

It is thought that the deposits were formed by the action of ground water upon the bedrock in which iron and manganese were originally disseminated, possibly in the form of carbonates. The circulating ground water dissolved the metallic elements which were subsequently deposited elsewhere in more concentrated form. The ores are secondary residual concentrations occurring mainly in the soil.

There is no evidence of any workable quantities of red iron ore, or hematite, in Russell County, despite its presence in Lee and Wise counties, to the west. The horizons of the western hematite beds are locally occupied by red sandstones that contain insufficient metallic iron to serve as an ore.

Helbert prospect.—The Helbert prospect[24] is 2,500 feet above sea level on the northwest slope of Moccasin Ridge, at the head of a small hollow 7 miles south of Castlewood and 6 miles southwest of Hansonville.

Manganese minerals were early discovered on Moccasin Ridge, but no encouragement was given to their development until the forced demand for manganese in 1917-18 brought attention to the local deposits. The prospect was worked in a small way by H. H. Kaylor and J. P. Jones, who took out about 80 tons of ore in 1918. The ore was hauled by wagon to a small washer in the hollow midway between the mine and Copper Creek. The sudden drop in the price of manganese immediately after the World War discouraged further development.

The ore occurs within a small area about 500 feet long and 150 feet wide near the contact of the Copper Ridge dolomite and Nolichucky shale. The rocks dip 40° SE. into the hill, and the ore min-

[24] Stose, G. W., and Miser, H. D., Manganese deposits of western Virginia: Virginia Geol. Survey Bull. 23, pp. 195-197, 1922.

erals occur in a shale along a minor shear or fault plane. There are several ore bodies, all of which are more or less tabular in shape. Several open pits and cuts have been made, but all have slumped in or are now filled with debris.

The ore consists of lumps and nodules of manganite, pyrolusite, psilomelane, and wad. Limonite, or brown iron, also occurs here. At the surface the ore minerals occur in a light-red or yellow residual soil; below ground they fill or replace a broken bedrock that contains chert. Irregular masses of manganese and iron that crop out along the crest of the hill led to the original discovery of the ore bodies. The average of several analyses of ore from this locality is reported to show about 50 per cent of metallic manganese, 10 per cent of silica, and 0.06 per cent of phosphorus. The character of the material now visible does not indicate that such an average working composition could be maintained.

The prospect is not promising. Although it has been examined several times in recent years, it is unlikely that manganese will be mined at this place unless there is a return of high prices for the metal, better facilities for transportation, and the discovery of a larger body of good ore below ground.

Bennett prospect.—The Bennett prospect is near the crest of Moccasin Ridge, about 2 miles southwest of the Helbert prospect and a quarter of a mile east of the road that crosses Moccasin Ridge toward Tumbez. This property was once prospected for manganese ore, and a number of shallow pits were dug over several acres of land that is irregularly covered with float of manganiferous limonite. The show at the surface is more promising than near the Helbert prospect, but there are no visible indications of ore underground, and there is little likelihood that operations on this property would be successful.

Fortner prospect.—The Fortner prospect[25] is also on Moccasin Ridge about midway between the Helbert and Bennett prospects. Although surface accumulations of lump manganese have attracted attention, there is nothing to indicate workable deposits.

It is probable that the entire northwestern slope of Moccasin Ridge carries loose lumps of limonite and associated manganese minerals, but not in sufficient quantity to be of present economic value. Surface accumulations have been examined as far southwest as the Osborne lead and zinc mine and can be traced for several miles northeast of the Helbert prospect. The ore is somewhat more abundant northeast than southwest of the road over Moccasin Ridge, but at no point is it now advisable to undertake mining operations, and it is doubtful if such operations will ever be practicable.

[25] Stose, G. W., and Miser, H. D., op. cit., p. 195.

Whitt prospect.—The Whitt prospect[26] is 2½ miles northeast of Sword Creek station on the Norfolk & Western Railway, and on the south slope of Stone Mountain, about 50 feet below Nipper Gap and 2,460 feet above sea level. It was briefly prospected by a long trench in 1898. The trench is now overgrown and slumped, and no other attempt at development has been made.

The mineral deposit, which is a mixture of limonite, hematite, and psilomelane, was formed by the replacement of crushed layers of Clinch sandstone near its contact with the Juniata formation. A local fault, or shear zone, cuts diagonally across the bedding of the rocks, which dip steeply toward the southwest. The Clinch sandstone forms the crest of Stone Mountain, and its undersurface—for the beds are overturned—passes below the Juniata and Martinsburg shales on the southeastern slope of the mountain.

The occurrence here has geologic significance, as it is unusual to find brown iron or manganese minerals in beds other than those of Devonian or Cambrian-Ordovician age. Little economic importance can be attached to the deposit, however, and further prospecting is not advised.

Hall prospect.—The Hall iron prospect[27] is about 6½ miles southwest of Castlewood, at the head of a tributary of Moll Creek, near the crest of Copper Ridge, not far from Lawson's store. The property was explored by the Union Iron & Steel Co. in 1906, and a small quantity of ore was extracted and hauled by wagon to Castlewood. The ore is reported to have contained 44 per cent of metallic iron, 21 per cent of silica, and 0.17 per cent phosphorus. The ore mineral is limonite, which occurs in lumps and irregular masses in a residual clay above the Copper Ridge dolomite. There is little about the site to attract further attention, for similar but equally unimportant accumulations of residual limonite occur elsewhere along Copper Ridge.

LEAD AND ZINC

General features.—Ore minerals of lead and zinc, commonly in intimate association in the southern Appalachian region, are for the most part limited in occurrence to the magnesian limestones and dolomites of early Paleozoic age. The two distinct groups of these minerals are primary sulphides, originally formed far below the level of underground water, and secondary or oxidized minerals, derived by weathering reactions from the sulphides and occurring in residual clays and soils. Galena, or lead sulphide, is a very heavy lead-gray mineral that breaks

[26] Stose, G. W., and Miser, H. D., op. cit., pp. 193-194.
[27] Watson, T. L., Mineral resources of Virginia: Virginia-Jamestown Exposition Commission, Lynchburg, Va., J. P. Bell Co., p. 463, 1907.

into cubical fragments. Sphalerite, or zinc sulphide, is a heavy mineral with a resinous or greasy appearance. It ranges from light brown to black, and the dark-colored varieties are known to the miner as "black jack." Secondary lead and zinc minerals are all nonmetallic in appearance. They are comparatively heavy and normally occur in porous, earthy, or finely crystalline masses that encrust the bedrock or are intermixed with soil. Chief of them are smithsonite (zinc carbonate), hemimorphite (zinc silicate), and cerussite (lead carbonate). Limonite, or brown iron oxide, is not uncommonly found with lead and zinc ores.

Lead and zinc minerals occur in but few localities in Russell County (Fig. 5), and none of the deposits are at present (1935) being operated.

Osborne mine.—The Osborne mine[28] is about 2,100 feet above sea level on the northwest slope of Moccasin Ridge. It is about 400 feet above Copper Creek, which flows 1,300 yards north of the mine. The workings are equally distant from Tumbez and Mason's store and are about 7 miles south-southwest of Dickensonville.

The first mining was done in 1900 by L. D. Crawford, who is reported to have taken out 7 carloads of lead ore. The next mining was by the Bertha Mineral Co., which worked it for a short time and then allowed the option to return to Crawford, who resumed his original small-scale operations. Subsequently the property was worked by H. H. Kaylor, of Bristol, who shipped both lead and zinc minerals.

In 1926 T. C. Boyd, under contract to the St. Joseph Lead & Zinc Co., prospected the property with 7 diamond-drill holes and mined one car of ore in 1928. The locality has not been worked since 1930, and all mining equipment, originally including a small crusher and washer, has now been removed. The ore taken from the Osborne mine was hauled by wagon or truck to the railroad at Castlewood.

The workings consist of several horizontal tunnels in a small shale knob that rises above a terrace or "flat" near the summit of Moccasin Ridge. The tunnels radiate into the west side of the knob, which is capped by the Nolichucky shale. From the large surface pit that constituted the original working a vertical shaft was later sunk to a depth of 63 feet. All the workings were in need of repair in 1935.

The bedrock from which the ore minerals were mined is the upper part of the Honaker dolomite, or its equivalent, the Maryville limestone. The rocks dip 45° SE. and strike N. 75° E. It is reported[29] that a thrust fault emerges near the workings in or beneath the Maryville limestone, but field evidence for a major displacement is wholly wanting. Although some of the interbedded shales are mashed, the lime-

[28] Watson, T. L., Lead and zinc deposits of Virginia: Virginia Geol. Survey Bull. 1, p. 114, 1905.

[29] Watson, T. L., op. cit., p. 114.

stones are relatively undisturbed and the ore was found to follow the bedding surfaces.

The deposit is reported to have been discovered when a stoneboat scratched or polished a ledge that displayed silvery streaks of galena. Near the surface the ore minerals are chiefly of the oxidized or secondary types, whereas at depth they are the primary ores, galena and sphalerite. Finely granular sphalerite was found in the shaly zones. Few gangue minerals occur in addition to the enclosing bedrock of limestone and dolomite, although fluorite is reported in the drill cores. At present it is impossible to examine any ore in place, and the dumps have been thoroughly worked over, especially during 1917 and 1918, when ore is alleged to have been smuggled out of the locality from the stock piles.

The present dumps contain a number of ore types such as irregular, porous masses of impure smithsonite and calamine, admixed with limestone; irregular lumps of porous brown iron ore, chiefly limonite, that are streaked with red iron oxide; and small quantities of solid rock containing shreds and veins of galena. No sphalerite was observed, although it is probably disseminated through some of the limestone masses.

It is reported that a mass of carbonate ore was encountered in a drill hole 600 feet below the surface. If this report is reliable, there are secondary ores that lie 200 feet below present creek level and also below the present water table. This fact has been interpreted to indicate that the gradient of the underground drainage is much less than that of the surface stream, and that a larger quantity of secondary ores might be expected in further developments.[30] It also suggests that primary ores may be too deep for practical developments. A few fragments of greenockite (cadmium sulphide), reported to have come from the bottom of the 63-foot shaft, were shown to the writer by Mr. Boyd.

The poor transportation facilities and the long haul to Dickensonville over Copper Ridge have hitherto provided a formidable barrier to full development of the property, and it is probable that they will continue to prevent active operations. It seems to be clear that both lead and zinc ores occur at this locality, but whether the quantities available are sufficient to warrant additional investigation cannot be readily determined. The results of the drill holes made in 1928 were not sufficiently encouraging to lead to immediate operation; nevertheless, it is not clear that they were so located as to test the ore resources adequately. More accessible and more extensive supplies of similar ores in adjacent areas in Tennessee are still awaiting adequate development, and it is not likely that the Osborne property will be able in the immediate future to produce ore that can compete with these Tennessee ores. Al-

[30] Holden, R. J., *in* Humbert, R. L., and others, Industrial survey of Russell County, Virginia, pp. 31-32, Blacksburg, Virginia Polytechnic Institute, 1930.

though the writer does not advise further development of these deposits under present conditions, yet it is his conclusion that an attempt to uncover valuable metallic ore at this point would be more successful than elsewhere in Russell County.

Prospects.—Within a short distance of the Osborne mine are other showings of lead and zinc minerals, but at no point is any quantity of ore visible, nor do the surface indications suggest ore bodies of value below ground. In a position analogous to that of the Osborne mine, samples of sphalerite, galena, and calamine have been found along Moccasin Ridge about 3 miles southwest of the Osborne property. Minor indications of similar minerals likewise occur a short distance northeast of the Osborne property. Grains and small masses of sphalerite disseminated in bedrock can be seen in low road cuts where Moccasin Ridge is crossed by the country road leading to Tumbez. A shallow quarry in Holston limestone near Mason's store, 1¼ miles due north of the Osborne mine, uncovered a few seams containing small quantities of calamine in thin irregular zones along the bedding of the rocks. This occurrence is unusual, for the lead and zinc ores of the southern Appalachian region almost invariably occur in rocks older than the Holston limestone.

The Pat Keith prospect is at the head of Sinking Creek on the northwest slope of Copper Ridge, 4 miles northwest of Mason's store, where a few small masses of sphalerite and galena are disseminated in the Copper Ridge dolomite. A selected sample from an old dump showed a few small specks of galena and tiny scattered masses of resinous yellow-brown sphalerite. The locality was prospected about 20 years ago and again in 1930, but no ore was shipped, and the only working is a shallow surface pit.

NONMETALLIC MATERIALS

Russell County contains a considerable supply of nonmetallic mineral resources, including barite, limestone, shale, clay, and building stone. Most of them are so familiar that the prospect of their commercial exploitation does not hold the lure which surrounds the metal mines and oil wells of other regions; nevertheless, the possibilities of their profitable development should be given careful study.

BARITE

Although barite, or barium sulphate ($BaSO_4$), also known as baryta, barytes, and heavy spar, has been extensively mined in Russell County, no workings are now in operation. Barite is a white mineral with a porcelaneous luster and high specific gravity. It commonly oc-

curs as granular, compact, and earthy masses in the residual soil and as veins and incrustations within bedrock. It is rarely found pure, being generally contaminated with such other materials as iron oxides (which stain the mineral red or yellow), limestone, sand, and clay. The largest percentage of crude barite produced in the United States is used in the manufacture of the important barium pigment, lithopone. Smaller amounts are ground and used principally as a "filler" in paint, rubber, paper, linoleum, and cloth industries, and in the production of chemicals. The barium chemicals are used chiefly in the manufacture of pigments, clay products, optical glass, enameled ironware, medicines, pyrotechnics, dyes, and in the refining of sugar.

Barite was early discovered in Russell and Tazewell counties but was not intensively mined until 1892, when operations were undertaken along Clinch River 2 miles below Gardner. Other mines were soon opened, and in 1906 the Russell-Tazewell field was the chief producing area in the State. As the immediately available supplies became exhausted, the mines were gradually closed, and Russell County has produced no commercial quantities of barite for more than 25 years.

Geologic relations.—The barite deposits[31] are restricted to a narrow belt that extends from the middle of Tazewell County nearly to Lebanon, along the southeastern slope of Kent Ridge and its linear extensions. (See Fig. 5.) In Russell County they are along Little (Maiden Spring) and Clinch rivers and on Cedar Creek. The deposits are associated with the residual material or bedrock of the upper members of the Beekmantown dolomite. The barite is most commonly found near the contact of the Bellefonte and Murfreesboro formations. There does not seem to be any controlling structural feature, such as a fault or crushed zone, that determines the position of the barite belt, and the deposits were not observed to favor any one type of topography, although the belt is moderately hilly.

Although the origin of the local deposits is not wholly clear, it is possible that the barium was originally present in the dolomites and limestones and was taken into solution by circulating ground water during an epoch of weathering and erosion. The barite was then deposited under favorable conditions as irregular lumps in the residual clay or as veins and replacement bodies in the bedrock. The association of the deposits with the Bellefonte-Murfreesboro contact seems to indicate that this stratigraphic horizon was close to the source of the original element from which the barite was derived. An alternate view is that the barite is of igneous origin.[32]

[31] Watson, T. L., Mineral resources of Virginia, pp. 322-325, Lynchburg, Virginia-Jamestown Exposition Commission, Lynchburg, Va., J. P. Bell Co., p. 463, 1907.

[32] Edmundson, R. S., Barite deposits of Virginia: Am. Inst. Min. Met. Eng. Tech. Pub. 725, pp. 13-17, 1936.

Hubbard mine.—This mine of the Clinch Valley Barytes Co. is near Clinch River, 1 mile south of the mouth of Lewis Creek. It is on the west bank about 100 feet above river level, and the workings extend westward into a low meander spur that points southward. The opening is a large cut, 100 feet long and 30 to 50 feet wide. The barite occurs as irregular masses in residual clay, veinlike bodies filling joints and fractures, and replacement deposits in bedrock. Although the mineral, which is white and crystalline, is largely free from impurities, small zones of limonite are common along some of the masses. A few fragments of barite were found with an incrustation of limonite 1 inch thick that surrounds a core of white crystalline barite. It is reported that chert and fluorspar are accessory minerals. In order to facilitate transportation, a standard-gage railroad track was laid from the Norfolk & Western Railway at Honaker to the company's mill on Clinch River, and an additional tramway was constructed to the mine. In 1906 the mill had a daily output of 16 tons. After the cessation of mining operations the railroad spur was extended to Blackford, in part to facilitate shipping of livestock from the Stuart estate, at Elk Garden.

The barite occurs in the Bellefonte dolomite immediately below the Murfreesboro limestone, which is exposed near the mine. There is no evidence of major faulting. Although considerable barite was noted on the dumps, and many veins appear on the face of the cut, it is probable that the locality has been commercially exhausted.

The Clinch Valley Barytes Co. also operated a large mine on Clinch River about 3 miles south of Gardner, from which barite was hauled by wagon to the railroad at Gardner. The barite at this mine occurs under conditions similar to those at the Hubbard mine, and the minable material is likewise exhausted.

Leonard mine.—This mine is on Cedar Creek about 2 miles above its junction with Clinch River and 2 miles northeast of Lebanon. It was operated between 1900 and 1905 by the Clinch Valley Barytes Co. The barite was elevated 100 feet by an incline to the top slope of Cedar Creek valley, hauled by wagon to Cleveland, carried by the Norfolk & Western Railway to Honaker, and then transported along the company's spurline to the mill on Clinch River.

The workings consist of several openings about 50 feet above creek level on the west bank of a sharp bend in Cedar Creek. The largest opening follows a 15-foot zone of veins and replacement deposits for a distance of nearly 30 feet into the bedrock. Some of the material is pure, but much of it is intimately admixed with limestone. The barite occurs in cracks, joints, bedding planes, and locally replaces the upper part of the Bellefonte dolomite. Barite in the workings is largely ex-

hausted, although it is reported that prospecting on adjacent property in 1905 found additional occurrences.

Little River mine.—This mine on the southeast side of Kent Ridge is due south of Sword Creek and near one of the large meanders of Little (Maiden Spring) River. The crude material was hauled by wagon to Gardner and then shipped to the Pittsburgh Baryta & Milling Corporation, which operated a mill at Richlands, Tazewell County. Barite at this locality ocurs on or in the upper beds of the Bellefonte dolomite. The largest of the several open cuts was about 40 feet long and 15 feet deep. The barite occurs in crevices, joints, and bedding planes, and there is no present evidence of either a definite vein or a former sizeable body. All usable barite in the workings has been mined.

Other prospects are reported on adjacent properties, but no extensive workings were observed. The Pittsburgh Baryta & Milling Corporation also operated small workings near Finney, which were not visited by the writer.

Reserves.—The available supplies of barite appear to have been exhausted at all the workings visited in Russell County. Inasmuch as transportation facilities are poor throughout the belt, it is unlikely that the county will again produce barite unless a considerable deposit is found at a place where it can be readily mined and distributed, and until shipping rates, demand for barium, and current loading price for milled barite are more favorable than at present.

LIME AND CEMENT MATERIALS

Limestone, argillaceous limestone or limy shale, and dolomite are the most valuable local materials for the manufacture of lime and cement.

Limestone.—Many of the local limestones are sufficiently pure to be used for agricultural lime, especially in small kilns which can be operated by individual farmers for their own use. For commercial lime production or for high-grade chemical lime, only the Holston limestone is considered a potential reserve. This formation is abundantly exposed in several belts, two of which extend the entire length of the county. The northernmost belt follows the valley of Little (Maiden Spring) River from Tazewell County to Blackford, then southwestward between Copper and Moccasin ridges into Scott County. Coarse crystalline limestone is well exposed in this belt between Lebanon and Dickensonville. The southern belt extends from a point near Belfast Mills through Say, near Elk Garden and Hansonville, and follows the valley of Moccasin Creek into Scott County. The rock is well exposed near Say, Hansonville, and Willow Springs. A third belt extends from Taze-

well County to Cedar Creek, exposing the Holston limestone near Old Rosedale and along Indian Creek near the Tazewell County line.

The most common rock type of the Holston formation is a dark-colored fine-grained thin-bedded argillaceous limestone which is similar to the beds of the underlying Lenoir and overlying Ottosee formations. It generally contains between 70 and 85 per cent of calcium carbonate and may be mixed with rock from the purer beds to form a usable source of lime. The chemical composition of the Holston and other rocks of Russell County is given in Table 5.

The most valuable limestone of the Holston formation is a very massive, coarsely crystalline light-gray to reddish rock that is exceptionally free from impurities, and contains between 90 and 98 per cent of calcium carbonate. This rock makes up about one-quarter of the mass of the Holston formation. It may be distinguished by its coarse texture and pink to chocolate-brown color. Although some of the beds of coarse-grained limestone are more that 50 feet thick, they do not occur at any persistent horizon within the formation and may be found at any place from bottom to top. (See Fig. 9.) No commercial development of this valuable economic resource has been undertaken in Russell County except for scattered quarries furnishing material for road construction and small lime operations, at present inactive, 1 mile northeast of Hansonville and 3½ miles west of Dickensonville.

Although most of the Holston limestone is inaccessible to rail transportation, the northern belt may be reached by rail at Blackford. All the outcrops, however, are easily reached by road, for improved highways follow all three belts for some distance.

Other limestones that might yield stone for lime or cement include the Mosheim, Lenoir, and Maryville limestones, but they do not contain any member that rivals the coarse beds of the Holston in thickness, purity, and general excellence. The Mississippian limestones of Sinkhole Valley contain members that are locally burned for lime.

Dolomite.—Of the many dolomitic formations in Russell County, the Bellefonte dolomite contains the purest magnesian rock, and for this reason its area of outcrop has been indicated on the accompanying geologic map (Pl. 1) and its chemical composition given in Table 5. Although the stone has not been locally exploited except in a quarry north of Dickensonville, where it has been used for road metal, tests should be made to determine if it can be used in the manufacture of a high-finish lime.

TABLE 5.—*Analyses of rocks from Russell and Scott counties*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Insoluble	41.72	3.88	31.22	1.94	5.54	8.02	0.95	2.76	3.06	1.61	1.21	9.48	28.86	39.20
Fe_2O_3 / Al_2O_3	5.68	1.36	6.20	2.26	12.38	3.72	0.97	0.24	0.67	0.66	1.08	2.34	4.40	5.80
$CaCO_3$	30.93	82.53	38.23	79.69	77.63	85.74	96.55	91.28	90.38	95.73	97.66	87.71	64.26	52.16
$MgCO_3$	19.29	11.80	22.89	16.17	4.32	1.93	2.12	4.96	4.44	1.74	0.36	0.75	1.17	0.15
	97.62	99.57	98.54	100.06	99.87	99.41	100.59	99.24	98.55	99.74	100.31	100.28	98.69	97.31

1-3, 12-14, J. H. Gibboney, analyst. (Bassler, R. S., Cement resources of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 2A, pp. 225-226, 233-235, 1909.)
4, 8, J. H. Gibboney, analyst. (Watson, T. L., Lead and zinc deposits of Virginia: Virginia Geol. Survey Bull. 1, p. 115, 1905.)
5-7, 9-11, J. H. Yoe, analyst.

1. Brown clay shale; upper Rome formation, Clinchport, Scott County.
2. Gray limestone; basal Rutledge formation, Clinchport, Scott County.
3. Calcareous shale; upper Rogersville shale, Clinchport, Scott County.
4. Dark-blue Maryville limestone; near Osborne lead and zinc mine.
5. Dark-colored granular Maryville limestone; near Creswell.
6. Light-gray Bellefonte dolomite; along U. S. Highway 19, north of Belfast Mills.
7. Pure dove-colored Mosheim limestone; near Say.
8. Crystalline Holston limestone; near Dickensonville.
9. Gray crystalline Holston limestone; along U. S. Highway 19, north of Belfast Mills.
10. Gray dense Holston limestone; near Hansonville.
11. Gray crystalline Holston limestone; near Hansonville.
12. Argillaceous Ottosee limestone; near Fugates Hill.
13. Red shaly limestone in middle Moccasin formation; near Fugates Hill.
14. Thin limestone in lower Martinsburg formation (Trenton); near Fugates Hill.

Argillaceous limestone.—Several formations contain stone suitable for mixture with purer limestone for the manufacture of cement. The Lenoir, Ottosee, Moccasin, and Martinsburg shaly formations contain a wide variety of limestones, and beds of almost any desired composition may be found in them. As the exact composition of the argillaceous material to be used in cement depends upon the original purity of the limestone with which it is mixed, it is impossible to forecast which beds of limestone may prove of most service. The argillaceous limestones adjoin the Holston outcrop and transportation facilities are equally convenient for all types of stone.

Development and reserves.—Russell County contains a large area of the Holston limestone which includes numerous beds of pure calcareous stone suitable for any purpose to which lime may be put. There are no geologic conditions to prevent or retard the commercial development of the limestone resources, and the general excellence of the stone and its nearness to the surface should stimulate its development. For such exploitation the transportation facilities of the county are of small service except at Blackford, where a spur of the Norfolk & Western Railway reaches the belt. There are several points near Blackford where the Holston can be quarried and where, under proper economic conditions, an operator should meet with reasonable success. Elsewhere in the county, unless quarries can be opened from which stone can be distributed by truck, development of the local limestones must await more adequate rail transportation.

That the limestones of Russell County constitute a valuable natural reserve cannot be doubted, but at what future time they can be exploited successfully is not determinable. It seems possible that a plant might now operate in a small way to furnish local farmers with agricultural lime at a small cost. It would also seem desirable to investigate the possibilities of a lime or cement plant near Blackford. Only economic factors, such as available markets, would prevent the success of such ventures as the geologic conditions are promising.

CONSTRUCTION MATERIALS

Stone.—In the absence of large towns in Russell County, there has been little call for building stone. Sandstone, limestone, and dolomites of suitable quality for building stone occur in various parts of the county. Any of the thick-bedded calcareous rocks might be used for local rough construction or even for the facing of

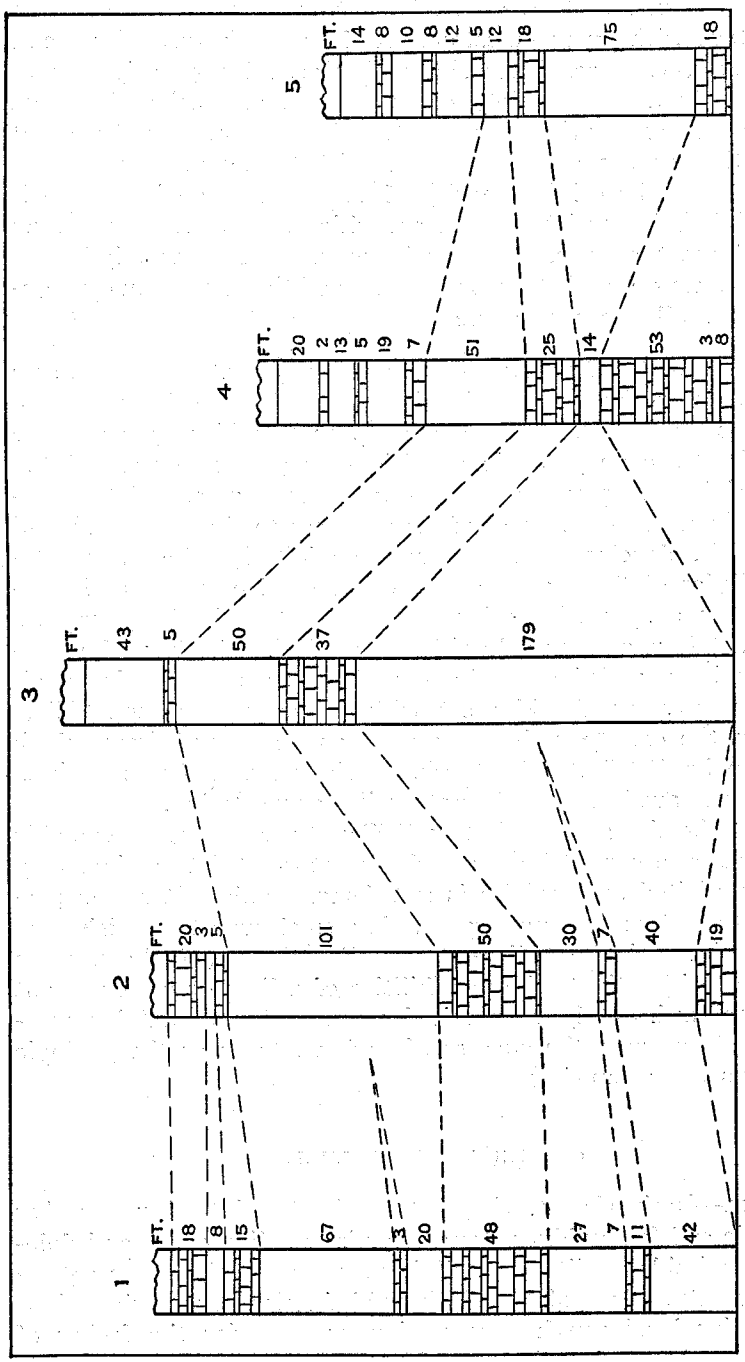


FIGURE 9. Sections of Holston limestone in Russell County. Measured from the top of the Lenoir formation. Coarsely crystalline beds of very pure limestone indicated by the block pattern. (1) Section near Dickensonville, at junction of State highways 64 and 71; (2) section along State Highway 64, 3 miles southwest of Lebanon; (3) section near State Highway 80, at Blackford; (4) section along U. S. Highway 19, 4.7 miles northeast of Old Rosedale; (5) section along country road, 1 mile southwest of Say.

more decorative structures. The Holston, Copper Ridge, Nittany, Bellefonte, and Honaker formations contain beds having a wide variety of texture, together with some variations in color. At any point in the limestone area where there are sufficiently steep slopes and little overburden, rock can probably be found that can be easily quarried and marketed for local use. The hard resistant Clinch sandstone could be used for any type of rough construction, but its position along Clinch, Stone, and Elk Garden mountains makes it somewhat inaccessible. Other sandstones, such as those of the Lee and Norton formations, are also usable for rough work but are less tough and resistant than the Clinch. The Gladeville sandstone has been locally used for buildings along the crest of Sandy Ridge, where the fresh rock can be cut with a handsaw or otherwise trimmed readily. After exposure, the rock dries out and hardens into a suitable building material.

The coarse limestones of the Holston formation and the fine-grained pink dolomites of the Bellefonte qualify for use as commercial marble, as both can be successfully polished. Although the Holston, which is widely quarried as a marble in Tennessee, does not locally contain many massive joint-free beds, a small supply of stone is readily available. It is reported, however, that the polished stone does not weather well, quickly becomes discolored, loses its polish, and that its surface soon becomes crumbly. If this report is correct, the polished stone should be used solely for interior work. The Bellefonte dolomite has a clean pinkish color when fresh and occurs in medium- to thick-bedded layers. Stone from this formation has recently been quarried in Tennessee under the trade name "New Tennessee marble" and has been used in Kingsport and Johnson City for interior work.

From any of the local limestones or dolomites it is possible to obtain quantities of crushed stone for road metal. The Nittany, Copper Ridge, Holston, Honaker, and Maryville formations have been used for this purpose at points where road construction has been adjacent to their outcrops, and there are localities along the railroad suitable for other quarries and crushers. The prevalence of such material throughout southwestern Virginia makes any area largely independent of others for road metal.

Sand and gravel for concrete or other purposes occur in the county, but the quantities present are insufficient at any point to attract commercial exploitation. The possibility of utilizing some of the purer sandstones for quartz or "silica" sand depends upon the facilities for transportation which the county offers, and at no point is the Clinch sandstone, the main potential source of glass sand, readily accessible.

Clays and shales.—Clays and shales are used in the manufacture of brick and tile. The material may be clayey or argillaceous bedrock, residual accumulations of rock weathering, or stream-transported clay of flood-plain origin. Physical tests of clay shales in Russell County are given in Table 6.

The Rome formation contains material that might be usable for brick manufacture. The most accessible belt, which contains a large volume of red and brownish shale, is along the Norfolk & Western Railway from Sword Creek to Castlewood. There are ample supplies of shale at several points along the railroad, especially between Castlewood and Carbo. Tests of these shales[33] show a material of moderate plasticity and strength, which is entirely suitable for the manufacture of common or face brick. (See Table 6.)

The Nolichucky shale,[34] which contains material of similar character, is most accessible on the northwest slope of Copper Ridge. It is well exposed on the main road (State Highway 64), leading to Castlewood, where it is a brown fissile calcareous shale. Although it is very hard, it makes a fairly plastic mass when finely ground, and can be used for brick if fired sufficiently hard. (See Table 6.) Raw materials could be transported to kilns at Castlewood and the finished product readily distributed by railroad. The Nolichucky is somewhat inferior to the shales of the Rome formation near Carbo.

The Brallier shale is being used for the manufacture of a good grade of building bricks[35] and blocks (Table 6) at Richlands, Tazewell County. The same belt with commercial quantities of shale extends westward past Raven into Russell County, where it is along the Norfolk & Western Railway. Other exposures of a similar or identical shale occur near Dump Creek, along the spur line extending from Carbo to Wilder.

A persistent seam of gray sandy shale occurs directly below the Upper Banner coal seam in mine 2 of the Clinchfield Coal Corporation at Dante, where it maintains a thickness of at least 6 feet.[36] This material would make a good hard brick (Table 6), but if used, it would have to be mined with the coal, as it is otherwise inaccessible.

Much of the limestone of central Russell County is overlain by a thick red residual soil produced by the weathering of limestone and dolomite. This clay may be regarded as a fair

[33] Ries, H., and Somers, R. E., The clays and shales of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 20, pp. 32-34, 1920.
[34] Idem, p. 32.
[35] Ries, H., and Somers, R. E., op. cit., p. 88.
[36] Ries, H., and Somers, R. E., op. cit., pp. 105-106.

TABLE 6.—*Physical tests of clay shales in and near Russell and Scott counties*

Formation	Locality	Water plasticity	Plasticity	Tensile strength	Air shrinkage	Cone 010		Cone 05		Cone 1		Color
						Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	
Nolichucky	Near Castlewood	20.0	Fair	25.0	3.7					1.5	10.5	Pink
Rome (Russell) shale	Carbo (Kiser)	21.0	Fair	25.0	3.3	0.0	13.6	1.7	7.4	4.7	3.8	Red
Brallier shale	Richlands	25.0	Good	80.0	4.8	.0	15.7	1.6	10.7	5.0	.4	Red
Brallier shale	Near Big Moccasin Gap	22.0	Fair	40.0	3.8			1.0	13.4	2.6	9.1	Red
Brallier shale	Oreton	20.0	Good	44.0	4.0	.0	16.0	2.6	8.5	4.3	1.0	Red
Pennsylvanian shale	Dante	20.0	Good		4.4	.0	18.0	1.6	13.0			
Pennsylvanian shale	Dante				5.2	.7	21.1	3.7	12.6	8.3	2.3	Red

[a] Ries, H., and Somers, R. E., Clays and shales of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 20, pp. 32-33, 88-92, 105-106, 1920.

brick clay and of usable quality wherever its thickness warrants development. Bricks made from residual clays near Lebanon were recently used in the construction of a building in town, but otherwise the material has not been tested.

It is apparent that the county contains material which merits exploitation as a possible source of clay for brick manufacture. Probably the belt of Rome shale between Carterton and Cleveland is the most promising, but the Nolichucky and Brallier shales offer other possibilities. In addition to favorable geologic conditions and an adequate supply of material—both of which are met by the Rome belt—other conditions of local demand, cost of manufacture, transportation, and competition would be controlling factors in the successful operation of a brick or tile plant.

OTHER MATERIALS

A thin bed of bentonite occurs between the Martinsburg and Moccasin formations in Little Moccasin Gap. Although bentonite is widely used as a filter in the oil industry, this occurrence is only of scientific interest.[37]

Small quantities of minerals that contain phosphate or other fertilizer occur in the county, but the presence of any valuable deposits of phosphatic material is to be doubted. A peculiar "blue soil" that weathers from the Murfreesboro limestone is described on page 9. As a simple test, it is suggested that some of the bedrock immediately below this soil be ground to powder and sprinkled upon a portion of a field, say, of clover. If the treated soil produces a sturdier crop than the untreated soil, use of this rock as a fertilizer should be considered. Several tests, however, should be made under varying conditions and with different crops, before any final conclusions are reached.

Although salt and gypsum are present in other areas of southwest Virginia, neither occurs in the rocks of Russell County. Onyx, or travertine, is found on the floors of some local caves but must be regarded merely as a curiosity of no commercial value. Ocher, elsewhere of use for paint, occurs in too small quantities for practical use.

[37] Butts, Charles, Southern Appalachian region: Internat. Geol. Cong., XVI, United States, 1933, Guidebook 3, Excursion A-3, p. 71, 1933.

WATER RESOURCES

SURFACE WATERS

As Russell County is well drained, it contains no swamps or natural lakes, and there are few parts of the county where springs or streams are not abundant. The chief stream is Clinch River, which has several large tributaries—Copper and Cedar creeks and Little (Maiden Spring) River—which drain about 78 per cent of the area of the county. Moccasin Creek, a large tributary of the North Fork of Holston River, drains about 18 per cent of the county. Clinch River, which flows southwestward through the area, has an average fall of about 4 feet to the mile. It maintains an average flow of about 720 cubic feet a second at Cleveland for the period 1921-33 and has reached, in flood, a flow of 15,000[38] cubic feet a second. The volume of the river increases considerably in its course through the county. (See Table 7.)

[38] Dirzulaitis, J. J., and Stevens, G. C., Water resources of Virginia: Virginia Geol. Survey Bull. 31, p. 439, 1927.

TABLE 7.—*Flow of rivers in Russell and Scott counties*

Locality	Basin in square miles	Discharge records available	Gage height in feet		Discharge in second-feet		
			Maximum	Minimum	Maximum	Minimum	Mean
Clinch River at Cleveland[a]	536	1920–1933	21.1	1.68	Not determined	41	724
Clinch River at Clinchport[b]	1,000	1907–1909	18.8	Not determined	Not determined	134	Not determined
Clinch River at Speer Ferry[a]	1,140	1920–1933	24.35	1.07	37,200	63	1,660
Clinch River near Tazewell, Tenn.[a]	1,500	1927–1933	14.9	1.02	37,800	122	[d]2,140
North Fork of Holston River at Mendota[c]	500	1920–1930	14.4	1.47	19,600	39	741
North Fork of Holston River at Gate City[a]	675	1931–1933	10.64	1.18	11,200	55	[d]906

[a] Data from U. S. Geol. Survey, Water-Supply Paper 743, pp. 281, 298-300, 1933.
[b] Data from Virginia Geol. Survey Bull. 31, pp. 445-8, 1927.
[c] Data from Tennessee Geol. Survey Bull. 40, p. 130, 1931.
[d] For year October, 1932-September, 1933, only.

Although the flow of Clinch River fluctuates somewhat with rainfall, disastrous floods are uncommon. The fall of the river is sufficient for several power plants, but at present the stream has not been developed for power. Some of the smaller streams, especially Cedar and Moccasin creeks, have been utilized for "roller" mills, and several lumber mills were formerly in operation. Except for these small developments, little use has been made of the water supplies of the county. Analyses of waters from Russell County are given in Table 8.

TABLE 8.—*Analyses of water from Russell and Scott counties*[a]

(F. H. Fish and J. A. Addlestone, Analysts. Parts per million.)

	SURFACE STREAMS				TOWN SUPPLIES	
	1	2	3	4	5	6
Silica	7.0	4.4	16.2	5.0	17.2	7.2
Iron and aluminum oxides	1.2	2.2	3.4	2.0	2.6	1.0
Calcium	19.9	28.0	37.3	44.5	42.0	34.2
Magnesium	9.9	7.8	9.9	7.4	20.3	19.9
Sodium[b]	1.63	4.85	0.5	11.1	None	14.5
Bicarbonates	106.3	115.0	147.6	133.3	211.8	155.8
Sulphates	3.28	11.5	1.6	6.5	1.9	5.0
Nitrite nitrogen	.01	.001	.05	.006		.001
Nitrate nitrogen	.075	.48	.10	.6	.092	.6
Total dissolved solids	91.8	122.0	166.5	174.5	193.5	171.5
Total hardness (calculated)	90.3	102.0	133.8	137.1	188.0	163.7
Suspended matter			448			
Turbidity	20	None	800	None	None	None

1. Holston River.
2. Clinch River at St. Paul.
3. Copper Creek near Nicklesville.
4. Cedar Creek near Lebanon.
5. Tap water in Gate City.
6. Tap water in Lebanon.

[a] Humbert, R. L., and others, Industrial survey of Russell County, Virginia (1930), and Industrial survey of Scott County, Virginia (1929): Virginia Polytechnic Institute, Blackburg.

[b] Calculated.

SPRINGS

An abundance of springs affords excellent water to nearly all parts of the county. Most of the springs emerge from limestone, where they represent surface outlets of channels that have developed in the soluble bedrock. Among the larger springs[39] are Big Spring, near Bickley Mill, 1 mile south of Castlewood, flow about 1,120 gallons a minute; Judge Hendricks Spring, on Little Cedar Creek, 4.1 miles southwest of Lebanon, flow about 300 gallons a minute; and Will Humbold Spring, on Wolf Creek, 5.3 miles southwest of Lebanon, flow about 2,810 gallons a minute. A flow of 100 gallons of water a minute amounts to 144,000 gallons a day, which would supply a town of 1,000 persons.

The water supply of Lebanon, which was derived from springs southwest of the town, is transported by gravity flow to the town and was distributed untreated. An analysis of the water as formerly supplied to the town is given in Table 6.

In the past three years a number of improvements have been made to this system, including a new source of supply from two limestone springs located 4½ miles west of town. A new concrete reservoir of 100,000 gallon capacity and a direct-feed chlorinator for applying liquid chlorine have been installed. The reservoir, chlorinator, and chlorinator building are located on the hill south of town. Chlorine is applied to the supply line 25 feet before it enters the reservoir.[40]

Privately owned supplies furnish all other communities with water for domestic use. There are no important mineral springs in the county.

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[39] Collins, W. D., and others, Springs of Virginia; a report on the discharge, temperature and chemical character of springs in the southern part of the Great Valley: Virginia Commission on Conservation and Development, Div. of Water Resources and Power, Bull. 1, p. 12, 1930.

[40] Messer, Richard, personal communication, August 4, 1938.

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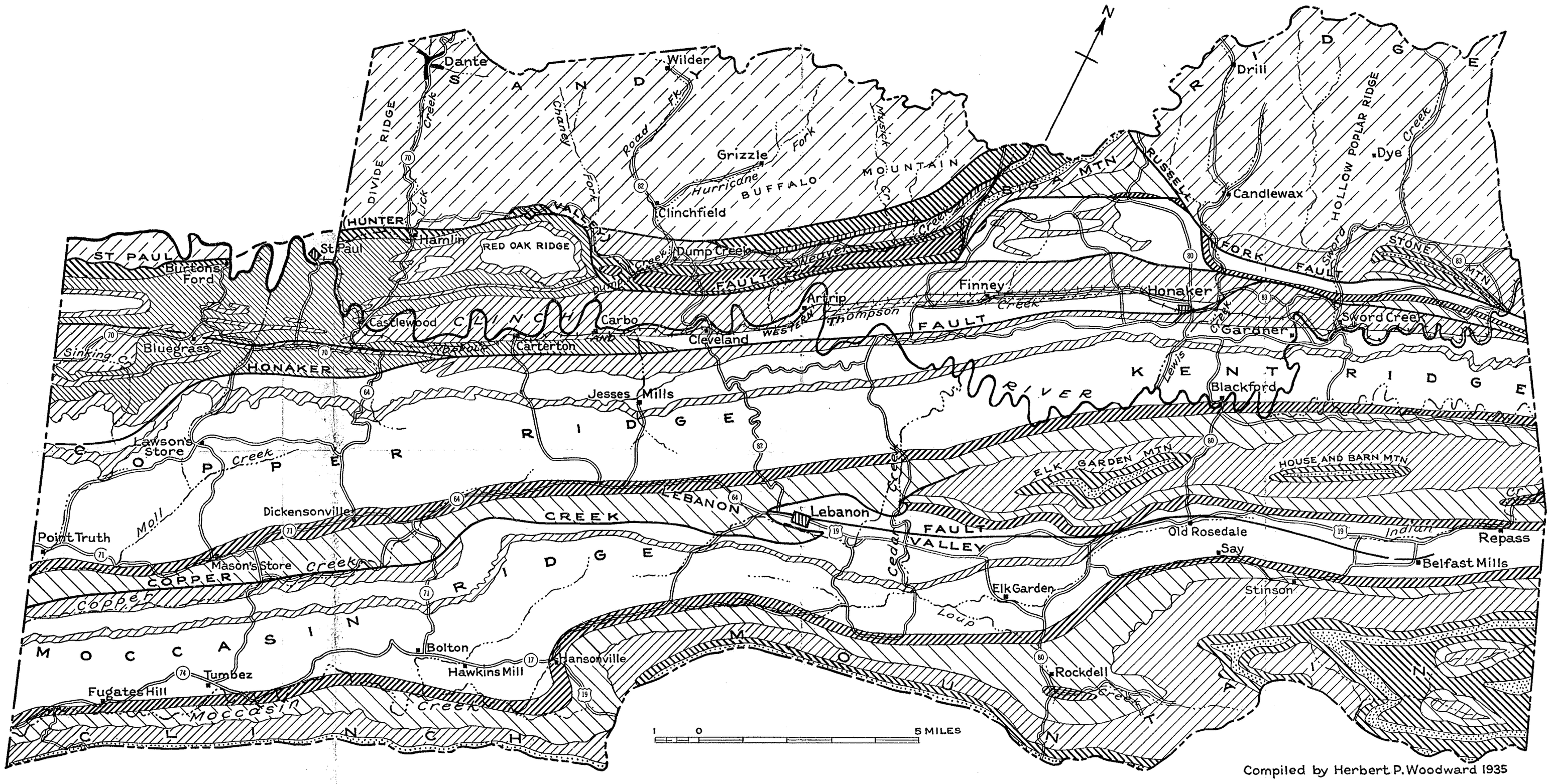

Sketch map of Russell County, Virginia, showing the distribution of the different types of rocks. Based in part on Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, 1933.