Geology and Oil Resources of the Jonesville District Lee County, Virginia

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GEOLOGICAL SURVEY BULLETIN 990

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March 3, 1849

Geology and Oil Resources of the Jonesville District Lee County, Virginia

By RALPH L. MILLER *and* WILLIAM P. BROSGÉ

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GEOLOGY AND OIL RESOURCES OF THE JONESVILLE DISTRICT, LEE COUNTY, VIRGINIA

By Ralph L. Miller and William P. Brosgé

ABSTRACT

The Jonesville district is in central Lee County in the extreme southwest corner of Virginia. It includes an area that is 25 miles long from northeast to southwest and averages 6 miles in width. Most of the district lies within a broad lowland named the Powell Valley, but the district includes Wallen Ridge, which bounds Powell Valley on the southeast.

The Jonesville district lies entirely within the area of the Cumberland overthrust block, which has been thrust to the northwest along the nearly flat lying Pine Mountain fault. The movement of the Cumberland block was pivotal. The maximum forward movement of the overriding block is about 9 miles at the southwest end of the block along the Jacksboro tear fault and probably less than 2 miles at the northeast end of the block along the Russell Fork tear fault. In the Rose Hill district, which adjoins the Jonesville district on the southwest, the forward movement was calculated to be 5.8 miles. The Cumberland block is folded into a broad syncline, the Middlesboro syncline, on the northwest and a broad anticline, the Powell Valley anticline, on the southeast. The Jonesville district is in the anticlinal section of the block.

A hilly central upland along the axis of the Powell Valley anticline consists of Cambrian and Lower Ordovician dolomite. The upland is flanked by parallel lowlands developed on Ordovician limestone, and the Powell Valley lowland is bordered by ridges of Silurian sandstone.

The exposed rocks of the Jonesville district range in age from Late Cambrian to Late Devonian; these beds have a total thickness of 6,400 feet. Unexposed formations, which probably underlie the Jonesville district and are known from drilling in the adjoining Rose Hill district, are of Early, Middle, and Late Cambrian age and probably have a total thickness of about 2,000 feet. The exposed sequence has been divided into 22 mapped formations, 2 of which have been subdivided into mapped members. New formation names have been applied to the 8 mapped formations of lower Middle Ordovician age that lie between the top of the Knox group and the Eggleston limestone.

The Jonesville district was peneplaned in the Schooley cycle of erosion, which has been recognized in the Appalachian region from New York to Alabama. Within the Jonesville district, however, remnants of the Schooley peneplain are poorly preserved and difficult to recognize. After uplift and erosion of the Schooley surface, a partial peneplain, which has been called the Harrisburg peneplain, was formed in the Jonesville district. Recent regional uplift has resulted in incision of the major streams beneath the Harrisburg surface and dissection of the surface by tributary streams. Meanders of the Powell River, formed in the late stages of the Schooley cycle, have been preserved as intrenched meanders in the Chestnut Ridge upland, but in the limestone lowlands

intrenched meanders of the Powell River are inherited only from the Harrisburg peneplain. Three sets of terraces have been mapped along the Powell River, designated high terraces, middle terraces, and low terraces. The low terraces are numerous, well preserved, and at consistent elevations above the river. The middle terraces and high terraces are fewer and are poorly preserved. In contrast with the low terraces, the terraces designated as middle terraces and as high terraces have been formed at many different times and at many different levels and have been grouped into two sets for convenience of mapping and reference.

There have been no major changes in the drainage pattern from Schooley time to the present, but minor changes include the cut-offs of several meanders of the Powell River and the encroachment of the surface drainage upon the extensive areas drained underground by sinkholes, caves, and underground streams. A small natural bridge has been formed in one place by partial collapse of the roof of an underground stream.

The major folds of the Jonesville district are the Chestnut Ridge anticline and the Sandy Ridge anticline, which are separated by The Cedars syncline. In addition, the eastern tip of the Powell Valley anticline, which is the major anticline of the adjacent Rose Hill district, lies within the Jonesville district. The Chestnut Ridge anticline, which is asymmetric throughout its extent, changes from an anticline to a monoclinal flexure in the western part of the Jonesville district, and it continues into the Rose Hill district, where it is named the Rose Hill flexure. Along the north flank of the Chestnut Ridge anticline are numerous small reverse faults upthrown on the northwest and at least one underthrust fault, along which beds on the northwest have ridden up over beds on the southeast, which were moving northwestward down the inclined Pine Mountain fault plane.

The Waddell fault is a thrust fault which merges with the Pine Mountain fault at depth and along which formations in the lower part of the Knox group on the southeast have been brought in contact with formations in the upper part of the group on the northwest.

The Ben Hur fault is an arched fault which, together with the underlying Pine Mountain fault, encloses a slice of rocks that have partly broken loose from the base of the overthrust block. The Bethel fault is similar to the Ben Hur fault except that the Bethel slice has completely broken loose from the overthrust block and has been rotated as it was overridden by subsequent forward movement of the overthrust block. The Cheek Spring fault is the only transverse fault of importance in the district.

The Wallen Valley fault, which forms the southeast border of the Jonesville district, is a major overthrust that is believed to merge with the Pine Mountain overthrust at depth. In the Jonesville district, Cambrian formations on the southeast have been brought into juxtaposition with Silurian or Upper Ordovician formations on the northwest.

The Pine Mountain fault has been folded in a manner similar to, though not identical with, the rocks of the overthrust block. Along the Chestnut Ridge anticline arching and subsequent erosion have exposed the rocks of the underlying block in a series of fensters, namely the Sulphur Springs fenster, Town Branch fenster, and Big and Little Fleenortown fensters. In all of the fensters rocks of Silurian age overlain locally by black shale of Late Devonian age have been exposed by the erosion. The fensters are enclosed by Maynardville limestone or by formations of the Knox group of Late Cambrian and Early Ordovician age, except for a short distance along the north side of the Sulphur

Springs fenster, where Silurian and Upper Devonian formations of the Ben Hur slice are in contact with the Silurian formations inside the fenster.

The amount of displacement along the Pine Mountain fault cannot be measured in the Jonesville district, although drilling of wells in the vicinity of the Sandy Ridge anticline may eventually provide a basis for measurement. The movement in the Jonesville district is estimated to be between 5 and 5½ miles.

In the Jonesville district, the Pine Mountain fault plane was formed in the incompetent Cambrian Conasauga shale beneath the southeastern part of the district, but it cut across the overlying competent beds to the next higher incompetent unit, the Upper Devonian and lower Mississippian(?) shale beneath the northwestern part of the district. Arching of the Powell Valley anticline began in the final stages of overthrusting.

Five wells have been drilled for oil in the Jonesville district. Of these only one has penetrated the Trenton limestone of the stationary block, which is the principal oil-producing formation of the Rose Hill oil field. This well encountered a small flow of gas in the Reedsville shale but there was no oil in the underlying Trenton. The stratigraphy and structure of the Jonesville district are very similar to that of the Rose Hill district; hence the possibilities for finding commercial oil in the Jonesville district seem good. The best structural locations for wildcat tests appear to be along the Chestnut Ridge anticline and particularly on the structural highs along the anticline, namely the environs of the Sulphur Springs fenster and Fleenortown fensters. Tests along or northwest of the Sandy Ridge anticline might penetrate the Trenton limestone where it rises to the surface of the stationary block and is truncated by the Pine Mountain fault.

Hematitic iron ore was formerly mined from the beds in the lower part of the Clinton shale along Poor Valley Ridge. Crushed stone is quarried locally for use on the roads.

INTRODUCTION

LOCATION AND SIZE OF AREA

Lee County is in the extreme southwest corner of Virginia (fig. 1), adjacent to Tennessee on the south and Kentucky on the northwest. The Jonesville district includes an area in central Lee County that

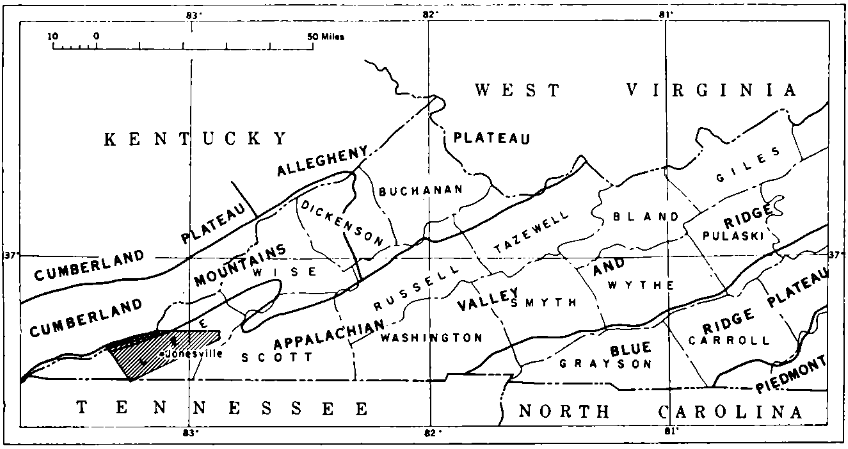

FIGURE 1.—Index map of southwest Virginia showing location of the Jonesville district.

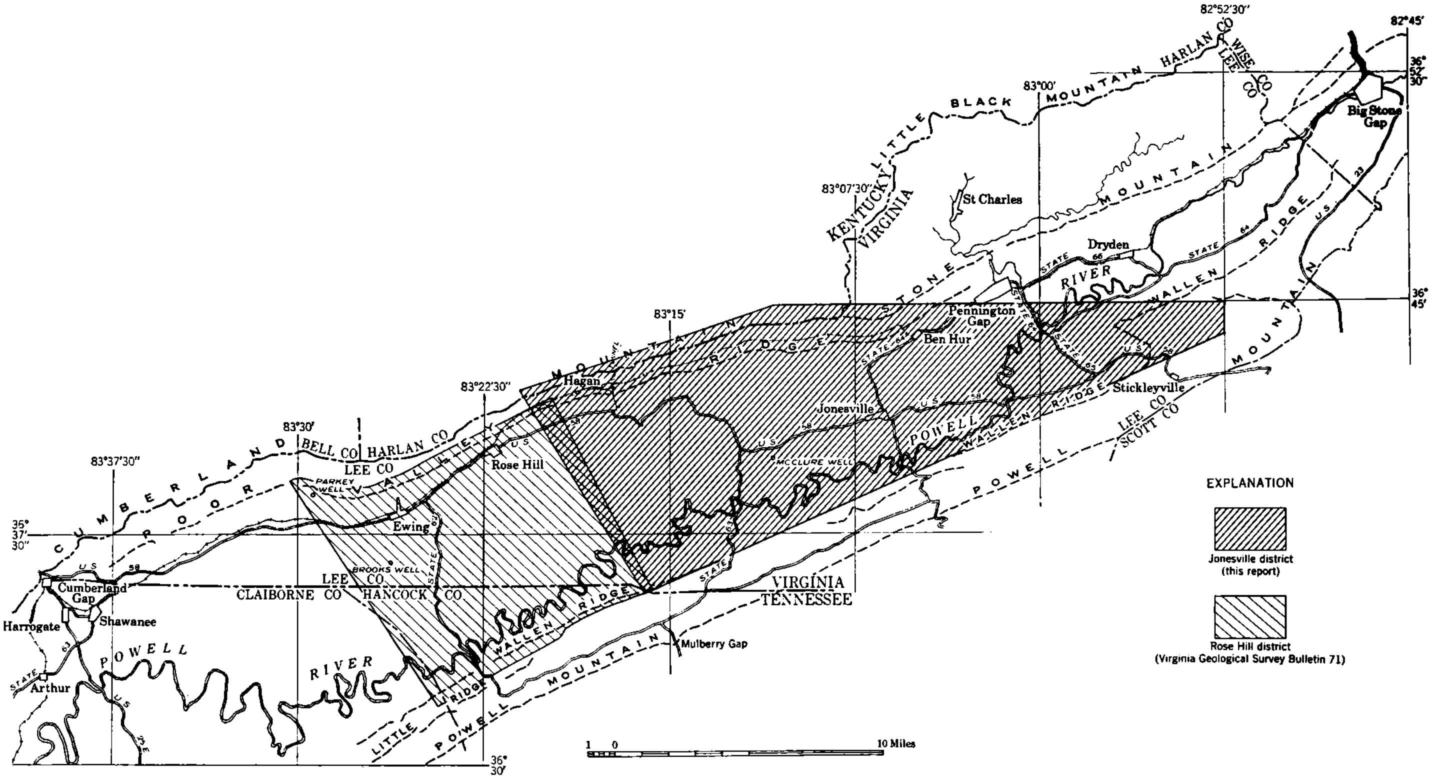

FIGURE 2.—Index map of Lee County showing principal features and location of the Jonesville and Rose Hill districts.

is 25 miles long from northeast to southwest and averages 6 miles in width (fig. 2). In general the district includes the outcrop areas of Cambrian, Ordovician, and Silurian rocks of the Powell Valley region that lie between the Rose Hill district mapped by Miller and Fuller (in press) on the southwest and northeastern Lee County mapped by Bates (1939, pp. 31–94) on the northeast. The mapped area shown on plate 1 includes parts of six 7½-minute quadrangles prepared cooperatively by the Tennessee Valley Authority and the Geological Survey, namely the Rose Hill, Hubbard Springs, Ben Hur, Stickleyville, Back Valley, and Sneedville quadrangles. Most of the Jonesville district lies within a broad lowland area named the Powell Valley, but the district includes Wallen Ridge, which bounds the Powell Valley on the southeast.

PREVIOUS WORK

The Estillville folio (Campbell, 1894), published in 1894, is the only publication that has dealt specifically with the areal geology of any part of the Jonesville district. The geologic map of this folio, which is on the scale of 1:125,000, includes approximately the eastern third of the Jonesville district. Because the topographic base maps were below modern standards and the publication scale was small, the geologic mapping in this folio was necessarily generalized. The stratigraphic and structural concepts, though representing excellent work at the time, are now outmoded.

Four more recent contributions, one by Wentworth and three by Butts, delineate the regional geologic framework of the Jonesville district. The first of these was Wentworth's paper (1921, pp. 351–369; 1921a, pp. 53–67) entitled "Russell Fork fault of southwest Virvinia." Wentworth here introduces the concept that the entire rectangular area 125 miles long and 25 miles wide bounded on the northwest by the Pine Mountain fault, on the northeast and southwest by the Russell Fork and Jacksboro tear faults, and on the southeast by the Hunter Valley (St. Paul) fault, is a structural unit that has moved several miles to the northwest along the nearly flat-lying Pine Mountain fault plane. Wentworth called this structural unit the Cumberland block.

Six years later Butts (1927, pp. 1–12) supplied convincing proof of the authenticity of the Cumberland block as an overthrust structural unit by discovering and describing four fensters along the axis of the Powell Valley anticline in western Lee County, Va. These fensters were attributed by Butts to arching upward of the Pine Mountain fault plane and local erosion of all the overthrust rocks of the Cumberland block, exposing the top of the stationary block beneath the fault. Recent detailed work by Miller and Fuller (1945;

1947; in press) and by Miller and Brosgé (1950) has corroborated this interpretation.

The areal geology and stratigraphy of the Appalachian Valley of Virginia, which includes all of Lee County, were mapped and described by Butts in two outstanding publications. The geologic map of the Appalachian Valley (Butts, 1933), which is on the scale of 1:250,000 or approximately 4 miles to the inch, depicts the major outlines of the geology of the Jonesville district. The Geology of the Appalachian Valley (Butts, 1940; 1941) describes the Paleozoic stratigraphy of the valley, including all of the Jonesville district. Refinements and some revisions of Butts' stratigraphic nomenclature and interpretations have been necessary in the light of recent stratigraphic work in southwest Virginia, but these manifestations of continuing scientific progress detract hardly at all from the enduring value of Butts' contribution to Virginia geology.

Recent publications bearing on the geology of the Jonesville district are of three types: areal geologic papers treating the geology of nearby regions, stratigraphic papers dealing with formations present in the Jonesville district, and general or miscellaneous papers that touch on other aspects of the geology of the Jonesville district. Among the areal papers, Bates' bulletin (1939, pp. 31–94) on the geology of northeastern Lee County, and Miller and Fuller's three publications (1945; 1947; in press) on the geology of the Rose Hill district cover areas that are adjacent to the Jonesville district on the northeast and southwest, respectively. Of the stratigraphic papers, those of Huffman (1945, pp. 145–174), Cooper and Prouty (1943, pp. 819–886), and Prouty (1946, pp. 1140–1191) on Lower and Middle Ordovician formations, and those of Bridge (1945) and Oder (1934, pp. 469–497), on Upper Cambrian and Lower Ordovician formations should be mentioned. Of the general and miscellaneous papers, Rich's discussion of the origin of the Cumberland block is the most important (Rich, 1934, pp. 1584–1596).

Miller and Brosgé (1950) have published a preliminary map with accompanying text, describing the geology and oil possibilities of the Jonesville district. The present bulletin is a more complete report on the area.

The geology of the Jonesville district is very similar to that of the Rose Hill district. Miller and Fuller's report (in press) on the Rose Hill district includes discussions of many problems common to the two areas. The reader is referred to that publication for supplementary information on and elaboration of many of the problems treated more briefly here, and particularly for a description of the geologic factors involved in the occurrence of commercial oil in the Rose Hill district. If commercial oil is found in the Jonesville district, the occurrence will probably be similar.

NATURE AND SCOPE OF THE INVESTIGATION

The investigation of the geology of the Jonesville district was sponsored jointly by the United States Geological Survey and the Virginia Geological Survey. The purpose was to map the geology of the district in detail and to work out the stratigraphy and structure, with particular emphasis on the possibilities for commercially exploitable accumulations of oil in the district.

Carle H. Dane and Watson H. Monroe of the U. S. Geological Survey, Arthur Bevan, former State Geologist of Virginia, and William M. McGill, present State Geologist of Virginia, supervised the project.

The field party consisted of Ralph L. Miller, W. Lynn Kreidler, and William P. Brosgé. Field work began on June 15, 1947, and continued through December 14. Miller was in the field for the full season, Kreidler from June 28 to the end of the season, and Brosgé from September 22 to the end of the season. Miller and Brosgé spent 3 weeks in the field in late March and early April 1948, and Miller spent four additional days in the field in June 1948. A narrow strip along the west edge of the district was mapped by R. L. Miller and J. O. Fuller in the fall of 1944. The laboratory work, preparation of illustrations, and writing of the report occupied most of the time from December 15, 1947, to September 17, 1948. Brosgé worked almost continuously on the project during this interval, and Miller worked intermittently on the project. The text of the chapter on physiography was written by Brosgé and the rest of the text by Miller.

The Jonesville district was mapped on the scale of 1:15,840 on enlarged advance sheets of the six topographic quadrangle maps. Aerial photographs of the region were used as an aid in making locations on the topographic maps and in studying significant topographic features. The completed geologic map was reduced to 1:24,000 for publication. Information on the wells drilled for oil in the Jonesville district was collected, and all available cuttings from the wells were studied microscopically. Cuttings of wells drilled in nearby areas also were studied. Stratigraphic sections of the formations were measured, both within the Jonesville district and in nearby areas where exposures are particularly good.

ACKNOWLEDGMENTS

Conferences in the field with W. M. McGill of the Virginia Geological Survey, W. H. Monroe, Robert A. Laurence, and Philip B. King of the U. S. Geological Survey, Robert L. Bates of Ohio State University, and John Rodgers of Yale University were most helpful. The writers also wish to acknowledge the contribution of J. O. Fuller of Ohio State University who collaborated with Miller

in the mapping and study of the adjacent Rose Hill district, and many of whose ideas—especially those on stratigraphic matters—have been incorporated into this report.

Many oil geologists, operators, scouts, drillers, and residents of Lee County have supplied information and assistance. To all of these contributors cordial thanks are given. Special acknowledgment is due Robert Spear of the Rouge Oil Co., E. Bruce Shade of the Ohio Oil Co., George W. Hindman of the H. and R. Oil Co., and B. N. Cooper of Virginia Polytechnic Institute for much valuable information on the drilling activities in and near the Jonesville district.

The Craftint sketches in the report were made by Ansel M. Miller. The paleontologic identifications were made by G. Arthur Cooper, A. R. Loeblich, Jr., and J. Brookes Knight of the U. S. National Museum and by Preston E. Cloud, Jr., of the U. S. Geological Survey.

GENERAL RELATIONS

REGIONAL STRUCTURE

The Jonesville district lies entirely within the area of the Cumberland overthrust block (pl. 2). This major structural unit of the southern Appalachians has been thrust to the northwest along the nearly flat-lying Pine Mountain fault. The movement of the Cumberland block was pivotal, the greatest forward movement being at the southwest end of the block. Here the displacement of the overthrust rocks to the northwest is approximately 9 miles, as shown by the mapped displacement of the belt of the Chattanooga shale on opposite sides of the Jacksboro tear fault, which forms the southwest border of the block (Keith, 1896). In the central part of the block in the Rose Hill district, the forward movement of the overriding block to the northwest was calculated by Miller and Fuller (in press) to be 5.8 miles. Their calculation was based on the measured interval between the truncated beds at the top of the stationary block, which may be seen in several of the fensters, and the position of these same beds at the base of the overriding block, which may be estimated quite accurately. At the northeast end of the Cumberland block the amount of displacement is not so accurately known, but it was estimated by Wentworth (1921a, p. 65) to be not more than 2 miles.

Nearly flat-lying beds of Pennsylvanian age are at the surface across nearly the entire width of the Cumberland block in its northeastern part. In the central and southwestern parts of the block, however, two large folds are present, the Middlesboro syncline on the northwest and the Powell Valley anticline on the southeast. Coal-bearing beds of Pennsylvanian age crop out across most of the flat-bottomed Middlesboro syncline. On the flanks of the syncline, however, the resistant Lee formation at the base of the Pennsylvanian comes to the surface and forms prominent ridges, Pine Mountain on the northwest side of the Middlesboro coal basin and Cumberland Mountain-Stone Mountain on the southeast side. The trace of the Pine Mountain fault lies on the northwest slopes of Pine Mountain. Detailed geologic studies have been made in only a few areas along this 125-mile fault trace. In several of these places the Pine Mountain fault consists of a fault zone with two or more major planes of movement. In general, however, black shale of Late Devonian and early Mississippian (?) age has been thrust northwest along the fault upon coal-bearing Pennsylvanian formations, as shown in the cross section (pl. 2). Beneath the central part of the Middlesboro syncline, the Pine Mountain fault is believed to be a bedding-plane fault and to lie within the Devonian and Mississippian black shale sequence.

The Powell Valley anticline is a broad gentle arch having steeper dips on the northwest flank. Along the Cumberland Mountain-Stone Mountain front, which approximately marks the border between the Middlesboro syncline and the Powell Valley anticline, the dips of the beds are in places nearly vertical. Beds of Devonian, Silurian, Ordovician, and Cambrian age are brought to the surface along the Powell Valley anticline. In most of the anticlinal area, beds of Late or Middle Cambrian age directly overlie the Pine Mountain fault and have been thrust upon formations of the stationary block ranging in age from Cambrian to Devonian.

In both the Jonesville and Rose Hill districts, the Pine Mountain fault plane and the underlying rocks of the stationary block are locally exposed by erosion of all the overthrust rocks along the structurally highest parts of the Powell Valley anticline. Nine fensters or windows of this type have been described in the Rose Hill district (Miller and Fuller, in press), and five similar fensters have been found in the Jonesville district (Miller and Brosgé, 1950). Bates and Miller believe that re-evaluation of the complexly faulted area mapped by Bates (1939) in eastern Lee County would probably show that some of these faults fall into a fenster-like pattern. It seems unlikely, however, that any of the exposed faults in eastern Lee County represent the principal plane of movement of the overthrusting, i. e., the Pine Mountain fault plane. Some are thought to be low-angle thrusts above the Pine Mountain fault which is believed to be concealed at depth, and others are thought to be higher angle faults of the imbricate type that merge at depth with the Pine Mountain fault plane. In the Tennessee section of the Powell Valley anticline no fensters are known, and it is unlikely that any are present.

Cambrian beds are known to overlie directly the Pine Mountain fault plane along the Powell Valley anticline, and Upper Devonian and lower Mississippian (?) black shale overlies it where the fault comes to the surface in the northwest slopes of Pine Mountain. It therefore seems logical that the fault plane must cut stratigraphically upward from the Cambrian across all the intervening formations to the Upper Devonian or lower Mississippian (?) in the 15-mile interval between the two regions. Theoretical considerations suggest that this cross-cutting takes place beneath the steeply dipping beds on the northwest flank of the Powell Valley anticline. Examination of the cuttings from the Anthony Ely well (p. 209), which started in the overthrust rocks and penetrated the fault plane in this area of steep dips, shows that at the site of this well the beds at the top of the overridden block are nearly a thousand feet higher stratigraphically than they are in the Rose Hill and Jonesville fensters. This evidence corroborates the view that some and probably all of the cross-cutting takes place beneath the northwest limb of the Powell Valley anticline and hence that the fault lies within the Devonian and (or) Mississippian black shale sequence beneath the Middlesboro syncline, as shown in the cross section (pl. 2).

In the Jonesville district, the structural continuity of the Cumberland block is interrupted on the southeast by the Wallen Valley fault, which is believed to be a fault of imbricate type that merges at depth with the Pine Mountain fault (pl. 2). The Wallen Valley fault is continuous to the southwest beyond the end of the Cumberland block, but to the northeast it dies out just beyond the limits of the Jonesville district. It thus fails by about 50 miles to span completely the base of the block. Hence the Hunter Valley (St. Paul) fault, which lies 3 miles southeast of the Wallen Valley fault and which is continuous across the base of the Cumberland block, has been considered by Wentworth and all subsequent writers to form the southeast border of the block. It seems quite probable, however, that the Hunter Valley fault does not have its roots in the crystalline basement, but rather that, downward, it merges with the Pine Mountain fault plane in much the same manner that the Wallen Valley fault is believed to do. This hypothesis postulates a Pine Mountain fault that is continuous above the crystalline basement for unknown distances southeast of both the Wallen Valley fault and the Hunter Valley fault. One of the major unsolved problems of the southern Appalachians is the location of the roots of the major flat overthrusts such as the Pine Mountain, Saltville, and Pulaski faults. Geophysical exploration or deep drilling may eventually supply evidence toward the solution of this problem.

TOPOGRAPHY

The Jonesville district includes a broad valley flanked on the northwest and southeast by bounding ridges, and bordered by narrow subsequent valleys beyond the ridges. The Powell River follows a meandering course through the broad central valley and gives its name to the valley. Powell Valley, though relatively low compared to the bounding ridges, is a compound lowland. It includes two hilly uplands, the Chestnut Ridge and Sandy Ridge uplands, which merge in the eastern part of the district. In the western part, these upland areas are separated from each other and from the flanking mountain ridges by relatively flat lowlands. The southern of these lowlands is occupied by the Powell River and is named the Powell River lowland. The lowland embayment that separates the Chestnut Ridge and Sandy Ridge uplands is named The Cedars lowland, and the northern lowland is named the Sugar Run lowland. The Powell River lowland and Chestnut Ridge upland are continuous southwestward into the Rose Hill district, where the same names are applied to these features. Sugar Run lowland is continuous with the northern lowland of the Rose Hill district, which is there called the Indian Creek lowland from the principal stream draining it.

Poor Valley Ridge is the flanking ridge on the northwest side of the Powell Valley. It rises from 400 to 800 feet above the Sugar Run lowland, and attains a maximum altitude of a little more than 2,300 feet along a particularly high stretch in the vicinity of Ocoonita. The ridge crest is sharp, linear, and relatively irregular in altitude, with frequent knobs surmounting the general crest level and occasional sags falling below the general crest level. A prominent row of rounded knobs on the upper south slopes of the ridge is a very distinctive feature. Poor Valley Ridge is cut by four watergaps, one at Hagan, two near Hubbard Springs, and one at Ben Hur. The watergaps are utilized by roads connecting Powell Valley and Poor Valley, and the gaps at Hagan and Ben Hur are also traversed by the Louisville and Nashville Railroad. Northeast of Ben Hur, Poor Valley Ridge is dual-crested because of duplication of the ridge-forming formations by faulting. The separate crests diverge in a southwest direction, and in the town of Ben Hur two distinct ridges are present. The southernmost of these ridges dies out just south of Ben Hur by passing beneath a sheet of overthrust rocks.

Poor Valley, lying to the northwest of Poor Valley Ridge, is a narrow V-shaped valley. It is drained by the headwaters of four streams, each of which leaves the valley by way of one of the watergaps in Poor Valley Ridge. Much of the valley is floored by talus from towering Cumberland and Stone Mountains, which lie just beyond the limit of the area mapped. Cumberland Mountain and Stone Mountain are different names for the same ridge. The change in name occurs where the Powell River drainage divide and also the Kentucky-Virginia State line, which follow the ridge crest to the southwest, turn northwestward into the Cumberland Plateau. Cumberland and Stone Mountains are underlain by Mississippian and Pennsylvanian formations younger than any rocks discussed in this report.

On the southeast side of Powell Valley, Wallen Ridge rises steeply from the Powell River lowland. In the southeastern and extreme southwestern parts of the district, Wallen Ridge is a prominent, sharp-crested mountain, but it is several hundred feet lower and very much less distinct for a 9-mile stretch in the south-central part of the area. In the eastern part of the area Wallen Ridge becomes progressively higher, and culminates in a pinnacle named Buzzard Roost at the northwest tip of a zigzag bend in the ridge. Buzzard Roost is 1,970 feet above the Powell River, which here flows close to the base of the mountain.

Where Wallen Ridge is high, an indistinct and discontinuous lowland lies on the southeast side of the ridge. This lowland, named Back Valley, is separated from the more prominent Wallen Valley southeast of the mapped area by a belt of low dolomite hills. Many small streams that start on the south slopes of Wallen Ridge cross the Back Valley lowland, where they open out amphitheatre-like valleys. Thence they enter narrow constricted valleys as they cross the belt of dolomite hills on their way to Wallen Creek.

The development of these major features of the topography is directly related to the differences in resistance to erosion of the rock formations of the district and to the structural attitude of the formations. The close relation between topography and geology is discussed in the chapter on physiography.

The Powell River is the master stream of the region and drains the entire Jonesville district, either directly within the area mapped or by way of tributary streams that enter the Powell outside the mapped area. Small streams that leave the district on the southeast side of Wallen Ridge enter Wallen Creek, whose headwaters are at the eastern tip of the Jonesville district and whose junction with the Powell River is in the south-central part of the district.

The lowest point of the Jonesville district is where the Powell River leaves the district along its southwest border, and is approximately 1,170 feet above sea level. The highest point is Buzzard Roost at an elevation of 3,192 feet above sea level. Thus the maximum relief of the area is approximately 2,020 feet.

CULTURE

Jonesville, the largest town of the district, is the county seat of Lee County. In 1940 Jonesville had a population of 588, but is somewhat larger now. Ben Hur, with a population of about 350, and Woodway, with a population of about 250, are the only other sizable towns; but

Pennington Gap, which has about 2,000 inhabitants, lies just north of the district. Ocoonita, Hubbard Springs, Hagan, and Dot are settlements of a few dozen people each.

Almost all parts of the area are accessible without walking more than a mile or two. U. S. No. 58, which passes through Hagan, Jonesville, and Dot, is the main route of travel from Cumberland Gap and southeastern Kentucky to Gate City and Bristol, Va. The route followed by this highway has been a thoroughfare from the time of the earliest exploration of the region by white men and was an Indian route of travel before that. Daniel Boone travelled the route frequently on his trips to the hunting grounds of central Kentucky, and the modern highway is named the Boone Trail in memory of his exploits.

State Route 70, the Trail of the Lonesome Pine, connects Norton and Big Stone Gap in Wise County with Rogersville and Greeneville, Tenn. The highway passes through Pennington Gap, Ben Hur, and Jonesville, and thence southward across Wallen Ridge. A network of all-weather roads serves almost all parts of the district. Only two areas of any size are relatively inaccessible. One of these is the rugged region east of the zigzag fold of Wallen Ridge, which is traversed by poor roads that are treacherous in wet weather. The other is the elongate area lying between the Powell River and the crest of Wallen Ridge in the 5-mile stretch between the U. S. No. 58 and State Route 70 bridges across the Powell. No roads enter this area, but the river may be crossed by rowboat at Cheek Spring or by a suspension footbridge at Poteet Ford, thus saving a much longer walk to reach this part of the district.

The Valley Line of the Louisville and Nashville Railroad, which connects Middlesboro, Ky., with Pennington Gap, Big Stone Gap, and Norton, Va., runs the full length of the Jonesville district. The railroad follows Poor Valley from the southwest edge of the district to Ben Hur, where it passes through two watergaps cut by Cane Creek and continues eastward in the open valley of lower Cane Creek. At Hagan, a freight spur of the Valley Line passes beneath Cumberland Mountain in a long tunnel and taps the Harlan County coal fields. The junction of this spur with the trackage of the Valley Line is accomplished by a complicated series of switchbacks.

Most of Powell Valley is under cultivation or in pasture, but many of the higher hills and steeper slopes have been left in timber, and small woodlots are common in the cultivated areas. Extensive areas in The Cedars lowland and Powell River lowland have been left in timber because rock ledges crop out so abundantly that the land has little value for farming. Cedar trees are very abundant in these woods. The crest and back slopes of both Poor Valley Ridge and

Wallen Ridge are mostly in timber, but on the scarp sides most of the lower and middle slopes have been cleared and are in pasture. A narrow belt along the floor of Poor Valley is cultivated, but most of the valley walls are still in timber. Along the Back Valley lowland the flatter and less rocky areas are cultivated.

Throughout the district many areas of poor soil or unduly steep slopes have been cleared of timber but later have been abandoned and allowed to go back to underbrush. Blackberries and greenbrier are the most common nuisances in these abandoned areas. In places they form thick tangles that are extremely difficult to penetrate.

Poisonous snakes are extremely rare in the Jonesville district. Both rattlesnakes and copperheads are indigenous to the region, but none was seen by any member of the field party in 6 months of tramping over all parts of the district. No large wild animals are known in the area, though there may be a few deer in the heavily timbered regions on the back slopes of Wallen Ridge, particularly at the east end of the district. Of the smaller mammals, rabbits, skunks, and opossum are seen in greatest abundance, usually dead on the highways, and fox and weasel are occasionally seen. Mink and otter are common in the Powell River. Quail are particularly abundant.

STRATIGRAPHY

GENERAL

The exposed rocks of the Jonesville district range in age from Late Cambrian to Late Devonian and total 6,400 feet of beds. This sequence has been divided into 22 formations, 2 of which have been subdivided into mapped members. The character and thickness of the formations and members are shown graphically in a generalized columnar section (pl. 3), which also includes brief descriptions of the formations. Detailed descriptions of each formation and member are given in the sections that follow. Measured sections are grouped together at the end of the chapter on stratigraphy.

Two older formations of Cambrian age that are not exposed have been encountered in drilled wells and total about 2,000 feet of beds.

The Maynardville limestone is the oldest formation exposed in the Jonesville district, and is, so far as is now known, the oldest formation included in the Cumberland overthrust block in the district. In the stationary block beneath the Pine Mountain overthrust, the Maynardville limestone probably overlies the Conasauga shale of Late and Middle Cambrian age, which in turn probably overlies the Rome formation of Early and Middle Cambrian age. Both of these formations crop out within a few miles of the Jonesville district. Pre-Rome formations are not exposed and have not been drilled anywhere within 50 miles of the Jonesville district.

The Conasauga shale of southwest Virginia and adjacent Tennessee is dominantly a green and sandy shale with occasional tongues of red shale and numerous platy interbeds of crystalline glauconitic limestone. In places the limestone contains abundant trilobites, usually fragmentary. The formation is probably about 500 to 600 feet thick in the Jonesville district.

The Rome formation consists of interlayered zones of green, gray, and red shale, glauconitic yellow sandstone, fine-crystalline glauconitic limestone, and massive-bedded dolomite. It is probably about 1,500 feet thick in the Jonesville district.

CAMBRIAN SYSTEM

MAYNARDVILLE LIMESTONE OF THE UPPER CAMBRIAN SERIES

Name and distribution.—The Maynardville limestone is named from the town of Maynardville in Union County, northeast Tennessee (Oder, 1934, pp. 475–476). It has sparse distribution in the Jonesville district, and good exposures of the formation are rare. It is present in discontinuous belts partially rimming the Fleenortown and Town Branch fensters, and it also occurs in discontinuous belts on the south side of the Wallen Valley fault. No attempt was made to map continuously the formations south of the Wallen Valley fault, but the presence of Maynardville is noted by symbols on plate 1 wherever it was recognized. In a few places the contacts between the Low Hollow limestone and the Chances Branch dolomite members of the Maynardville, and between the Maynardville limestone and the overlying Copper Ridge dolomite are shown in areas near the fault where the contacts were clear-cut and could be traced without undue expenditure of time.

Low Hollow limestone member.—Approximately the lower half of the Maynardville limestone is assigned to the Low Hollow limestone member. This member has its type locality in the Rose Hill district (Miller and Fuller, in press). It consists of dense, fine-grained, light-gray, ribbon limestone in its lower part, grading upward into similar limestone that is, however, mottled rather than ribboned. The ribboning and mottling are due to the alternate or simultaneous deposition of pure blue-gray limestone and gray silty limestone. Ribboning and mottling are very indistinct in the fresh rock but are conspicuous on weathered surfaces because the silty ribbons and patches weather much whiter than do the pure limestone, and they tend to stand in relief above it. In its uppermost part the limestone of the Low Hollow member is interbedded with dense, fine-grained, light-gray dolomite, and the contact with the Chances Branch dolomite member is drawn at the horizon above which dolomite exceeds limestone in abundance.

The lithology of the Low Hollow limestone member may best be seen in a small quarry on the east side of State Route 70 just south of Town Branch fenster. In this vicinity, however, the Low Hollow and Chances Branch members are not mapped separately because they do not appear to be in normal contact with each other, and the exposures are not adequate to trace the suspected small fault or faults. In the Rose Hill district the Low Hollow member averages about 150 feet in thickness. It would probably have about the same thickness in the Jonesville district if it were all present, but the lower part of the formation has everywhere been eliminated at the surface by overthrust faulting. The measured section of the Low Hollow limestone member (see geologic section 1) given at the end of the stratigraphic chapter is from the Rose Hill district but is representative of the member as developed in the Jonesville district.

Chances Branch dolomite member.—The Chances Branch dolomite member forms approximately the upper half of the Maynardville limestone. The type section of this member is also in the Rose Hill district (Miller and Fuller, in press). The dominant rock type of the member is fine-grained light-gray dolomite in even beds from 1 to 3 feet thick. In the lower part of the member much of the dolomite is silty, and it weathers with parallel, closely spaced, indistinct laminations. The color of the weathered beds is very light gray to nearly white. In the lower part of the member, the fine-grained dolomite is interbedded with darker-colored fine-grained limestone typical of the Low Hollow member, and in the upper part the fine-grained dolomite is interbedded with medium-crystalline dark-colored dolomite typical of the lower part of the overlying Copper Ridge dolomite. The upper contact of the Chances Branch dolomite member is drawn at the horizon above which the darker-colored medium-crystalline dolomite exceeds the lighter-colored fine-grained dolomite in abundance.

The Chances Branch dolomite member crops out in numerous places just south of the Wallen Valley fault; it may also be seen in the southern part of the area mapped as Maynardville undivided just south of the Town Branch fenster. There is no well-exposed section of the Chances Branch dolomite member in the Jonesville district. The measured section given at the end of the stratigraphic chapter (see geologic section 2) is from the Rose Hill district but is typical of the member as developed in the Jonesville district. In the Jonesville district the Chances Branch dolomite member is apparently between 100 and 200 feet thick.

Weathering of the Maynardville limestone.—The Maynardville limestone weathers to a tough yellow clay. Cobbles of white-weathering chert are scattered over slopes underlain by Maynardville, but most of these are derived from the overlying Copper Ridge dolomite and have crept downhill to their present positions. In some places, however, it appears that considerable chert has been derived in situ from weathering of the Maynardville, even though chert is nowhere conspicuous or abundant in the Maynardville bedrock.

Paleontology, age, and correlation.—Fossils are extremely rare in the Maynardville. None were seen in the Jonesville district, but elsewhere in Lee County chertified *Cryptozoon* has been collected from float derived from the Chances Branch dolomite member, and small fragmentary trilobites have been found in beds near the base of the Low Hollow limestone member. The Maynardville limestone is known to be of Late Cambrian age because its scanty fauna consists of Late Cambrian types and because in southwest Virginia and northeast Tennessee it is both overlain and underlain by beds whose Late Cambrian age has been established by abundant faunal and stratigraphic evidence.

In some earlier reports the beds here assigned to the Chances Branch dolomite member of the Maynardville were included in the overlying Copper Ridge dolomite, and the beds here assigned to the Low Hollow limestone member were included in the upper part of the Conasauga or Nolichucky shale.

KNOX GROUP (UPPER CAMBRIAN SERIES)

GENERAL

In early reports the thick sequence of dolomites overlying Upper Cambrian shale and limestone and underlying Lower Ordovician (Stones River) limestone was called the Knox dolomite. Although this sequence forms a gross lithologic unit, recent stratigraphic studies in northeast Tennessee by Bridge, Hall and Amick, Oder, and Rodgers and Kent, and in southwest Virginia by Miller and Fuller have shown that the Knox dolomite may be subdivided into thinner formational units that are persistent as recognizable units over large areas and are mappable. The name Knox has therefore been raised to group status. In southwest Virginia it is divided into five formations as follows: Copper Ridge dolomite of Late Cambrian age, overlain by Chepultepec dolomite, Longview dolomite, Kingsport dolomite, and Mascot dolomite of Early Ordovician age. On plate 1 of this report the Copper Ridge dolomite and Chepultepec dolomite are mapped separately, but the Longview, Kingsport, and Mascot dolomites are mapped together except where their subdivision seems desirable to bring out important aspects of the areal or structural pattern of the geology.

COPPER RIDGE DOLOMITE

Name and distribution.—The Copper Ridge dolomite was named by Ulrich (1911, pp. 635–636) from Copper Ridge in northeast Tennessee. The formation is now restricted to a considerably thinner unit than that originally described by Ulrich.

In the Jonesville district the Copper Ridge dolomite crops out in a belt along the structural high of the Chestnut Ridge anticline in the northeast part of the district and in two irregular-shaped areas along the same structural high in the northwest part of the district. It is also present south of the Wallen Valley fault in a continuous belt extending from the eastern to the western edges of the district. This belt of Copper Ridge was not mapped, and only the outcrops in the lowest part of the formation close to the Wallen Valley fault were studied.

The Copper Ridge dolomite has almost no outcrops on the rolling hills of the Chestnut Ridge upland, but it crops out in a few places in sharply incised stream valleys, in sinkholes, and in roadcuts. Its best exposures in the district are along Hardy Creek, Fleenortown Creek, Town Branch, and Long Hollow. The Long Hollow referred to here and elsewhere in the discussion of the formations of the Knox group is the eastern of the two Long Hollows in the Jonesville district.

Character.—The Copper Ridge dolomite is roughly divisible into lower and upper members on the basis of lithology. The lower member, which forms approximately the lower half of the formation, consists of dark-gray and dark-brown, medium-crystalline dolomite in massive beds that weather with rough, pitted surfaces. The crystal size is not uniform, however, some beds being considerably finer crystalline and others coarser crystalline than the average. The crystals are nearly equidimensional, giving the rock a sugary or saccharoidal texture. Crystals of dark-colored dolomite tend to group in small clusters surrounded by thin, irregular areas of white dolomite crystals. Tiny vugs are abundant, most of which are lined with small crystals of white dolomite. One of the most distinctive features of the dark-colored dolomite is the strong petroliferous odor that is noticeable immediately after the rock has been fractured. This has caused the rock to be aptly though inelegantly named "the stinkstone." At the base of the member, beds of stinkstone are interbedded with light-colored fine-crystalline dolomite typical of the underlying Chances Branch dolomite member.

The upper lithologic member of the Copper Ridge consists of interbedded stinkstone and light-gray fine-crystalline dolomite in the lower part, overlain by light-gray fine-crystalline dolomite and medium-crystalline saccharoidal dolomite in the upper part. Much of the medium-crystalline dolomite has a resinous luster and contains abundant small vugs. Some of the dolomite is silty and shows parallel, straight, wavy, or even cross-bedded laminations on weathered surfaces. The light-colored dolomites are in general thinner bedded and weather with smoother surfaces than do the beds of stinkstone. A few beds near the top of the formation contain lenses or thin layers of sandy dolomite, but sandstone and sandy dolomite are much more abundant in the overlying Chepultepec dolomite.

Lenses and nodules of chalcedonic chert are present throughout the Copper Ridge but are most abundant near the top of the formation. Some of this chert consists of light-colored to milky-white, parallel-banded chalcedony, but much more of it is oolitic. The oolites are spherical or oval and are closely packed. Most are from 0.02 to 0.01 inch in diameter. Some oolitic grains have excellent concentric banding, but others are uniform throughout. Oolitic grains without banding but with dark-colored cores are common.

Because bedrock exposures of the Maynardville limestone, Copper Ridge dolomite, and Chepultepec dolomite are rare, mapping of the contacts between these formations is necessarily based largely on the character of their soils and float. The dark-colored dolomite (stinkstone) of the lower part of the Copper Ridge produces a reddish-orange to deep-red clay that contrasts markedly with the yellow clay derived from the limestone and light-colored dolomite of the Maynardville. The concentration of chert in the soil near the top of the Copper Ridge and the concentration of cobbles of sandstone in the soil of the lower part of the Chepultepec define quite accurately the contact between these two formations.

The Copper Ridge dolomite conformably overlies the Maynardville limestone, and rock types of the two formations are interbedded near the contact. The Chepultepec dolomite is believed to overlie the Copper Ridge with minor disconformity. This disconformity is described in the section on the Chepultepec. A complete section of the Copper Ridge dolomite in the Rose Hill district is given in geologic section 2, and the upper part of the formation is included in the measured section along Long Hollow in the Jonesville district. (See geologic section 3.)

Paleontology, thickness, age, and correlation.—The only fossil that was found in the Copper Ridge in the Jonesville district is the algal form *Cryptozoon.* Chertified colonies of *Cryptozoon* are quite common in the float derived from the Copper Ridge and particularly from the lower part of the formation.

No localities are known in the Jonesville district where the outcrops of Copper Ridge dolomite are sufficiently abundant to permit accurate measurements of the thickness of the formation. In the fair section along Town Branch north of Jonesville, the formation is calculated to be 818 feet thick, but the location of the upper contact is unreliable. In the Phipps well in the western part of the district, 842 feet of nearly flat-lying Copper Ridge dolomite was drilled between the Chepultepec dolomite above and an overthrust fault below. Only the basal beds of the Copper Ridge are believed to have been eliminated by the overthrusting, so this figure probably represents nearly the full thickness of the formation. Along Chances Branch in the Rose Hill district, a well-exposed complete section of the Copper Ridge is 840 feet thick. The evidence thus indicates that the Copper Ridge in central and western Lee County is between 800 and 850 feet thick.

The Copper Ridge dolomite is of Late Cambrian age. It correlates with the Conococheague limestone of Pennsylvania, Maryland, and the eastern belts of the Appalachian Valley of Virginia.

ORDOVICIAN SYSTEM

KNOX GROUP (LOWER ORDOVICIAN SERIES)

CHEPULTEPEC DOLOMITE

Name and distribution.—Ulrich (1911, pp. 638–640) named the Chepultepec dolomite from a town in Blount County, Ala. In the Jonesville district the formation crops out in belts and irregular-shaped areas along or near the axes of the Chestnut Ridge, Powell Valley, and Sandy Ridge anticlines. In the western part of the district its area of outcrop includes about half the width of the Chestnut Ridge upland.

Outcrop character.—Outcrops of the Chepultepec dolomite are confined almost entirely to the deeply incised stream valleys. The formation is mappable, however, because the soil and float derived from it are distinctive. Well-exposed complete sections of the formation are present along Hardy Creek (geologic section 4) and Long Hollow (geologic section 3), and there are fair sections along Fleenortown Creek and Town Branch.

Sandy dolomite member.—For purposes of description the Chepultepec dolomite may be divided into two lithologic members, but the distinctions between the two members are not clear-cut and their separate mapping was not attempted. Approximately the lower half of the formation is included in the sandy dolomite member. Most of the rock in this member is dolomite, but the distinguishing characteristic is the presence of beds and lenses of sandstone and sandy dolomite. These are thickest and most abundant in the lower part of the member, but a few are present in the upper part. The sandstone consists of well-rounded small sand grains in a matrix of dolomite. The dolomite dissolves readily, leaving a porous friable yellow- and brown-stained rock. In a few places chert has replaced the interstitial dolomite, forming a distinctive rock that has been called "chert-matrix sand." Cobbles of sandstone are conspicuous in the float derived from the sandy member.

Dolomite, which is the major constituent of the sandy member, is of several types. Most is fine crystalline, but occasional beds are medium to coarse crystalline and are saccharoidal. The fine-crystalline beds are light gray, medium gray, and grayish brown, whereas the coarser-crystalline beds are almost all light-colored to nearly white. The darker-colored beds are impure dolomite, which will be referred to hereafter as argillaceous dolomite. Nodules and lenses of chert are sparingly present in the sandy member and are thin.

The base of the sandy member is the base of the formation and is marked by a bed of sandstone 19 inches thick at Long Hollow and 3 feet thick on Hardy Creek. A few lenses of sandstone and sandy dolomite occur in the upper part of the Copper Ridge dolomite, but the greater abundance and thickness of the sandy beds in the lower part of the Chepultepec and the much greater abundance of chert in the upper part of the Copper Ridge prevent confusion. The top of the sandy member is arbitrarily drawn at the top of the highest sand, above which are several hundred feet of nonsandy dolomite.

Argillaceous dolomite member.—The argillaceous dolomite member forms approximately the upper half of the Chepultepec dolomite. Except for a somewhat greater proportion of argillaceous dolomite, the types of dolomite in this member are similar to those in the sandy member. In this member there are also a few beds of flesh-colored dolomite, some of which have faint pinkish patches and streaks. Some of the fine-crystalline dark-colored dolomite has a saccharoidal texture and emits a petroliferous odor immediately after it has been fractured. This rock differs from the stinkstone of the lower part of the Copper Ridge in that the color is not so dark and the odor is not so pronounced. Sandstone and sandy dolomite are absent from most of the member, but a few beds and lenses occur near the top. In places "chert-matrix sands" have developed from these beds by replacement of the dolomite matrix by silica. Chert is sparingly present in the argillaceous dolomite member, in marked contrast with the great development of chert in the overlying Longview dolomite.

Chert and soil of the Chepultepec dolomite.—Most of the chert in the Chepultepec dolomite is light-colored to white, but occasional beds are gray to black. Most of the chert is oolitic. The oolitic grains are spherical or oval, and many show excellent concentric banding.

Although some of the chert derived from the Chepultepec is nearly identical with the chert of the Copper Ridge and some is nearly identical with chert of the Longview the three formations can be identified by their chert float alone when the overall character of the chert in each is considered. The criteria are as follows: chert of the Copper Ridge is conspicuously oolitic, the oolites are conspicuously zoned, and much of the oolitic chert is dark colored. The chert float from the upper part of the Copper Ridge is much more abundant than the chert float from any part of the Chepultepec, and many of the cobbles are several inches in size. Much of the chert of the Chepultepec is also oolitic, but the oolites are normally not as conspicuous or as closely packed as oolites from the Copper Ridge. Concentric banding or zoning of the oolites is not common, but some of the most perfect examples of zoned oolites are from the Chepultepec. Most of the chert of the Chepultepec, both oolitic and non-oolitic, is light colored to white. The chert float from the Chepultepec is not abundant and few of the pieces are more than 2 inches in length. The chert of the Longview is nearly white to white, is very abundant and is in large pieces, many of which are more than a foot in longest dimension. Pieces of oolitic chert are uncommon, but much of the chert is banded. Beautifully formed, concentrically ridged, disc-shaped concretions are common.

The Chepultepec normally forms a yellow clay soil which is quite sandy in the lower half of the formation. In many places, however, the soil of the Chepultepec is bright orange, which helps to distinguish it from the yellow clay of the overlying dolomitic formations and the underlying upper part of the Copper Ridge dolomite and also from the deep-red to reddish-orange clay derived from the lower part of the Copper Ridge. There appears to be a direct relation between color of the bedrock dolomite and color of the derived clay. Dark-colored dolomites produce orange to red soil, and the deeper the bedrock color the redder the color of the clay derived. Light-colored dolomites produce yellow clay. Apparently the iron in the dolomites that have abundant organic matter is not hydrated during weathering of the bedrock and formation of residual clay; whereas in the dolomites that have little or no organic matter hydrated iron oxide is formed in the residual clay.

Stratigraphic relations.—The Chepultepec dolomite is believed to overlie the Copper Ridge dolomite with a slight disconformity. Small conglomeratic pebbles of dolomite have been seen in the basal sandstone, and there is evidence of slight erosion of the uppermost part of the Copper Ridge before deposition of the basal sandstone of the Chepultepec. Along Hardy Creek a disconformity occurs in the upper part of the Copper Ridge 200 feet below the base of the Chepultepec as mapped. (See geologic section 4, unit 4.) This disconformity might make a stratigraphically more acceptable base for the Chepultepec than the one used in the mapping, but it is not a mappable horizon because it has been seen in only the one locality. The Chepultepec dolomite is conformably overlain by the Longview dolomite. The nature of this contact is discussed in the section on the Longview.

Complete sections of the Chepultepec along Hardy Creek and Long Hollow and a partial section of the Chepultepec along State Route 70 north of Jonesville are given at the end of the chapter on stratigraphy.

Paleontology, thickness, and age.—The only fossil seen in the Chepultepec of the Jonesville district is *Cryptozoon*. Butts (1940, pp. 100–101) has described a sparse but characteristic fauna of cephalopods and gastropods from the Chepultepec of western Virginia and eastern Tennessee.

In the measured section along Hardy Creek (geologic section 4) the Chepultepec dolomite is 696 feet thick, and in another section south of Hardy Creek Church it is 776 feet thick. It is 775 feet thick in the Long Hollow section (geologic section 3), but along State Route 70 north of Jonesville it appears to be only 595 feet thick. At this locality, however, the base of the Chepultepec is in a long covered interval, and its position was estimated on the basis of float. The apparently thinner section here may thus represent merely an error in location of the lower contact. In the Cavins well just west of the Jonesville district, 706 feet of beds were assigned to the Chepultepec, and in the Snodgrass well in the south-central part of the Jonesville district approximately 720 feet of beds were assigned to the Chepultepec. In most, if not all, of the Jonesville district the Chepultepec dolomite is apparently between 690 and 780 feet thick.

The Chepultepec dolomite of the Jonesville district is believed to be identical with the formation as recently mapped in the Rose Hill district and in northeast Tennessee. In earlier work the limits of the Chepultepec were not clearly defined, and the name has not been consistently used. (Miller and Fuller, in press.) On the basis of fossils reported in the Chepultepec from other localities, it has been established that the formation is of Early Ordovician age.

LONGVIEW DOLOMITE

Name and mapping procedure.—The Longview dolomite was named by Ulrich (1924) from a town in Shelby County, Ala., but the name was first defined and the formation described by Butts (1926). In most of the Jonesville district it was not mapped separately but was included with the overlying Kingsport and Mascot dolomites. On the geologic map (pl. 1) the same pattern has everywhere been used for the Longview, Kingsport, and Mascot, but in several localities, such as along Tanbark Ridge, at Poteet Ferry bridge, and near Long Hollow, the Longview and Kingsport contact is locally shown, with the appropriate symbols on opposite sides of the contact.

Distribution.—In the western part of the Jonesville district the undivided Longview, Kingsport, and Mascot dolomites form belts on both flanks of the Chestnut Ridge and Powell Valley anticlines. Because of gentler dips on the southeast flanks of these folds, the southeastern belt is wider and considerably more irregular in shape. In the eastern part of the district the three formations are gently dipping or nearly flat and they underlie extensive areas along the axis of the Sandy Ridge anticline and also along the axis of The Cedars syncline. The latter area narrows northeastward and becomes a belt of south-dipping rocks on the south side of the faulted Chestnut Ridge anticline.

Character and stratigraphic relations.—The Longview consists mainly of light-gray to nearly white dolomite, some of which is medium crystalline and some fine crystalline. Both medium-crystalline and fine-crystalline dolomites have a saccharoidal texture. The dolomite is in beds from 6 inches to several feet thick, and weathers with smooth surfaces. A few beds and lenses of sandstone and sandy dolomite are included, but sandstone is much less abundant than in the Chepultepec dolomite, nor is it conspicuous in the float of the Longview.

Masses, nodules, lenses, and beds of white-weathering chert are abundant in the bedrock. The chert is not uniformly distributed; it occurs in zones with chert-free dolomite between. Several beds of chert more than 1 foot thick are present in most sections, and chert beds as much as 4 feet thick have been seen. Most of the fresh chert is light-colored to white, but some is blue or gray. Banding of the chert is common, but very little of it is oolitic. Disc-shaped concentrically laminated concretions from a few inches to 2 feet thick are a striking and common component of the chert. These may weather out as individual concretions such as the one shown in figure 3*A*, or as coalescing groups such as the ones shown in figure 3*B*.

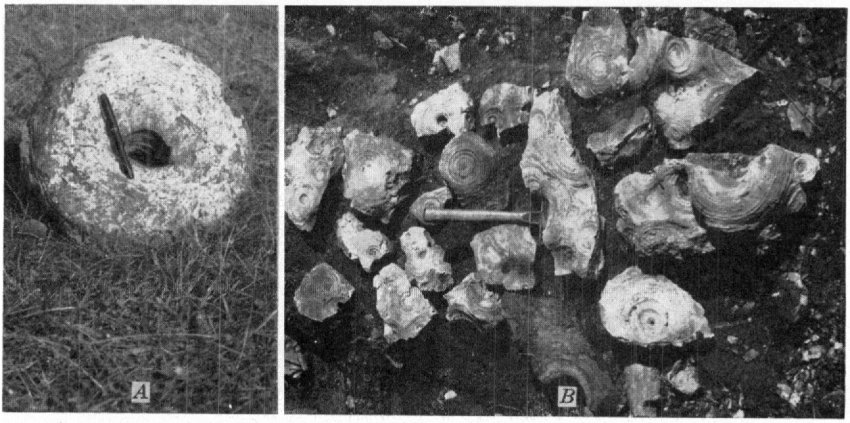

FIGURE 3.—*A*, Large individual chert concretion from Longview dolomite used for a decoration in front yard west of Kinzer Hollow. *B*, Pieces of chert concretions from Longview dolomite from a roadcut on United States Highway No. 58 just east of York Church.

Chert from the Longview forms very abundant float on the surface. Cobbles from a few inches to several feet in longest dimension are so abundant that the soil is difficult to cultivate and the land is usually left in pasture or in woods. On some farms the larger cobbles of chert have been piled up in heaps or in rock fences on the margins of the cultivated fields. The dolomite of the Longview produces a yellow nonsandy clay soil. Both the underlying Chepultepec dolomite and the overlying Kingsport dolomite in places produce orange soils, but the color differences are not sufficiently distinct or consistent to form very reliable mapping criteria.

The base of the Longview is not clear-cut at all localities. In the section along Hardy Creek (geologic section 4) a transition zone 11 feet thick separates typical Chepultepec dolomite from typical Longview dolomite. In the Long Hollow section (geologic section 3), however, there is an abrupt change from the gray, laminated chert-free argillaceous dolomite of the upper part of the Chepultepec to the light-colored saccharoidal dolomite with chert of the Longview. The basal few inches of the Longview here consist of sandstone grading upward into sandy dolomite. The contact between the basal sandstone and the underlying Chepultepec dolomite is wavy, but there is no evidence of appreciable erosion along the contact. The Longview dolomite is disconformably overlain by the Kingsport dolomite.

Paleontology.—The Longview dolomite of the Jonesville district is the most fossiliferous formation of the Knox group. A few cobbles of fossiliferous chert may be found by careful search at most localities of the Longview. The lower part of the formation appears to be more fossiliferous than the upper part. Most of the fossils of the Longview seen in the district are gastropods, of which the most abundant form is *Lecanospira.* The following forms have been identified by Preston E. Cloud, Jr., of the U. S. Geological Survey, from collections made at many different localities in the district.

Lecanospira sp.
Lecanospira? sp.
Rhombella sp.
Unidentified gastropods.
Unidentified cephalopods.

Thickness and age.—In measured sections at Long Hollow, along Hardy Creek, and along State Route 70 north of Jonesville, the Longview is 222 feet, 272 feet, and 222 feet thick, respectively. Along the ravine south of Hardy Creek Church it appears to be only 98 feet thick, and in the Cavins well 137 feet of beds were assigned to the Longview. Precise recognition in well cuttings of the contacts between formations of the Knox group is extremely difficult, which may account for the subnormal thickness of the Longview in the

Cavins well. The reason for the thinness of the section at Hardy Creek Church is not known. It may be due to pre-Kingsport erosion of the upper part of the Longview, an interpretation which seems the more plausible because of the prominent conglomerate that has been seen at the base of the Kingsport at some localities.

The Longview dolomite is of Early Ordovician age. It correlates approximately with the *Lecanospira*-bearing formations of other parts of the Appalachian Valley—that is, the Nittany dolomite of Pennsylvania and the lower part of division C of the type Beekmantown limestone in New York State. (Oder, 1934, p. 483.)

KINGSPORT DOLOMITE

Name.—Rodgers (1943) first used the name Kingsport on a preliminary map of the Copper Ridge zinc district in Tennessee. The name was proposed by Oder and Bridge who subsequently also used it in publications (1945). The name is there applied to a limestone formation that has the same stratigraphic position and is believed to be of the same age as the dolomitic beds here referred to the Kingsport. The name comes from the city of Kingsport in Sullivan County, northeast Tennessee.

Character, stratigraphic relations, and paleontology.—The Kingsport dolomite of the Jonesville district consists almost entirely of massive-bedded, medium- to coarse-crystalline, saccharoidal dolomite containing very little chert. Small vugs lined with dolomite crystals are abundant. The dolomite is light-colored to white, but it weathers to a dirty gray owing to the retention of dust particles on the rough friable surfaces. On hills just northwest of Sulphur Springs, a few dozen feet of beds that are believed to belong in the Kingsport consist of bluish-gray to flesh-colored limestone. This limestone facies has not been seen elsewhere in the district. Thin beds, lenses, stringers, and small nodules of chert are present in some places, but elsewhere the formation seems to be nearly free of chert. The chert is all light colored and much of it is white. It may be banded, but banding is not prominent. Very little chert of the Kingsport is oolitic.

The contact between the Longview and Kingsport dolomites (fig. 4) is a disconformity. This may best be seen in the section measured along the roadcut of U. S. No. 58 in the bluff just west of the Powell River bridge (geologic section 6). Here the basal few inches of the Kingsport are of sandstone grading upward into sandy dolomite. Above this are 2 feet of saccharoidal dolomite containing abundant irregularly shaped blocks of white-weathering chert which are tilted at various angles. This conglomeratic zone is overlain by 5 feet of saccharoidal dolomite, also conglomeratic, in which the cobbles of chert are smaller and less numerous. The chert cobbles in the basal beds of the Kingsport are believed to have been derived by weathering and erosion of the underlying Longview. They could not have moved far as they show little rounding. A conglomeratic zone has not been observed elsewhere at the base of the Kingsport, but the Kingsport commonly begins with a few inches of sandstone or sandy dolomite. The dolomitic matrix between sand grains may be replaced by chert (chert-matrix sand), making a very distinctive rock. In northeast Tennessee the base of the Kingsport has been mapped on the basis of float derived from a basal bed of chert-matrix sand. This criterion must be used with extreme caution in the Jonesville district, however, because chert-matrix sands have been seen at several other horizons. The Kingsport dolomite is disconformably overlain by the Mascot dolomite. The only fossil seen in the Kingsport in the Jonesville district was a straight tubular form which was part of the siphuncle of an endoceratid (family Endoceratidae of nautiloid cephalopods). Measured sections of the Kingsport are given in geologic sections 3, 4, 5, and 6.

FIGURE 4.—Basal conglomerate of the Kingsport dolomite, consisting of cobbles of white chert in a saccharoidal dolomite matrix, overlying Longview dolomite. Hammer is at contact. In a roadcut of U. S. No. 58 along bluff west of Powell River bridge (Poteet Ferry bridge).

Thickness and age.—The Kingsport varies considerably in thickness, probably because it has disconformities at both base and top. The measured thicknesses are as follows: 119 feet at Poteet Ferry bridge, 272 feet at Long Hollow, 250 feet at Hardy Creek Church, 180 feet along Hardy Creek at Lambs Chapel, and 156 feet along State Route 70 north of Jonesville.

The Kingsport dolomite is of Early Ordovician age. It correlates approximately with Oder's Jefferson City formation, (Oder, 1934, pp. 483–486), and with Hall and Amick's Forked Deer formation, (1934, pp. 157–168, 195–220).

MASCOT DOLOMITE

Name.—The name Mascot dolomite, like Kingsport dolomite, was first used by Rodgers (1943) on the preliminary map of the Copper Ridge zinc district. The name was proposed by Oder (1945) and Bridge (1945) for dolomitic beds in the upper part of the Knox group of east Tennessee that overlie the Kingsport limestone and underlie the so-called Stones River limestone.

Character.—In the Jonesville district the Mascot dolomite has more abundant outcrops than any other formation of the Knox group. The upper part of the formation is better exposed than the lower part, and the contact with the overlying Dot limestone can be accurately located in many places. The Mascot is completely exposed in the section along Hardy Creek in the vicinity of Lambs Chapel (geologic section 4). The upper part of the formation is also well exposed in roadcuts of State Route 70 just north of Jonesville (geologic section 5), and the lower part of the formation is equally well exposed in roadcuts along Long Hollow in the eastern part of the Jonesville district (geologic section 3).

The formation consists predominantly of light-colored to nearly white dolomite. In the lower part of the formation most of the dolomite is medium to coarse crystalline and is saccharoidal, but in the upper part the dolomite is almost all fine crystalline. This accounts for the more abundant outcrops of the upper part of the formation, because the fine-crystalline dolomites are less readily dissolved than are the coarser-crystalline ones. The saccharoidal dolomites are thick-bedded and weather with irregular surfaces, whereas the fine-crystalline dolomites are normally in beds from 1 to 2 feet thick which weather with smooth surfaces. A distinctive feature of the Mascot dolomite, and one that is especially helpful in identifying the formation in well cuttings, is the presence of numerous partings and beds of green shale from fractions of an inch to several inches thick.

The thickest and most prominent sandstones in the Knox group of the Jonesville district are in the Mascot. In the vicinity of Jonesville and Ben Hur, a zone of sandstone that is traceable for several miles lies about 100 feet below the top of the formation. This zone is 8½ feet thick in the State Route 70 roadcut north of Jonesville, about 6 feet thick on the same highway southeast of Jonesville, and 6 feet 3 inches thick in a small pit southwest of Ben Hur, where the weathered sandstone has been quarried for sand. Some of the sand grains are well rounded; others are angular, owing in part to the addition of secondary silica in crystallographic continuity with the sand grain. The cement between grains is dolomite, which dissolves readily leaving a porous friable rock. Thinner beds and lenses of sandstone have been seen in the upper part of the Mascot at other localities, but sandstone is not nearly as abundant in the Mascot dolomite as it is in the Chepultepec, and it is not a conspicuous component of the float derived from the Mascot, except near the thick bed of sandstone described above.

Beds, lenses, nodules, stringers, and irregular-shaped masses of chert are distributed through the lower and middle parts of the Mascot but are practically absent from the upper part. Near Jonesville the chert-free zone at the top of the formation is 193 feet thick. The Mascot normally contains thicker beds of chert than does the Longview, with the result that the float derived from the Mascot has bigger and blockier cobbles of chert than the float derived from the Longview. In the Jonesville roadcut one bed of chert in the Mascot is 3 feet 4 inches thick, and beds more than 2 feet thick are common. Almost all of the chert of the Mascot is chalcedonic, and much of it is banded. It is light-colored to white and weathers white. Oolitic chert is present, but most of the chert is non-oolitic. The senior author spent considerable time trying to discover lithologic criteria for distinguishing chert float derived from the Longview from that derived from the Mascot, but the only thoroughly reliable criterion was the presence of *Lecanospira*, which indicates Longview, or the presence of small high-spired gastropods *Hormotoma*, *Coelocaulus*, etc., which indicate Mascot.

The Mascot dolomite disconformably overlies the Kingsport dolomite. The contact has been seen in the Hardy Creek-Lambs Chapel section (geologic section 4), the section near Hardy Creek Church, the U. S. No. 58-Powell River bridge section (geologic section 6), the State Route 70-Jonesville section (geologic section 5), the Long Hollow section (geologic section 3), and also on the margin of a small isolated area of Mascot dolomite north of Mt. Hope Church. In all but the section at Powell River bridge, the basal unit of the Mascot is a gnarled conglomeratic bed consisting of tilted chert and (or) dolomite cobbles in a matrix of dolomite or chert. In some places this basal bed is also sandy. The hiatus represented by the disconformity is probably small, but the amount of erosion during the hiatus may in places be appreciable. Unusually thin sections of the Kingsport dolomite such as the section at Powell River bridge seem best explained by pre-Mascot erosion. Two minor disconformities along which 1 to 2 feet of beds are cut out are present in the upper part of the Mascot in the Jonesville section. Similar disconformities have been seen at several places in the Rose Hill district.

The Mascot dolomite, the top formation of the Knox group, is unconformably overlain by the Dot limestone. This unconformity, the most conspicuous one in southwest Virginia, is described in a following section (p. 30).

Thickness and paleontology.—The thickness of the Mascot dolomite has been measured in sections at four localities. The formation is 421 feet thick at Long Hollow, 462 feet along Hardy Creek at Lambs Chapel, and 498 feet at Jonesville. At Hardy Creek Church, however, the Mascot is only 169 feet thick. The unusual thinness of the section at Hardy Creek Church is probably due to profound erosion of the Mascot during the hiatus between the Mascot and Dot formations. The total thickness of the undivided Longview, Kingsport, and Mascot dolomites is 517 feet at Hardy Creek Church, 912 feet at Lambs Chapel, 915 feet at Long Hollow, and 872 feet at Jonesville, and it is calculated to be approximately 730 feet thick in the vicinity of the Snodgrass well.

The Mascot contains a few gastropods, of which small high-spired forms are most characteristic. An unidentifiable triolobite fragment was also found. The list of forms identified from the Jonesville district by Preston E. Cloud, Jr., follows:

Orospira sp.
Orospira? sp.
Plethospira? sp.
Hormotoma spp.
Fragment of unidentifiable gastropod allied to *Ophileta.*
Fragmentary unidentifiable gastropods, trilobites, cephalopods, and orthoid brachiopods.

Age.—The Mascot dolomite is of Early Ordovican age. It correlates approximately with the Cotter-Powell beds of Oder (1934) and with the Thorn Hill formation of Hall and Amick (1934), and it correlates approximately with the upper part of the Beekmantown dolomite as mapped in southwest Virginia.

RELATION OF POST-MASCOT UNCONFORMITY TO THE BASAL CONGLOMERATE OF DOT LIMESTONE

After the deposition of the Mascot dolomite, a hiatus ensued during which there was considerable erosion before deposition of the next overlying formation, the Dot limestone. Although this is not the longest hiatus in the stratigraphic column of the Jonesville district, the resulting unconformity is the most pronounced one in the region. The land surface was eroded unevenly to produce a surface of considerable relief, as shown by variations of several hundred feet in the thickness of the Mascot dolomite over short distances, by variations within short distances in the thickness of the basal conglomerate of the Dot limestone, and by variations in the size of pebbles and cobbles in the conglomerate.

The first deposits following this hiatus show considerable variation in lithology, as might be expected. In places conglomeratic cobbles of dolomite and chert derived from the Mascot are included in a matrix of dolomite or sandy dolomite, as shown in figure 5. In this photograph the distinctive slashed ("butcher block") weathered surfaces of the large cobbles of dolomite are well exhibited. The two large cobbles of dolomite to the right of the hammer contain nodules of chert which photograph nearly black.

FIGURE 5.—Basal bed of the Dot limestone, showing large cobbles of dolomite with "butcher-block" weathering in a matrix of argillaceous dolomite. Taken on the south edge of an outlier of the Dot limestone just west of Lambs Chapel.

More commonly the basal beds of the Dot limestone lack large cobbles of dolomite or chert, but the basal few feet are of impure dolomite which contains scattered small angular chips of white chert, mostly less than an inch in size. These chips are often sparingly present, but a few may be found in the basal 5–10 feet of the Dot limestone at almost any locality. They are an unfailing guide in locating the Mascot and Dot unconformity, as angular chips of chert have not been seen at any other stratigraphic horizon in the column. Although the chert fragments are commonly confined to the lowest

5 or 10 feet of the Dot limestone, in a few places they have been seen as high as 30 feet above the base of the formation. In some places the basal inch or two of beds above the unconformity consists of fine- to medium-grained sandstone, and in the overlying beds lenses of sandstone and sandy dolomite may be present.

Although the conglomeratic facies at the base of the Dot limestone is very conspicuous in weathered outcrops, it may be quite obscure in fresh exposures. In the active quarry at the south end of Hurricane Bridge, the contact is well-exposed and is more obvious than normal in the fresh rock. In the photograph (fig. 6) taken in this quarry, the contact, which is at the hammer head, is "frozen," and a solid specimen may be collected across it. The pebbles in the conglomeratic bed above the hammer are of chert in a matrix of argillaceous dolomite.

Where the conglomeratic facies above the unconformity is absent or concealed, the location of the unconformity may still be determined because of the contrast in weathering between the dolomite of the upper part of the Mascot and that of the lower part of the Dot limestone. The Mascot dolomite weathers into slabby white or grayish-white beds with prominent crisscross grooves ("butcher-block weathering"), and contains nodules, lenses, and masses of white chert. The dolomite of the Dot limestone, on the other hand, is chert-free and weathers with smooth, well-rounded surfaces that have a buff or light-brown color.

FIGURE 6.—Unconformity between Mascot dolomite and Dot limestone in the active quarry at the south end of Hurricane Bridge. Hammer head is at the contact. Basal unit of Dot limestone above hammer consists of angular pebbles of chert in a matrix of argillaceous dolomite.

TABLE 1.—*Correlation of Middle Ordovician formation names used in Lee County, Va.*

Lee County Butts: Virginia Bull. 52 1940	Northeast Lee County Bates: Virginia Bull. 51-B 1939	Ben Hur, Lee County Prouty: Am. Assoc. Petroleum Geologists Bull. 1946	Lee County Huffman: Jour. Geology 1945	Rose Hill District Miller and Fuller: Virginia Bull. 71, in press		Jonesville District Miller and Brosge: This report	
Trenton limestone	Trenton limestone	Trenton limestone	Hermitage limestone Curdsville limestone	Trenton limestone		Trenton limestone	
Eggleston limestone	Lowville limestone	Eggleston limestone	Eggleston limestone	Eggleston limestone	Upper member	Eggleston limestone	Upper member
					Middle member		Middle member
					Lower member		Lower member
Lowville limestone facies of Lowville-Moccasin formation		Moccasin limestone	Moccasin limestone	Moccasin limestone	Hardy Creek member	[1] Hardy Creek limestone	
					Lower member	[1] Ben Hur limestone	
		Witten limestone	"Lower Moccasin limestone"	Lowville limestone	Platy member	[1] Woodway limestone	
			"Ottosee limestone"		Red bed member	[1] Hurricane Bridge limestone	
Lenoir limestone	Lenoir limestone	? Peery, Ward Cove, Thompson Valley? and Lincolnshire? limestones ?	"Lenoir limestone"	"Lenoir limestone"		[1] Martin Creek limestone	
Mosheim limestone	Mosheim limestone	Five Oaks limestone	"Mosheim limestone"	"Mosheim limestone"		[1] Rob Camp limestone	
Murfreesboro limestone		Blackford formation	"Murfreesboro limestone"	"Murfreesboro limestone"	Chert member	[1] Poteet limestone	
					Limestone member Dolomite member	[1] Dot limestone	
Beekmantown dolomite	Formations of Beekmantown age	Beekmantown dolomite	Beekmantown dolomite	Mascot dolomite		Mascot dolomite	

[1] New formations described in this report

MIDDLE ORDOVICIAN SERIES

NOMENCLATURE OF MIDDLE ORDOVICIAN FORMATIONS IN LEE COUNTY

The formation names in general usage for the Middle Ordovician rocks of Lee County have in recent years been those established by Butts (1940). The Middle Ordovician series is divisible into many mappable units, but facies changes both along and across the strike make it extremely difficult to correlate the mapped units of one area with those of another area some distance removed, particularly where the second area is in a different belt of outcrop. Butts' mapped formations, shown in the left-hand column of table 1, were for the most part consistently used by him in southwest Virginia. Recent stratigraphic work in Virginia and Tennessee has shown, however, that the beds in Lee County assigned by Butts to the Murfreesboro, Mosheim, and Lenoir limestones are not of the same age as these formations in their type regions. The exact relation of beds designated as Lowville in Lee County to type Lowville in New York State is not known, and the so-called Moccasin limestone of Lee County is strikingly different lithologically from type Moccasin, though it is approximately the same age.

Cooper and Prouty (1943, pp. 819–886) and Cooper (1944) have recognized the inadvisability of using the names Murfreesboro, Mosheim, Lenoir, and Lowville in southwest Virginia, and have applied new formation names to this part of the section in Tazewell County, Va. The mapped units of Tazewell County are not, however, the same as the mapped units of Lee County, nor is the sequence of lithologies the same. Prouty (1946, pp. 1140–1191) recently extended the use of some of the Tazewell County names to a broad area of southwest Virginia and northeast Tennessee. He encountered difficulties, however, in recognizing the Tazewell County formations in Lee County. In some of his sections in Lee County, one Tazewell County formation name has been applied to the same beds which in others are given a different formation name. The present writers doubt that the Tazewell County formations carry through as recognizable and mappable units between the two areas. According to personal communications from B. N. Cooper and G. A. Cooper, their recent work in the intervening areas corroborates this view. The affinities of the Middle Ordovician formations of Lee County are closer to the central Tennessee sequence than to the Tazewell County sequence, but the mapped formations of central Tennessee are not the same as the mapped formations of Lee County.

Inasmuch as the names previously used in Lee County by Butts, and more recently used with qualifications by Miller and Fuller (1945, 1947, in press) are known to have been erroneously applied, and because formation names that have been used in Tazewell County, Va., and in central Tennessee are not applicable to the mapped units in Lee County, it is necessary to establish and define new formational units for Lee County. The writers recognize the desirability of keeping stratigraphic nomenclature as simple as possible in order to facilitate the task of the student and of the geologist not specializing in the field of Ordovician stratigraphy. Understanding of the complex Middle Ordovician stratigraphy of the Valley of Virginia will not be advanced, however, by retention of erroneously applied old names or by misapplication in one region of newer formational names that have been established and defined in other regions where the facies and sequence of lithologies are different. The new formation names that have been proposed by Miller and Brosgé (1950) for the Middle Ordovician rocks of Lee County and are here fully described are shown in the right-hand column of table 1. Their correlation with other formational names that have been applied by various authors in Lee County in recent years is shown in the remainder of the table. The column showing names used by Prouty in Lee County is taken from his graphic section at Ben Hur. In some of his other sections in and near the Jonesville district, the correlation of his names with the proposed new names would be in part quite different.

DOT LIMESTONE

Name.—The name Dot limestone was first used on a preliminary map of the Jonesville district by Miller and Brosgé (1950). A complete description and type section of the formation are here given. The name is taken from the small settlement of Dot, which is at the junction of U. S. No. 58 and State Route 66 in the eastern part of the Jonesville district. Along U. S. No. 58 a good section of the formation is exposed 2½ miles west of the road junction (geologic section 7). The type section of the formation is taken in the cut of the Louisville and Nashville railroad spur at Hagan (geologic section 8), however, because the section there is somewhat better exposed and is also more typical of the formation as mapped in the Jonesville district and as seen elsewhere in Lee County. The name Hagan and other usable names in the immediate vicinity of the type section are preoccupied.

Distribution and limits.—The Dot limestone crops out in two continuous belts on opposite sides of the main anticlinal axis of the Jonesville district. The northern belt is quite straight, and follows closely the southern edge of the Sugar Run lowland. The southern belt is much less regular in shape and trend because its lowermost beds tend to form hogbacks on the south slopes of the Chestnut Ridge upland and because The Cedars syncline and Sandy Ridge anticline produce pronounced zigzag bends in the belt west of Jonesville and southwest of Woodway.

The Dot limestone includes beds from the top of the Mascot dolomite to the base of the abundantly cherty, dark-colored, and locally coarse-crystalline Poteet limestone. The Dot limestone and Poteet limestone combined are exactly equivalent to the Murfreesboro limestone described by Butts in Lee County, the Dot limestone being approximately the lower two-thirds of the sequence. Miller and Fuller (1947; in press) did not map subdivisions of Butts' Murfreesboro in the Rose Hill district but did describe three lithologic members of the Murfreesboro. The Dot limestone is exactly the same as their combined dolomite and limestone members of the Murfreesboro, and the Poteet limestone is exactly the same as their chert member of the Murfreesboro. (See table 1.)

Character.—The Dot limestone is composed predominantly of fairly massive-bedded argillaceous dolomite in the lower part and relatively pure tan or light-gray limestone in the upper part. The two types of rock are generally interbedded through a transition zone from 20 or 30 to 100 feet thick. Despite this interbedding the formation may in general be considered to have two lithologic members, a lower or dolomite member and an upper or limestone member.

Dolomite member.—The dolomite member varies greatly in thickness from place to place because of the relief of the eroded Mascot surface on which it was deposited. In the low places on this surface, such as at Dot (geologic section 7) and Hagan (geologic section 8), more than 45 feet of dolomite were deposited before the deposition of the first bed of limestone, whereas on the high places, such as at the Poteet Ford footbridge (geologic section 9), only 10–20 feet of dolomite were deposited before the first bed of limestone.

The basal beds of the dolomite member are slightly to abundantly conglomeratic as described in the section on the post-Mascot unconformity. Both the conglomeratic and nonconglomeratic basal beds are composed predominantly of argillaceous dolomite in beds from 1 to 2 feet thick, which weather with smooth, very well rounded outer surfaces. Above this is a zone from 5 to 30 feet thick in which the dolomite is more argillaceous and is locally shaly. In most places this zone consists of light-gray dolomite that weathers to a buff color and has smoothly rounded surfaces, but locally, as at Dot and east of Long Hollow in the eastern part of the district, this zone is a conspicuous red or purple both on weathered surfaces and in the fresh rock. The colors may be pervasive throughout an entire bed or may be in patches or stringers in an otherwise gray or greenish-gray dolomite. The shaly dolomite normally weathers to an ash-gray color. The remainder of the dolomite member consists of light-gray even-bedded dolomite that weathers buff and has the distinctive rounded surfaces; but in the upper part of the member it is interbedded with limestone that becomes more abundant upward.

Limestone member.—The upper member of the Dot limestone consists predominantly of limestone, but in the lower part it contains interbedded dolomite similar to that described above. In some sections occasional beds and zones of dolomite are present in the upper part of the member. The limestone is tan or dove-colored, dense, and cryptocrystalline, and is in even beds from a few inches to as much as 2 feet thick, but averages about 1 foot in thickness. A few of the beds are fossiliferous. Small brachiopods, ostracodes, gastropods, and crinoid stems are the most common forms.

A distinctive zone of massive-bedded very pure limestone is present throughout most of the Jonesville and Rose Hill districts at or near the top of the member. This limestone zone contains numerous small patches of coarse crystalline white calcite (birdseyes), a feature that is not common in the underlying limestone. This limestone was referred to as "Massive birdseye limestone No. 1" in the report on the Rose Hill district (in press). The terms vaughanite (Butts, 1940, p. 136), calcilutyte (Cooper and Prouty, 1943, p. 826), and sublithographic limestone (Huffman, 1945, p. 150), have all been used in southwest Virginia for limestones that are extremely dense, pure, and cryptocrystalline, and that break with a conchoidal fracture. Massive birdseye limestone, the so-called 10-foot vaughanite, is distinguished particularly, however, by its more massive bedding and by its tendency to form prominent ledges or small cliffs. The zone averages about 10 feet thick but is considerably thicker in places.

Normally the Dot limestone contains no chert except for the conglomeratic pebbles and fragments of chert in the basal beds. However, in some places, such as in the section near Dot, there are one or two zones of chert nodules near the top of the limestone member. The chert in the overlying Poteet limestone is much more abundant, so the contact between these two formations can be mapped quite accurately in areas with no outcrops by mapping the lowest stratigraphic appearance of abundant chert in the soil. The Poteet limestone overlies the Dot limestone with slight disconformity.

Paleontology.—The dolomitic beds of the Dot limestone are unfossiliferous. Some of the limestone beds carry fairly abundant small fossils, mostly fragmentary. Ostracodes are most conspicuous. Collections were made from three localities, but the forms were too fragmentary and too poorly preserved to be identified.

Thickness and stratigraphic relations.—Ten reliable measurements of the thickness of the Dot limestone were made in and near the Jonesville district. The measurements ranged from 120 feet at Jonesville to 193 feet at Dot, and they averaged 142 feet. Graphic sections showing the lithology and thickness of the Dot limestone in measured sections at various localities in and near the Jonesville district are given in plate 4. It is apparent in these sections that the dolomite and limestone members vary greatly in thickness. The contact that has been shown between them has been drawn on the basis of relative proportions of dolomite and limestone. This contact is not at a consistent stratigraphic horizon. The variations in thickness of the members are due more to changes in facies between sections, causing the contact between the members to be drawn at different horizons, than to thickening or thinning of units that are time equivalents. The changes in thickness of the whole formation are largely due, as previously described, to the relief of the erosion surface on which the Dot limestone was deposited.

Correlation.—The Dot limestone is equivalent to the lower part of Butts' Murfreesboro limestone as applied in and near Lee County by Butts (1940) and by Miller and Fuller (1947). It seems to correlate with zones 1 and 2 of the Blackford formation as used by B. N. Cooper (1944) in the Burkes Garden quadrangle, Tazewell County. The Dot limestone is older than any beds exposed in the Nashville Basin of Tennessee or in the Bluegrass region of Kentucky.

POTEET LIMESTONE

Name, limits, and distribution.—The Poteet limestone gets its name from Poteet Ford, an old crossing of the Powell River in the south-central part of the Jonesville district. An excellent and nearly complete section of the formation (geologic section 9) lies along a woods lane at the base of a bluff overlooking the Powell River 0.2 mile north of the suspension footbridge at Poteet Ford.

The formation is exactly equivalent to the chert member of the Murfreesboro limestone in the Rose Hill district, as described by Miller and Fuller (in press). It includes the abundantly cherty, relatively thin bedded limestone lying between the Dot limestone below and the Rob Camp limestone above. The Poteet limestone forms narrow belts adjacent to the previously described belts of the Dot limestone, and it is also present along the Wallen Valley fault zone and in the faulted area near Ben Hur.

Character.—The formation consists predominantly of tan and light-brown dense cryptocrystalline limestone in even beds. The limestone forming the lowest 10 to 30 feet of the formation is, however, much darker in color, and it gives forth a pronounced petroliferous odor immediately after fracturing. The dark-colored limestones are predominantly dense and fine-grained, but at many localities a zone of the dark limestone ranging in thickness from a few feet to a few tens of feet and lying at or a few feet above the base of the formation consists of coarse-crystalline limestone. This rock is referred to hereafter as fragmental limestone because it contains numerous fragmental fossils. It appears to have been formed by the breaking up by wave action of a previously deposited zone of dark-colored fossiliferous limestone. This is a type of intraformational conglomerate. It is confined to the lowest part of the formation because the water was shallowest and the effect of wave action on bottom sediments most violent in the advancing seas at the beginning of Poteet time. In a few places where fragmental limestone forms the basal unit of the Poteet limestone, a few rounded pebbles of limestone lie just above the basal contact. These are true conglomeratic pebbles derived from the underlying Dot limestone.

In a few places there are one or two beds of dolomitic limestone near the top of the Poteet limestone. Nodules of flint and lighter-colored chert are common throughout most of the formation but are rare in the fragmental limestones. The fine-crystalline dark-colored limestone contains extremely abundant chert nodules (fig. 7), and the tan and light-brown limestone has zones with abundant chert nodules separated by noncherty zones. In general the chert is most abundant in the lower half of the formation and becomes progressively less abundant toward the top. The nodules are in irregular knobby shapes, flattened in the plane of the bedding. Along some layers, the nodules are so closely spaced that they coalesce.

Stratigraphic relations.—The Poteet limestone disconformably overlies the Dot limestone, as shown by erosion of several inches to

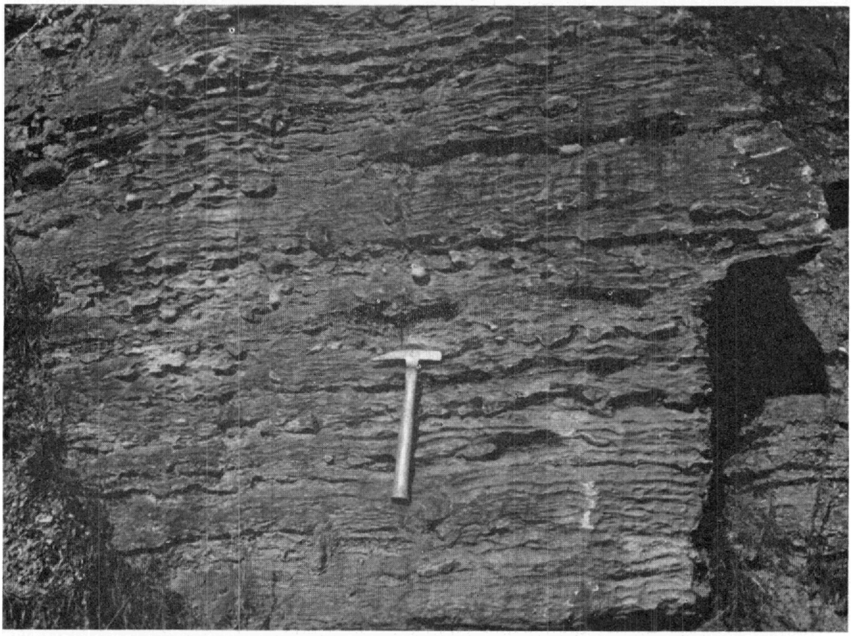

FIGURE 7.—Nodular chert in dark-colored limestones of the lower part of the Poteet limestone at the east end of the main street of Jonesville.

a foot of beds below the contact. This may be seen in good exposures of the contact, such as the one on State Route 70 at the east end of Jonesville. The disconformity is also evidenced by the inclusion of conglomeratic pebbles in the basal bed of the Poteet. The contact is in most places sharp and clear even where the basal bed of the Poteet is not conglomeratic or fragmental, because of the contrast between the tan pure limestone at the top of the Dot limestone and the dark-gray, impure, and oily-smelling limestone at the base of the Poteet limestone.

Where the Rob Camp limestone overlies the Poteet limestone, the formations are conformable. The Rob Camp limestone is absent, however, in much of the western part of the district, and in these areas the Martin Creek limestone unconformably overlies the Poteet limestone.

Paleontology and thickness.—Fossils are present but not abundant in the Poteet limestone. The fauna consists of brachiopods, gastropods, straight cephalopods, bryozoans, and cystids; but in most places the fossils are too poorly preserved and too fragmental to be identified. The only form that has been positively identified is a massive species of *Tetradium.*

The Poteet limestone ranges in thickness from 56 feet at Dot to 97 feet at Hagan. The average of eight measurements in and near the Jonesville district was 79 feet.

Correlation.—The Poteet limestone is equivalent to the upper part of the Murfreesboro limestone of Butts in Lee County, and it probably correlates with zone 3, the blocky chert zone, of the Blackford formation of Cooper (1944) in Tazewell County.

ROB CAMP LIMESTONE

Name and type section.—The Rob Camp limestone is named from excellent exposures of the formation half a mile north of Rob Camp Church in the Rose Hill district. Rob Camp Church is in the northwest corner of Hancock County, Tenn., 3 miles south of the Lee County line. The section measured by Fuller and Miller at Rob Camp Church and listed as geologic section 7 in the Rose Hill report (Miller and Fuller, in press, pl. 1 and geologic section 7), is reproduced here as geologic section 10; new formation names as used in this report are applied as shown below:

Geologic section 10 *(this report)*	*Geologic section 7* *(Rose Hill report)*
Martin Creek limestone	Lenoir limestone.
Rob Camp limestone	Mosheim limestone.
Poteet limestone	Chert member of Murfreesboro limestone.
Dot limestone	Limestone and dolomite members of Murfreesboro limestone.

Distribution.—The Rob Camp limestone is present in the western and the extreme eastern parts of the Jonesville district, but is absent over the east central part of the district. Along most of the Sugar Run lowland the exposures of this part of the section are extremely poor, but the Rob Camp limestone is known to be present along the lowland from the vicinity of Chances Chapel to the western edge of the district. It is believed to be continuously absent from Chances Chapel to Ben Hur, although its absence can be unequivocally demonstrated at only a few places along this 10-mile belt. It is present again in Cane Creek valley east of Ben Hur. Along the Powell River lowland, the Rob Camp limestone is present in the section at Yellow Branch half a mile southwest of the edge of the Jonesville district, but it pinches out just southwest of the border of the Jonesville district. From there it is continuously absent as far east as State Route 70, beyond which it is continuously present to the eastern edge of the district, except for one short interval near Poteet Ferry bridge. The Rob Camp limestone, where present, forms narrow belts along the Powell River and Sugar Run lowlands, but in the vicinity of Hickory Flats, where the dips are very gentle, the belt of outcrop widens in places to more than 500 feet.

Character.—In the western part of the Jonesville district and throughout almost all of the adjacent Rose Hill district, the Rob Camp limestone is lithologically uniform. It consists of pure, very massive-bedded, dove-gray to tan, dense cryptocrystalline limestone with numerous specks and patches of white crystalline limestone called birdseyes. The rock weathers white and commonly has fluted surfaces caused by solution along subparallel or radiating rill-like grooves. This lithology has been variously referred to by differnet authors as vaughanite, calcilutite, sublithographic limestone, Mosheim-lithology, and massive birdseye limestone. It is very distinctive but is not confined to the Rob Camp limestone. Zones of identical-appearing limestone occur near the top of the Dot limestone (see p. 36) and in the Hurricane Bridge limestone. In eastern parts of the Jonesville district, the Rob Camp limestone is composed predominantly of massive birdseye limestone identical to that described above, but it also includes one or two zones of thinner-bedded cryptocrystalline limestone that contain nodular chert. (See geologic section 11.) Inasmuch as the chert-bearing zones are overlain and underlain by massive-bedded birdseye limestone typical of the Rob Camp, and the whole sequence is underlain by typical Poteet limestone and overlain by typical Martin Creek limestone, the chert-bearing limestones must be included in the Rob Camp limestone.

Stratigraphic relations.—The Rob Camp limestone conformably overlies the Poteet limestone. The contact in most places is a sharp break, but there is no sign of any erosion of the beds below the contact. The Rob Camp is unconformably overlain by the Martin Creek limestone. This unconformity is best exhibited in a quarry near Walnut Hill School on U. S. No. 58, 17 miles west of Hagan. At this locality the Rob Camp limestone is deeply channeled and the channels filled by fragmental limestone of the lower part of the Martin Creek limestone. Within a horizontal distance of only 300 feet the Rob Camp limestone dwindles from a thickness of 34 feet to nothing and then increases to 18 feet as the result of channeling in pre-Martin Creek time. The exposure has been diagrammed in figure 7 of Virginia Bulletin 71, where the names Murfreesboro, Mosheim, and Lenoir limestones were used for beds that are here referred to as Poteet, Rob Camp, and Martin Creek limestones respectively. Where the basal beds of the Martin Creek limestone are fine-crystalline or cryptocrystalline limestone rather than fragmental limestone, the contact with the Rob Camp limestone is commonly "frozen" and a solid hand specimen may be collected across it. Nevertheless, it is sharp rather than gradational, and is irregularly undulatory.

Paleontology and thickness.—The Rob Camp limestone is sparingly fossiliferous, and the fossils are extremely difficult to collect because the rock normally fractures and weathers across rather than around the fossils. The commonest forms are gastropods belonging to the genera *Lophospira* and *Trochonemella*, and the coral *Tetradium syringoporoides*. Many of the small calcite birdseyes are said to be sections of *Tetradium* corallites that have been replaced by crystalline calcite. One specimen of *Stromatocerium* was found in the Rob Camp limestone along State Route 66 just west of Woodway.

The Rob Camp limestone ranges in thickness from a knife edge in places along the Powell River to 153 feet in the section west of Dot (geologic section 7). Where the Rob Camp limestone is less than 2 feet thick it is practically indistinguishable from other limestones of similar appearance in the Poteet limestone and its presence would probably be recognized only in perfect exposures. The thickness is greatest in the eastern part of the district, around Woodway and Dot, where its thickness approaches or exceeds 100 feet. The formation is absent in about half of the Jonesville district. The changes in thickness may be due in part to facies changes and convergence but are principally due to varying amounts of erosion in the hiatus between Rob Camp time and Martin Creek time.

Correlation.—The Rob Camp limestone is the exact equivalent of the Mosheim limestone as the name Mosheim limestone has been used by Butts (1940, pp. 135–139) and by Miller and Fuller (in press) in Lee County. In northeastern Lee County, Bates (1939) included in his Mosheim limestone all of the beds here assigned to the Rob Camp limestone, Poteet limestone, and limestone member of the Dot limestone.

Prouty (1946) has recently identified his Five Oaks limestone, which has its type locality in Tazewell County, in various sections in and near Lee County. His description of the formation and general discussion of sections indicate that his Five Oaks limestone is in most places the same as Butts' Mosheim limestone of southwest Virginia. In Lee County, Butts' Mosheim is identical with the Rob Camp limestone of this report. In specific localities within the Jonesville and Rose Hill districts, however, Prouty has applied the name Five Oaks to different stratigraphic units. For example, at Yellow Branch just southwest of the Jonesville district, Prouty (1946) calls the massive-bedded limestone at the top of the Dot limestone (10-foot vaughanite) the Five Oaks limestone. But at Dot, where the section is nearly identical to the one at Yellow Branch, the 10-foot vaughanite at the top of the Dot limestone was not seen by Prouty. It lies at the top of his zone 2 of the Blackford formation in the exact stratigraphic position of the 18-foot covered interval at the top of his measured section. (Prouty, 1946, table 2, p. 1147.) The 10-foot vaughanite (calcilutite or massive birdseye limestone) is exposed a few feet south of the road along which he measured his section and is overlain by the cherty Poteet limestone. At Ben Hur, Prouty's graphic section (1946, fig. 5*A*) shows his Blackford and Five Oaks to be covered, but he states (p. 1148): "Just west of Ben Hur the zone (Five Oaks) shows a normal relationship to the overlying beds." According to Prouty (1946, pp. 1152, 1158), the overlying beds here are a few feet of "gradational Lincolnshire and Thompson Valley" overlain by a few feet of beds believed to be Ward Cove limestone. The exposures he is describing must be in the roadcut a few hundred feet west of the quarry along the highway and approximately a third of a mile west of the center of Ben Hur, because there are no other good exposures along the road west of Ben Hur and only one or two small scattered outcrops in the fields south of the road. The beds in that roadcut are basal Hurricane Bridge limestone overlying typical chert-bearing Martin Creek limestone. The beds cropping out in the quarry and on the slopes north of the highway are higher in the Hurricane Bridge limestone and may be the ones to which Prouty was referring. The Rob Camp limestone is believed by the writers to be absent in the vicinity of Ben Hur, but this cannot be proved as there are no outcrops from a point near the base of the Martin Creek limestone to the top of the Mascot dolomite. The so-called 10-foot vaughanite at the top of the Dot limestone, which was Prouty's Five Oaks at Yellow Branch, lies in this covered interval.

Thus the name Five Oaks limestone has been applied by Prouty to three different limestone horizons in Lee County, with the result that his underlying Blackford formation, which includes everything from his Five Oaks down to the top of the Knox group, has also been applied in various ways. At Yellow Branch, his Blackford includes all of the Dot limestone except the 10-foot vaughanite at the top. At Dot the lower two zones of his Blackford comprise all of the Dot limestone, including the 10-foot vaughanite, and he indicates that his upper or blocky chert zone is either absent or covered (Prouty, 1946, p. 1147). At Ben Hur, his Blackford includes the Dot limestone, Poteet limestone, and Martin Creek limestone.

The writers believe that the Rob Camp limestone of the Jonesville district probably correlates with the Five Oaks limestone of Cooper and Prouty in Tazewell County, but this correlation cannot be considered established until more stratigraphic work, paleontologic work, and detailed mapping are done to see how the various interfingering chert-bearing limestones and pure massive-bedded limestones behave in the intervening areas.

MARTIN CREEK LIMESTONE

Name.—The type section of the Martin Creek limestone is along the county road that climbs the bluff west of the bridge across Martin Creek at its junction with the Powell River (geologic section 12). This section is in the northwest corner of Hancock County, Tenn., and is shown on plate 1 of Virginia Survey Bulletin 71 on the geology of the Rose Hill district. In that report the Martin Creek limestone was called the Lenoir limestone after Charles Butts.

Distribution and topographic expression.—The formation forms a narrow belt of outcrop along Sugar Run lowland on the north side of the district and a somewhat wider belt along the Powell River lowland. A narrow belt of Martin Creek limestone is also present in the Cane Creek lowland east of Ben Hur, and another belt lies in the slice between branches of the Wallen Valley fault in the south central part of the district.

This formation is the least resistant to erosion of those studied, with the possible exception of the Upper Devonian shale, and it commonly underlies the lowest parts of the limestone valleys and lowlands. Outcrops of the formation are relatively rare except along stream valleys, in bluffs of the Powell River, and in roadcuts. Areas underlain by the Martin Creek limestone are almost everywhere cleared of timber, and most of the cleared land is cultivated. In the Powell River lowland and in the area known as The Cedars, the overlying Hurricane Bridge limestone has abundant ledgy outcrops that begin practically at the base of the formation. This ledgy land has consistently been left in timber, and the line between cleared and timbered areas follows the Martin Creek and Hurricane Bridge contact with remarkable fidelity.

Character.—Three types of limestone comprise the Martin Creek limestone. The first of these is coarse-crystalline, dark-colored limestone that contains numerous fossil fragments and emits a petroliferous odor immediately after being fractured. Cross-bedding is visible on weathered surfaces of some ledges. This type of limestone is called fragmental limestone. It occurs also in the lower part of the Poteet limestone, and its origin was discussed under that formation. The fragmental limestone normally does not contain chert, but locally a few nodules of chert are present. In most sections there are a few beds of fragmental limestone at or near the base of the formation, but in some areas fragmental limestone is absent and in others it attains a thickness of several dozen feet. One of the best and thickest displays of fragmental limestone in the lower part of the Martin Creek limestone is in the quarry along Fleenortown Creek an eighth of a mile north of U. S. No. 58. The zone of fragmental limestone exposed in the quarry is 43 feet thick.

The second type of limestone is also dark-colored and oily smelling, but it is very dense and fine-grained. It invariably contains abundant knobby nodules of chert, which are flattened in the plane of the bedding. Along some zones the nodules are very closely spaced or they have coalesced. The chert is various shades of gray to black, but it weathers with peripheral bands about an eighth of an inch thick from which most of the dark color has been removed. The fine-grained, dark-colored limestone is the predominant rock type in the lower part of the Martin Creek limestone. Where fragmental limestone is present in the formation, a few feet of the fine-grained dark-colored limestone may underlie the fragmental limestone, and several dozen feet of this type of rock invariably overlie the fragmental beds. Where fragmental limestone is absent, the lower one-third to one-half of the Martin Creek limestone is composed almost entirely of the fine-grained, dark-colored limestone.

The upper part of the Martin Creek limestone is composed of light-tan or buff, dense, fine-crystalline to cryptocrystalline limestone in beds from a few inches to about a foot thick. Some of this limestone is very pure, but other beds are argillaceous or silty. Nodular chert, similar to that described above, is abundant in the lower part of the zone of light-colored limestone and is present but much less abundant in the upper part. The light-colored limestone is interbedded with the dark-colored fine-grained limestone in a transition zone about in the middle of the formation.

The Martin Creek limestone produces a very abundant float of broken chert nodules. The chert cobbles in places are as abundant as those derived from the Longview and Mascot dolomites, but they differ in being darker in color and generally smaller in size, and in having one or more well-rounded surfaces. A good display of chert of the Martin Creek in a cultivated field is shown in figure 8. The dark-colored limestones of the Martin Creek limestone produce a clay soil that tends to be bright orange or red but is not consistently so, and the light-colored limestones produce a yellow clay soil.

Stratigraphic relations.—The Martin Creek limestone unconformably overlies the Rob Camp limestone, or where this is absent it overlies the Poteet limestone. As previously explained, absence of the Rob Camp limestone is believed to be due to its removal by erosion in pre-Martin Creek time. Where the Rob Camp limestone is the underlying formation, the basal bed of the Martin Creek limestone is normally of the fine-grained, dark-colored limestone, which has a sharp but undulatory, frozen contact with the light-colored cryptocrystalline birdseye limestone of the Rob Camp. Where the Martin Creek limestone lies on the Poteet limestone, the basal beds of the Martin Creek may be either fine-crystalline, dark-colored limestone or coarse-crystalline fragmental dark-colored limestone. These may lie on light-colored, even-bedded limestones of the upper part of the Poteet limestone, or if erosion in pre-Martin Creek time has been still more profound they may lie on the dark-colored limestones of the lower part of the Poteet. A contact is illustrated in the photograph in figure 9, where fragmental dark-colored Martin Creek limestone above the hammer overlies tan cryptocrystalline Poteet limestone below the hammer. The lighter-colored lenticular bed along the

FIGURE 8.—Abundant float of nodular chert derived from the Martin Creek limestone, on a hill crest directly north of Hurricane Church.

contact belongs in the Poteet limestone. Its color was probably removed by leaching in pre-Martin Creek time. Where dark-colored fine-grained limestones of the two formations are in juxtaposition, the exact contact is extremely difficult to locate. It should be noted, however, that the sequence of lithologies of the Martin Creek and Poteet limestones is identical, namely fragmental limestone at or near the base, overlain by chert-bearing fine-grained dark-colored limestone, in turn overlain by fine-grained to cryptocrystalline light-colored limestone. The Poteet-Martin Creek contact lies at the base of the upper or Martin Creek sequence and it is at the base of, or a very few feet below, the second zone of fragmental limestone encountered in going upward across the section.

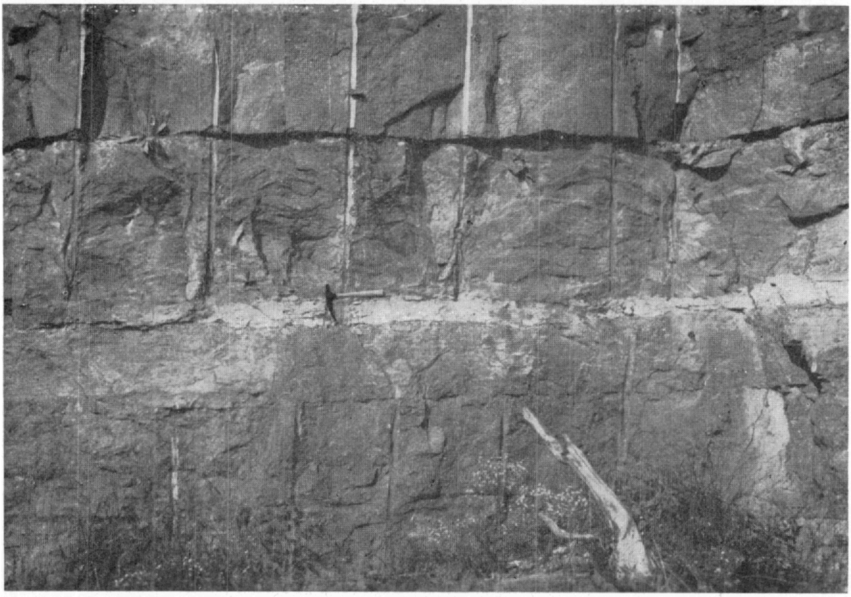

FIGURE 9.—Dark-colored fragmental limestone of the Martin Creek limestone directly overlying tan cryptocrystalline limestone of the Poteet limestone, with the Rob Camp limestone missing. In quarry on the west side of Hardy Creek just above its junction with the Powell River.

The Martin Creek limestone is conformably overlain by the Hurricane Bridge limestone. The contact is described in the section on the Hurricane Bridge limestone.

Paleontology.—Fossils are abundant in the fragmental limestones of the Martin Creek but are normally too fragmented to be identified. Cystid plates, small bryozoans, crinoid (?) stems, and brachiopod fragments may be seen in almost any weathered exposure of the fragmental limestone. The overlying limestones contain fossils in some zones, but most of the beds are barren. Brachiopods, corals of the genus *Tetradium*, ostracodes, and straight cephalopods are commonest. The following from the Jonesville district have been identified by G. A. Cooper of the U. S. National Museum:

Strophomena sp.
Strophomena n. sp.
Rostricellula sp.
New genus related to *Strophomena.*
New genus related to *Camerella.*
New genus related to *Leptaena.*
Isotelus sp.
Cystid plates.

Thickness.—The Martin Creek limestone ranges in thickness from about 50 feet southeast of the Poteet Ferry highway bridge to 182 feet in the section at Poteet Ford (geologic section 9). In general the Martin Creek limestone is thickest where the Rob Camp limestone is thin or absent. This is not due to facies changes whereby part or all of the Rob Camp limestone has gone over to Martin Creek lithology, for the two are separated by a distinct unconformity. Rather it appears to be caused by the fact that Martin Creek deposition began in the lowest areas, which were probably the most deeply eroded areas, and by the fact that in these lowest areas a much greater thickness of rapidly deposited clastic fragmental limestone accumulated. There are exceptions, however, to the statement that the Martin Creek limestone is thickest where the Rob Camp limestone is thinnest. On the first meander spur on the south side of the river west of Sewell Bridge, the Martin Creek has fair exposures and appears to be only 40–50 feet thick, and the underlying Rob Camp appears to be only 16–30 feet thick.

Correlation.—The Martin Creek limestone is equivalent to the Lenoir limestone described by Butts (1940, pp. 120–141) in Lee County and the "Lenoir limestone" of Huffman (1945) in Lee County. It seems to correlate at least in part with Cooper and Prouty's Lincolnshire limestone of Tazewell County. (Cooper and Prouty, 1943.) The relation of the Martin Creek limestone to the type Lenoir limestone in Loudon County, Tenn., has not been established.

HURRICANE BRIDGE LIMESTONE

Name.—The Hurricane Bridge limestone has its type locality in the vicinity of Hurricane Bridge and Hurricane Chapel on the Powell River 2½ miles southwest of Jonesville. The formation is well exposed in the woods in this vicinity, but the section measured along the north-south county road (geologic section 13) has a long covered interval. Hence the type section is taken along State Route 70 north of Sewell Bridge (geologic section 14), where the exposures are more nearly continuous. The name was first used by Miller and Brosgé

(1950) on a preliminary map. The formation is identical to the redbed member of the Lowville limestone as mapped by Miller and Fuller (1947; in press) in the Rose Hill District.

Distribution.—The Hurricane Bridge limestone has only narrow belts of outcrop along the Sugar Run lowland and in the valley of lower Cane Creek because of the steep dips in these areas. A short belt of Hurricane Bridge limestone is also exposed inside the Bethel fenster. Along the Powell River lowland, the belt of this formation is of moderate width in the south-central part of the district, but spreads out over broad areas where the dips are very gentle in the southwestern part of the district and near Cedar Knob. It also underlies a broad area named The Cedars, which lies along the deepest part of the trough of The Cedars syncline.

Topographic expression.—Taken as a whole, the Hurricane Bridge limestone is the best-exposed formation in the district. The outcrops are moderately abundant along the Sugar Run lowland, where the dips are consistently steep, but they are extremely abundant along the Powell River lowland, where the dips are gentle. The small and medium-sized ledges produced by the nonargillaceous limestones of the formation are closely spaced. Most of the land has been left in timber and supports a scrub forest in which cedar trees predominate. The land underlain by the Hurricane Bridge limestone thus has little value for either agriculture or timber. In places it is used for pasture land.

Character.—The Hurricane Bridge limestone is mainly composed of interlayered zones of three types of limestone. The most conspicuous of these in outcrop is a tan or dove-gray, dense, pure, cryptocrystalline limestone in massive beds from 1 to 4 feet thick. This limestone has numerous individual crystals and patches of white coarse-crystalline calcite (birdseyes). It weathers to a bluish-white color. The massive beds weather with very irregular surfaces that are pitted and fluted by solution. The rock is lithologically identical to that previously described at the top of the Dot limestone and in the Rob Camp limestone, and as previously noted has been called by different authors vaughanite, calcilutite, sublithographic limestone, massive birdseye limestone, and Mosheim-like or Mosheim-lithology. A typical exposure of a thick zone of this type of limestone is shown in figure 10.

This massive-bedded birdseye limestone forms zones from a few feet to 65 feet thick, which crop out as massive ledges. The thicker zones are traceable for many miles, but they tend to become interbedded along the strike with thin-bedded platy limestones or argillaceous limestones, and so eventually lose their identity. At Hagan three zones of massive birdseye limestone are present, as shown in the cor-

FIGURE 10.—Massive-bedded birdseye limestone in the lower part of the Hurricane Bridge limestone along the county road one-fourth mile north of Flanary Bridge.

relation chart of stratigraphic sections (pl. 5). The highest one, though only 4 feet thick, forms a prominent ledge, and was traced over most of the Rose Hill district to the west. It has not been recognized east or southeast of Hagan. The second zone from the top is 29 feet thick at Hagan. It is present in the vicinity of Hurricane Bridge but lies in a covered interval in the section measured at that place (pl. 5). It was not recognized in the eastern part of the Jonesville district. The third zone from the top is 25 feet thick at Hagan if only continuous massive beds of birdseye limestone are included, or 40 feet thick if an overlying zone of interbedded massive and platy birdseye limestone is included. This is the same zone as the 46-foot zone of massive birdseye limestone at Hurricane Bridge and the 54-foot zone at Sewell Bridge. In the section at Woodway only one zone of massive birdseye limestone is present. It lies somewhat higher above the base of the formation than does the 54-foot zone at Sewell Bridge, but it may be the same one.

The second type of limestone in the Hurricane Bridge limestone is tan and cryptocrystalline, like that previously described, but is in even platy beds a few inches thick, and it normally lacks the calcite birdseyes. In some areas the bedding is wavy, giving a nodular appearance to the weathered rock. This type of limestone is most abundant in the lower and upper parts of the formation but is present throughout.

The third type of limestone in the Hurricane Bridge limestone is an argillaceous fine-grained limestone that weathers buff, yellow, or red, and forms weak, earthy to shaly zones. Mudcracks are common, but stripped bedding surfaces affording good exposures of the mudcracks are rare. These argillaceous zones are also persistent for miles along the strike. They tend to change facies gradually, however, so that argillaceous zones are present in some measured sections and are absent in others. The most persistent argillaceous zone is the one a few feet above the base of the member. This is recognizable throughout the Jonesville district. Other argillaceous zones are less widespread, but the 18-foot zone in the lower part of the formation at Hagan is recognizable 9 miles to the southeast at Hurricane Bridge, where it is 11 feet thick.

A fourth type of limestone that is present at some places but totally lacking at others is a tan or brown medium- to coarse-crystalline limestone with a marble-like texture. This is abundant in the upper half of the formation in the Sewell Bridge section, and one zone of it is present at Woodway (pl. 5).

The Hurricane Bridge limestone is essentially noncherty, but nodules of chert are locally present in two zones. The lower of these is about a third of the way above the base of the formation. Normally the chert is confined to two or three lines of nodules spaced a few feet apart in a zone 5–10 feet thick, as at Hagan (pl. 5). At Woodway, however, the chert is very abundant through a zone 40 feet thick. The upper chert-bearing zone is at the top of the formation, where chert nodules and chertified fossils are common in the top 10–20 feet of limestone.

Stratigraphic relations.—The Hurricane Bridge limestone conformably overlies the Martin Creek limestone. The contact is placed above the highest tan cryptocrystalline limestones that carry numerous chert nodules and below the persistent buff-weathering, argillaceous and shaly zone that lies from a few feet to 10 or 15 feet higher. One or more beds 1–2 feet thick of massive birdseye limestone crop out persistently throughout the Jonesville district below the buff-weathering argillaceous zone. The contact was drawn at the base of the zone in which these birdseye limestones occur because that furnished the most mappable horizon and because this type of limestone is common in the Hurricane Bridge limestone. The application of these criteria for identifying the Martin Creek and Hurricane Bridge contact has resulted in a mapped contact along the southern limestone lowland in the western part of the district that is believed to be consistently at, or within a few feet of, the same horizon and is the same as the contact mapped in the Rose Hill district. The mapped contact throughout the northern limestone lowland and in the central and eastern parts of the southern limestone lowland is also believed to be consistently at, or within a few feet of, the same horizon. Along the Powell River, in the vicinity of Tyler Bend, however, the mapped contact changes horizon by 23 feet because the chert-bearing zone and the overlying argillaceous zone are higher southwest of Tyler Bend than in the region to the northeast. Thus 23 feet of beds that are included in the basal Hurricane Bridge limestone east of Tyler Bend are of the same age as beds at the top of the Martin Creek limestone west of the bend. The change in mapped horizon is shown on plate 1 as an overlapping and offsetting of the mapped contact at two places, one on the north side of the Powell River southwest of Tyler Bend and the other on the south side of the river southeast of Tyler Bend.

Within the formation, the zones and lenses of massive birdseye limestone, argillaceous limestone, platy cryptocrystalline limestone, and coarse crystalline limestone change thickness and facies from one part of the district to another. These lithologic zones within the formation are mappable over short or moderate distances, but their intertonguing relationships cause the sequence of lithologic zones to differ in different parts of the district. Thus on lithologic grounds or on sequences of lithologies, the correlation of subdivisions of the Hurricane Bridge limestone with stratigraphic units or formations in other areas is subject to serious error.

The Hurricane Bridge limestone is conformably overlain by the Woodway limestone. The criteria used in mapping the contact are discussed in the description of that limestone.

Paleontology.—The Hurricane Bridge limestone has abundant fossils in a few beds and scattered fossils in many beds, but most of the beds are unfossiliferous. *Tetradium* sp. is common, especially in the lower part of the formation, and brachiopods, bryozoans, straight cephalopods, medium-spired gastropods, and ostracodes, are also common. The fossils identified from the formation in the Jonesville district are listed below.

Tetradium sp., probably new species.
Stromatocerium sp.
Holopea sp.
Trochonema sp., probably same as Butts' *Trochonemella trochonemoides.*
Fragmentary gastropods suggesting *Hormotoma.*
Unidentified bryozoans.

Thickness and correlation.—The thickness of the Hurricane Bridge limestone has been determined in measured sections at four localities. At Hagan it is 331 feet thick, at Hurricane Bridge 327 feet thick, at Sewell Bridge 368 feet thick, and at Woodway 288 feet thick. The Hurricane Bridge limestone correlates with the lower part of the Lowville limestone as mapped by Butts and others in southwest Virginia and northeast Tennessee. The correlation with the New York section has not been established.

WOODWAY LIMESTONE

Name.—The Woodway limestone is named from the town in the eastern part of the Jonesville district, near which the formation has numerous exposures. The type section (geologic section 11) was measured on the north slopes of Elk Knob, 1¾ miles east of Woodway. There are numerous other sections almost equally good along the steep slopes of Elk Knob and Wallen Ridge east of Woodway. The name Woodway limestone was first used by Miller and Brosgé (1950) on a preliminary map of the Jonesville district. The formation is exactly equivalent to the platy member of the Lowville limestone as mapped by Miller and Fuller (1947; in press) in the Rose Hill district.

Distribution and topographic expression.—The Woodway limestone occurs in two long narrow belts on opposite sides of the Jonesville district. Shorter belts are also present in the valley of lower Cane Creek and inside the Bethel fenster. The formation has numerous outcrops on the lower slopes of Wallen Ridge on the south side of the Powell River lowland, and somewhat less numerous outcrops on the low hills and the spurs of Poor Valley Ridge that rise above the floor of the Sugar Run lowland. Because the Woodway limestone is thin-bedded it forms small discontinuous ledges that are much less prominent than those in the underlying Hurricane Bridge limestone. The outcrops are sufficiently numerous and closely spaced that they are a considerable obstacle to cultivation of the soil, and most of the belts of Woodway limestone have been left in timber. Cedar trees predominate in the scrubby woods, but in places moderate-sized deciduous trees are sufficiently abundant to have some value as timber.

Character.—The Woodway limestone is composed predominantly of tan or light-brown, thin-bedded limestone that is cryptocrystalline or fine-grained. Local zones of the limestone are argillaceous or silty, but most of the limestone is quite pure. The beds weather bluish-gray to bluish-white. A few beds are included that are a foot or more thick and resemble the massive-bedded birdseye limestones so characteristic of the Hurricane Bridge and Rob Camp limestones. The only other rock type of quantitative importance is a light- to medium-brown, medium- to coarse-crystalline limestone with a marble-like texture; it occurs as lenses, individual beds, and zones a few feet thick at numerous horizons and is particularly abundant in the middle and lower-middle parts of the formation. Scattered small irregular-shaped nodules of light-colored chert are almost invariably present in the bottom 10–20 feet of the formation, and one or more zones containing chert nodules may be present in the upper half of the formation. A chert-bearing zone about 50 feet below the top of the formation was seen at many localities. The top 10 or 15 feet of the formation are composed of more argillaceous limestone than the rest of the formation and are transitional into the overlying highly argillaceous Ben Hur limestone. Graphic sections of the Woodway limestone at four localities are shown on plate 5, and measured stratigraphic sections at Woodway, Hurricane Bridge, and Sewell Bridge (geologic sections 11, 13, and 14) are given at the end of the stratigraphic chapter.

Stratigraphic relations.—The Woodway limestone conformably overlies the Hurricane Bridge limestone with no break in the sedimentary sequence. There are, however, striking differences in the gross lithology of the two formations. The contact is drawn at a horizon above all the prominent zones of massive-bedded birdseye limestone and yellow- or red-weathering argillaceous limestone, and it is below the part of the section that contains abundant medium- and coarse-crystalline limestone interbedded with the fine-grained limestone. This lithologic division is not clear-cut, but the contact may be consistently drawn at, or within a few feet of, the same horizon because of the association in an interval about 40 feet thick of three fossiliferous zones, the lowest containing conspicuous silicified large gastropods of the genus *Holopea*, the middle containing the sponge-like coelenterate *Stromatocerium rugosum*, and the upper containing the brachiopod *Öpikina* in persistent abundance and locally the brachiopod *Hesperorthis* in abundance. The fossiliferous zone is further marked by the presence of chert nodules, usually at several different horizons, whereas the limestones for more than 80 feet above and below this zone are noncherty. The base of the Woodway was drawn at the lowest appearance of *Stromatocerium rugosum* in this zone. This first appearance is consistently at or very close to the same stratigraphic horizon, as shown by its relation to the *Holopea* zone below and particularly to the *Öpikina* zone above, which is only a few feet thick and is invariably 5–15 feet above the first appearance of *Stromatocerium*. In the Rose Hill district there are in places one or two zones of abundant *Stromatocerium* above the *Stromatocerium* zone that marks the base of the formation; but in the Jonesville district no zones of abundant *Stromatocerium* were found above the base of the formation, though individual specimens were noted at several higher horizons in the Woodway limestone.

The Ben Hur limestone conformably overlies the Woodway limestone. The contact is transitional through a few feet of beds that are intermediate in purity between the platy, relatively pure limestones of the Woodway limestone and the yellow-weathering, argillaceous, earthy and shaly limestones of the Ben Hur limestone. The contact was drawn above this transition zone. The transition zone is characterized by a great abundance of bryozoans belonging principally to the genera *Rhinidictya* and *Escharopora*.

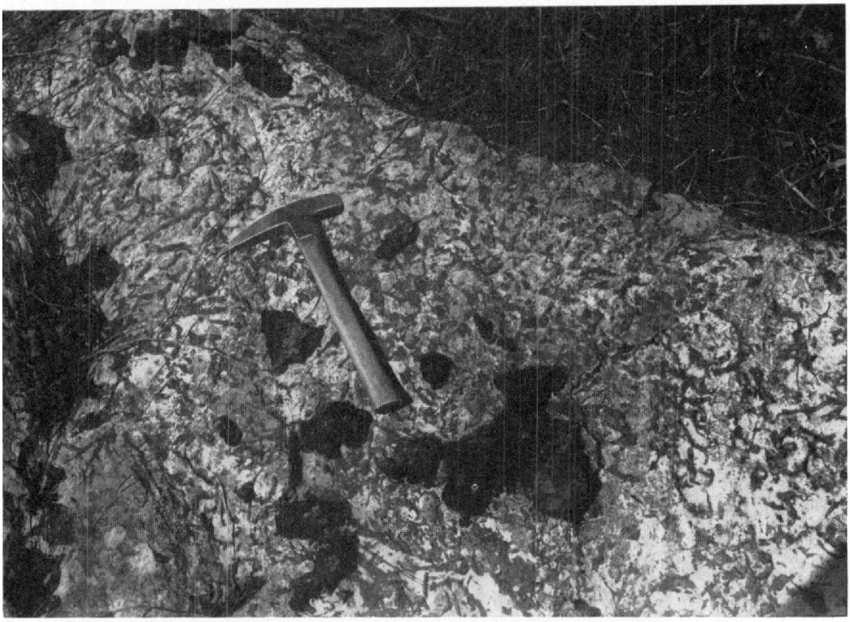

FIGURE 11. Chert nodules and markings of the sponge *Camarocladia* in a bed 55 feet below the top of the Woodway limestone. From unit 28 of measured section 14 near Sewell Bridge.

Paleontology.—The Woodway limestone contains a few beds or zones with abundant fossils and numerous zones with scattered fossils. In addition to the previously discussed *Stromatocerium* zone and *Öpikina* zone at the base of the formation and the bryozoan zone at the top of the formation, the upper half of the formation is characterized by stem-like markings of the sponge *Camarocladia.* These are extremely abundant in the upper half of the formation and are locally present below the middle of the formation (pl. 5). A good example of *Camarocladia* in a bed which also contains chert nodules is shown in figure 11. The stromatoporoid *Cryptophragmus antiquatus* first appears about 75 feet above the base of the formation and ranges through about 100 feet of beds. It is by no means abundant, but one or more specimens may usually be found in any locality where the outcrops of this part of the formation are extensive. In addition to the fossils discussed above that characterize zones or parts of the Woodway limestone, the formation as a whole contains numerous brachiopods, especially of the genera *Öpikina* and *Zygospira*, corals identified as *Tetradium cellulosum* and *Tetradium* sp., bryozoans, orthoceracone cephalopods, gastropods, and ostracodes of the genus *Isochilina.* The forms identified from incomplete collections made in the Jonesville district are:

Stromatocerium sp.
Cryptophragmus antiquatus Raymond.
Foerstephyllum sp.
Camarocladia? sp.
Rostricellula sp.
Zygospira cf. *Z. recurvirostris* (Hall).
Doleroides sp.
Öpikina sp.
Strophomena sp.
Ancistrorhyncha costata Ulrich and Cooper.
Liospira sp.
Modiolopsis sp.
Unidentifiable sponge.
Bryozoa.
Crinoid stems.

Thickness.—The thickness of the Woodway limestone is remarkably uniform throughout the Jonesville district. In four measured sections of the formation, the thicknesses were as follows: 256 feet at Hagan, 251 feet at Hurricane Chapel, 267 feet at Sewell Bridge, and 289 feet at Woodway.

Correlation.—The Woodway limestone is equivalent to the middle part of the Lowville and Moccasin limestone sequence of Butts and Bates. The *Cryptophragmus* and *Camarocladia* zones, which account for the upper three-fourths of the formation, probably correlate exactly with the same zones of Cooper and Prouty's Witten limestone in Tazewell County (Cooper and Prouty, 1943); but where the base of their Witten limestone would lie in Lee County is not clear. It must, however, be above the basal *Stromatocerium* zone of the Woodway limestone, which seems to be at or near the same horizon as the *Stromatocerium* zone in their Wardell formation of Tazewell County. Prouty (1946, pp. 1172–1176) has recently described his Witten formation in Lee County. In the belt of limestone along the Powell River lowland he includes in his Witten the *Camarocladia*- and *Cryptophragmus*-bearing beds plus an indeterminate thickness of underlying beds. These underlying beds cannot, however, exceed 50 feet because he includes in his Wardell formation the basal *Stromatocerium* zone of the Woodway limestone. Along the northern limestone lowland (Cumberland belt of Prouty), however, he includes in his Witten limestone more than 500 feet of beds underlying the *Cryptophragmus*-bearing beds (Prouty, 1946, p. 1175). In his section at Ben Hur (1946, fig. 5*A*) he includes 650 feet of pre-Moccasin (pre-Ben Hur) beds in his Witten. This is probably almost the same interval as is occupied by the combined Woodway and Hurricane Bridge limestones of this report, although our measurement of the thickness of these two formations at Ben Hur is 583 feet. If Prouty is correct in stating that in the southern limestone lowland (Powell Valley belt of Prouty) the *Camarocladia-* and *Cryptophragmus*-bearing beds plus a few tens of feet of underlying beds are the equivalent of the Witten limestone of Tazewell County, then he cannot be right in his identification of a greatly thickened Witten in the northern limestone lowland (Cumberland belt of Prouty). By mapping and measuring the closely spaced sections in the Jonesville district (pl. 5) and in the Rose Hill district (Miller and Fuller, in press), it is readily demonstrable that numerous previously described key horizons in both the Hurricane Bridge limestone (redbed member of the Lowville limestone in the Rose Hill report) and the Woodway limestone (platy member of the Lowville limestone in the Rose Hill report) are identifiable in both the northern and southern limestone lowlands of the two districts and that the thicknesses of the Woodway and Hurricane Bridge limestones are remarkably uniform in the two belts. Prouty apparently did not see the *Stromatocerium*-bearing zone anywhere in his Cumberland belt. In his Powell Valley belt he assigns the massive-bedded birdseye limestones (calcilutites) of the Hurricane Bridge limestone to the Gratton limestone, which includes the third calcilutite of Tazewell County; but in his Cumberland belt he assigns the same beds to the Witten limestone, which includes his fourth calcilutite of Tazewell County.

BEN HUR LIMESTONE

Name and distribution.—In Lee County the so-called Moccasin limestone of Huffman (1945, p. 158) and others contains two lithologic divisions, a lower yellow-weathering argillaceous limestone or calcareous mudstone and an upper pure limestone. These divisions are distinct and mappable throughout all of Lee County. In the Rose Hill district (Miller and Fuller, 1947; and in press), the lower division was called the lower member of the Moccasin, and the upper division was called the Hardy Creek member. Miller and Brosgé (1950) have proposed the name Ben Hur limestone for the lower or argillaceous limestone division and the name Hardy Creek limestone for the upper or pure limestone division. The type section (geologic section 15) of the Ben Hur limestone is along the railroad cut of the Louisville and Nashville Railroad 1,000 feet west of the railroad station at Ben Hur.

The Ben Hur limestone has a narrow belt of outcrop along the north side of the Sugar Run lowland and another long narrow belt of outcrop on the lower slopes of Wallen Ridge on the south side of the Powell River lowland. It also crops out in the Bethel fenster, in lower Cane Creek valley, and in the slice between the lower and upper branches of the Wallen Valley fault.

Character.—The Ben Hur limestone is composed predominantly of only one rock type, a light-bluish-gray and light-brown, fine-grained and fine-crystalline, argillaceous limestone with occasional lenses and patches of coarse-crystalline limestone. In the few places where one may see the unweathered bedrock, such as in cliffs along the Powell River or in the quarries at Wheeler east of Cumberland Gap, the rock is in beds from 1 to 2 feet thick and differs very little in appearance from the underlying Woodway limestone or the overlying Hardy Creek limestone. In the normal exposures, however, the Ben Hur limestone weathers to a yellow or greenish-yellow crumbly and shaly rock. Mudcracks are common, but they are not well displayed because stripped bedding surfaces are rare in most exposures of the formation. In regions with good exposures, the belt of outcrop of the Ben Hur is very conspicuous because of the smooth grassy surfaces developed on it, in contrast with the ledgy outcrops of the Woodway limestone below and of the Hardy Creek limestone above.

In places the Ben Hur limestone is moderately fossiliferous, with bryozoans, brachiopods, and ostracodes the most abundant forms.

Stratigraphic relations.—The Ben Hur limestone conformably overlies the Woodway limestone. The contact is drawn at the base of the thick zones of yellow-weathering, shaly, crumbly limestone and above the previously described zone of slightly argillaceous limestone that contains abundant bryozoans. The lithologic change takes place by gradation through a zone a few feet thick. At the top of the formation, the contact with the overlying Hardy Creek limestone is also conformable.

The Ben Hur limestone is equivalent to a tongue of Moccasin limestone extending westward from the area of the type Moccasin at Gate City in Scott County, Va. Lithologically the two formations differ somewhat, however, in that the Ben Hur limestone contains no red beds whereas the Moccasin limestone is predominantly red. It is also more argillaceous than the Ben Hur limestone. Because of similar relations to the underlying *Cryptophragmus*- and *Camarocladia*-bearing beds, the base of the Ben Hur limestone and the base of the type Moccasin are believed to lie at about the same stratigraphic horizon. The top of the Ben Hur limestone would be somewhere in the middle of the type Moccasin. These relations are illustrated in the restored section shown in figure 13.

Paleontology, thickness, and correlation.—Fossils are abundant in some beds of the Ben Hur limestone. The patches and lenses of coarse crystalline limestone are made up in considerable part of fossil fragments. Of the identifiable forms bryozoans of the genera *Rhinidictya*, *Escharopora*, and *Helopora* are abundant, and brachiopods of the genera *Zygospira*, *Strophomena*, *Pionodema*, and *Rhynchotrema* are common.

Five measurements of the thickness of the Ben Hur limestone in the Jonesville district ranged from 126 to 153 feet. This is the normal range of thickness of the formation in the district. At Hurricane Bridge, the formation is apparently only 99 feet thick. In this section the base of the formation is not exposed along the road where the measurements were made. Although the calculated position of the contact in the covered interval may have been somewhat in error, the error could hardly have been large enough to account for all of the discrepancy between this measurement and the next-thinnest measurement.

The Ben Hur limestone correlates with the lower part of the type Moccasin limestone at Gate City as the Moccasin has been restricted by Cooper and Prouty (1943, pp. 879–881).

HARDY CREEK LIMESTONE

Name and distribution.—The name Hardy Creek was first applied by Miller and Fuller (1947) to the upper or pure limestone member of the Moccasin limestone in the Rose Hill district. The unit was raised to formational status by Miller and Brosgé (1950) in a preliminary map on the geology of the Jonesville district. The type section of the formation (formerly a member) is in the cut of a spur of the Louisville and Nashville Railroad along the headwaters of Hardy Creek near Hagan. The section of the Hardy Creek limestone at that locality is given in geologic section 13 in the bulletin on the Rose Hill district,

FIGURE 12.—A zone of oval and lenticular chert nodules in the Hardy Creek limestone along the road south of Hurricane Bridge.

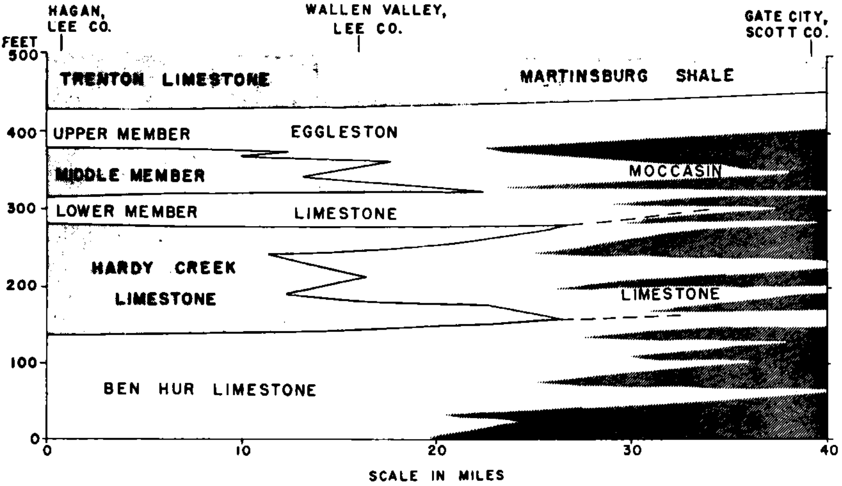

FIGURE 13.—Restored section showing relation of Ben Hur, Hardy Creek, and Eggleston limestones of Lee County to the Moccasin limestone of Scott County. Tongues of pure limestone are shown by light shading, tongues of red calcareous mudstone by heavy shading. Yellow and green calcareous mudstones in the pre-Trenton strata, and gray shale in the Martinsburg shale are blank.

(Miller and Fuller, in press) and is reproduced here as a part of geologic section 16.

The Hardy Creek limestone forms narrow belts on the lower slopes of Wallen Ridge, on the north side of the Sugar Run lowland, in the valley of lower Cane Creek, in the Bethel fenster, and in the slice between the lower and upper branches of the Wallen Valley fault. The belts are characterized by numerous small ledgy outcrops, which are the more prominent because the belts are delimited by the Ben Hur limestone below and the lower member of the Eggleston limestone above, both of which have few and very inconspicuous outcrops.

Character.—The Hardy Creek limestone is composed of tan and brown limestone in platy to fairly massive beds. Some of the limestone is very pure and cryptocrystalline, resembling the pure dense Woodway limestone. Other beds of the Hardy Creek limestone are fine-grained, siliceous, slightly silty and show faint laminations on weathered surfaces. A few beds and lenses may be fine or medium crystalline. All of the above-mentioned limestones weather to a blue-white or light-gray. In addition the Hardy Creek contains lenses and zones of yellow-weathering argillaceous and somewhat shaly limestone that resemble the typical Ben Hur limestone. These tongues of more argillaceous limestone are thin and rare in the Rose Hill district but are thicker and more numerous in sections of the Hardy Creek in the Jonesville district.

One of the most characteristic features of the Hardy Creek limestone is the presence of one or more zones of oval or nearly oval nodules of brown or gray chert. In a few places only one zone of nodules could be found, in the average section two or three zones are present, and in a few places more than three zones have been seen. There is normally one zone of nodules 20 or 30 feet above the base of the formation. Other zones that were seen were not persistently present at any particular horizon. The nodules of chert in the Hardy Creek are very distinctive because of their smooth, symmetrical shapes. Figure 12 is a photograph of typical chert nodules of the Hardy Creek exposed along the road south of Hurricane Bridge (geologic section 13, unit 13). In areas of complex folding and faulting where the identity of the limestone formations may be in doubt, the best criterion for identification of the Hardy Creek limestone is the presence of one or more zones of chert nodules such as are shown in the photograph. The formation is never abundantly cherty.

The Hardy Creek limestone is sparingly fossiliferous except in the top 10 feet of the formation.

Stratigraphic relations.—The Hardy Creek limestone conformably overlies the Ben Hur limestone. The lithologic change from argillaceous yellow-weathering shaly limestones of the Ben Hur to dense hard bluish-white-weathering ledgy limestones of the Hardy Creek is normally abrupt but in places is gradational by interbedding through a zone from a few feet to 15 feet thick.

The Hardy Creek limestone changes facies eastward to yellow-weathering argillaceous limestone. In a section in Wallen Valley almost on a line between Hagan in the Jonesville district and Gate City in Scott County, the base and top of the formation are of dense hard limestone but the middle part, representing about half the thickness of the formation, is argillaceous and weak. Along the line of the restored section there are no belts of outcrop of Middle Ordovician rocks between the Wallen Valley belt, where the Hardy Creek limestone is still recognizable and mappable, and the Gate City belt, where the whole sequence from the top of the Woodway limestone (or Witten or Lowville) to the base of the Martinsburg (or Trenton) consists of calcareous mudstone, much of which is red. There seems little doubt, however, that in the interval between the two belts the dense limestone of the upper and lower parts of the Hardy Creek limestone of Wallen Valley changes facies through argillaceous limestone to red calcareous mudstone. The Hardy Creek limestone of Lee County thus correlates with approximately the middle part of the Moccasin limestone at Gate City.

Paleontology.—Very few fossils have been found in the main mass of the Hardy Creek limestone. Markings of *Camarocladia* are present on some bedding surfaces but are neither as abundant nor as distinct as those in the Woodway or Eggleston limestones. *Tetradium* sp.

and fragmentary brachiopods were seen in a few places. A zone about 10 feet thick at the top of the Hardy Creek is abundantly fossiliferous. Huffman (1945) has included this fossiliferous zone with the overlying Eggleston limestone. Lithologically the unit seems to the writers to belong with the underlying Hardy Creek limestone because the big lithologic change occurs at the top of the fossiliferous zone. Paleontologically the zone contains forms found in both the underlying Woodway limestone and the overlying Eggleston limestone. The fossils identified from this zone in the Jonesville district are given below:

Tetradium cellulosum (Hall).
Tetradium clarki Okulitch.
Camarocladia sp.
Michelinoceras sp.
Bryozoa.

Thickness.—The thickness of the Hardy Creek limestone is 123 feet at Woodway, 124 feet at Hurricane Chapel, 134 feet at Ben Hur, 138 feet at Hagan, and 151 feet at Sewell Bridge. It averages about 130 feet thick in the district.

EGGLESTON LIMESTONE

Name and typical section.—The Eggleston limestone has its type locality in Giles County, Va. Mathews (1934, p. 11), who named the formation, did not give a type section; but sections at Narrows in Giles County that include the beds assigned to the Eggleston limestone have been published by Butts (1940, p. 192) and Rosenkrans (1936, pp. 105–106). Because it has slumped, the section along the highway at Narrows is now less well exposed than when studied by Rosenkrans and Butts, but several of the bentonite beds listed in their sections are still visible. The base of the Eggleston as defined by Mathews was clearly intended to begin with the drab-green mudstones that overlie red mudstones typical of the Moccasin. Butts draws the base of his Eggleston limestone at this horizon. Rosenkrans, who does not recognize the Eggleston as a valid formation, places the top of the Moccasin 106 feet higher, thus including most of the Eggleston in his Moccasin formation. The top of the Eggleston is less readily seen in this section, as the critical zone in which the contact was placed by Butts is now largely covered. Now the lowest exposed beds of typical Trenton lithology and containing *Dalmanella* and *Sowerbyella*, which characterize the basal Trenton, are 25 feet above the place where Butts draws the top of the Eggleston. Drawing the contact close below the lowest exposed *Dalmanella-Sowerbyella* beds would keep the two thick bentonites that should occur in this 25-foot covered interval within the Eggleston limestone, where they seem to belong according to evidence from other parts of southwest Virginia. Nonetheless, one must assume that Butts' placing of the contact is correct, unless the covered beds in the critical zone are re-excavated by extensive digging and the beds are found to be other than he reported. Excavation and restudy of the section are highly desirable, as there are considerable discrepancies in Rosenkrans' and Butts' published sections in both description and thickness of the units, and particularly in the thickness of the bentonites.

Distribution and topographic expression.—The Eggleston crops out in belts adjacent to the Hardy Creek limestone and is present in all the localities where the Hardy Creek occurs. In the northern belt along the Sugar Run lowland, the Eggleston limestone and the overlying basal Trenton limestone tend to form low hills in the northern part of the limestone lowland (fig. 21*A*). These hills are, in many places, parts of spurs extending southward from Poor Valley Ridge; but the spurs rise to higher elevations along the Trenton and Eggleston contact than they do directly to the north or south. The contact is normally at or near the highest point of these gently sloping hills and the main body of the Eggleston lies on the south slope of the hills. The middle member of the Eggleston produces abundant small ledgy outcrops, and the lower and upper members have few and inconspicuous outcrops.

Character.—Throughout Lee County and in adjacent Tennessee the Eggleston limestone is divisible into three lithologic members. These are readily mappable but were not mapped because it was not practicable to show such narrow belts of outcrop. For purposes of clarity of description, the three members are treated separately below.

Lower member.—The lower member of the Eggleston is a lithologic unit that consists of drab-greenish-gray calcareous mudstone with indistinct crystals, patches, and stringers of dirty-white calcite. The mudstone weathers to a yellowish brown and is weak and crumbly. Normally there is no visible bedding from base to top of the member, but locally one or more thin, slightly more resistant, limy layers may be present as bedded units. The lower member is 36 feet thick at Hagan, 40 feet thick at Hurricane Bridge, 44 feet thick at Sewell Bridge, and 42 feet thick at Woodway. It thus appears to thicken slightly in an eastern direction.

Middle member.—Above the mudstones is a sequence of brown dense thin-bedded limestone, most of which is cryptocrystalline but some beds and lenses of which are fine and medium crystalline. This limestone weathers bluish-gray to white and has numerous outcrops. It is quite fossiliferous, commonly showing *Camarocladia* on a few bedding surfaces and has an abundance of brachiopods and bryozoans. The horn coral *Streptelasma* is fairly common. In addition to the resistant platy limestones, the middle member contains in places zones of yellow-weathering argillaceous limestone ranging from a few feet to 10 feet in thickness.

At the top of the middle member is a thick bentonite, the lower of two big bentonites that characterize the Eggleston in Lee County. The bentonite is greenish-white when fresh but weathers to a yellow, greasy-looking, crumbly rock that shows fairly abundant large bronze mica flakes. It is normally seen at the surface only in its weathered colors. The thickness of the bentonite has been measured accurately only at Hagan, where it is 2 feet 2 inches thick. Figure 14 shows its appearance at this locality. In the photograph the width of the bentonite in the upper right-hand part of the belt represents its true thickness. The over-thickening near track level is due to flowage and crumpling. The hammer rests on beds directly underlying the bentonite, which have been duplicated by minor faults.

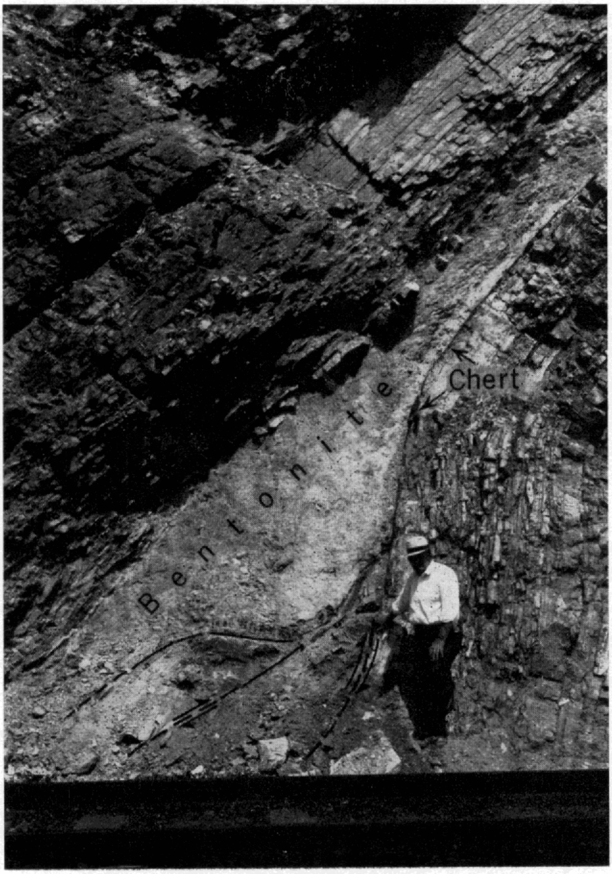

FIGURE 14.—Lower of the two big bentonite beds of Eggleston limestone in the railroad cut at Hagan. Folding and faulting of the beds directly beneath the bentonite accounts for the thickening of the bentonite in the lower part of the cut.

The bentonite is everywhere underlain by a bed of gray chert from 1 to 3 inches thick, formed by replacement of the top part of the underlying limestone by silica set free during alteration of the volcanic ash to bentonite. The bentonite is rarely seen in outcrop except in such very favorable places as recent railroad or highway cuts, but the underlying chert crops out abundantly. It can be distinguished from all other chert beds in the column, except the similar chert underlying the upper big bentonite of the Eggleston limestone, because of its uniform thickness, smooth upper surface, frozen contact with the underlying limestone, and very angular blocky fracture. Figure 15 shows a typical exposure of the chert bed associated with the lower bentonite of the Eggleston, with the hammer lying on the smooth upper surface of the chert. The bentonite, which is extremely weak, has been eroded, but some of it could unquestionably be found just above the chert by extensive digging in the soil bank in the background of the photograph.

The middle member of the Eggleston is 57 feet thick at Hagan, 60 feet at Hurricane Bridge, and 66 feet at Sewell Bridge. This member also appears to thicken slightly in an eastward direction.

Upper member.—The upper member is composed dominantly of calcareous mudstone similar to that described in the lower member, but it contains considerable proportions of platy and argillaceous limestone. The mudstone and limestone zones are interlayered and are from a few feet to 20 feet thick. The upper of the two big bentonites of the Eggleston is 9 to 15 feet below the top of the member. At Hagan this bentonite is 3 feet 4 inches thick but contains about 3 inches of shale near the middle. It is light gray but weathers yellow. It also contains numerous flakes of bronze mica. It is underlain by a bed of chert about 2 inches thick, which is identical in appearance with the chert bed below the lower bentonite. At some localities both lower and upper chert beds crop out, but in many other places only one chert bed is exposed and it is usually the lower chert bed. This is probably because the lower chert is underlain by resistant beds that tend to crop out, whereas the upper chert is both underlain and overlain by weak beds that have few outcrops.

The beds between the upper bentonite and the base of the Trenton contain more fine- and medium-crystalline limestone than the remainder of the upper member. They are, however, less coarse than the overlying coquinal limestone of the basal Trenton, from which they are readily distinguished. The upper member of the Eggleston is 53 feet thick at Hagan and 53 feet thick at Sewell Bridge. It appears to be 80 feet thick at Hurricane Bridge but is not well enough exposed for the geologist to be certain that unnoted folding or faulting is not present to account for the greater thickness.

FIGURE 15.—Two-inch bed of chert underlying lower big bentonite bed of Eggleston limestone. Hammer lies on smooth top surface of chert.bed from which bentonite has been eroded. One mile east-northeast of Dot.

Stratigraphic relations and thickness.—The Eggleston limestone conformably overlies the Hardy Creek limestone. The lithologic change is abrupt along the contact but there is no sign of erosion of the Hardy Creek before deposition of the Eggleston. The Eggleston is conformably overlain by the Trenton, again with an abrupt lithologic and faunal change but without evidence of erosion along the contact.

Three measurements of the total thickness of the Eggleston in the Jonesville district were 146 feet at Hagan, 181 feet at Hurricane Bridge, and 164 feet at Sewell Bridge. In the Anthony Ely well the formation is 126 feet thick.

Structural behavior.—The lower member of the Eggleston is probably the least competent unit of appreciable thickness in the column. It has flowed readily under the deforming stresses to which the region has been subjected, with the result that the adjacent competent Hardy Creek limestone and the competent middle member of the Eggleston have in many places been folded or faulted in adjusting to the new space relations. The upper member of the Eggleston is also relatively incompetent, though less so than the lower member. In places, however, the whole Eggleston as well as the upper part of the Hardy Creek and lower part of the Trenton limestones has participated in severe folding and faulting, which does not affect higher or lower beds but is confined to the immediate vicinity of the two incompetent mudstone members of the Eggleston. Excellent examples of this may be seen on the slope of Wallen Ridge south and a little east of Cedar Knob and also near the eastern tip of the belt of Eggleston rocks northeast of Dot and north of U. S. No. 58.

Paleontology and age.—The middle member of the Eggleston is moderately fossiliferous, and occasional fossils are found in the upper member. The forms that have been identified from collections made in the Jonesville district are listed below:

Streptelasma sp.
Camarocladia sp.
Pionodema sp.
Doleroides sp.
Strophomena incurvata Shepard.
Zygospira recurvirostris (Hall).
Zygospira sp.
Zygospira n. sp., aff. *Z. recurvirostris* (Hall).
Bryozoa.

In general the Eggleston fauna resembles that of the Woodway limestone, and it is quite distinct from the fauna of the overlying Trenton limestone. In the Ordovician of southwest Virginia the two great faunal breaks are between the Knox group and the overlying limestones, whether these be called Dot limestone, Murfreesboro limestone, or Blackford formation, and between the Eggleston limestone and the overlying limestones and shales, whether these be called Trenton limestone or Martinsburg shale. These are also the two most prominent lithologic breaks in the Ordovician. A considerable body of evidence has been building up tending to show that the Eggleston limestone of southwest Virginia correlates with the lower part of the Trenton group of New York State. (Huffman, 1945, fig. 9.) The complex problem of correlation between southwest Virginia and the type sections of the Ordovician in New York State is beyond the province of this report; but it is not amiss to point out that as the result of recent stratigraphic work in the central and southern Appalachians, beds formerly considered of upper Black River age have been consistently moved upward into the Trenton group because they seem to correlate with beds included in the lowest part of the Trenton group as defined in New York State by Raymond (1921) and Kay (1937). In eastern Pennsylvania and in southwest Virginia where the senior author has studied Middle Ordovician rocks, the beds now considered by many to be of early Trenton age appear to have closer lithologic and faunal affiliations with the underlying beds of undoubted Black River age than with the overlying beds of undoubted Trenton age. If these age assignments are correct, perhaps the solution to the problem is a redefinition of the limits of the Trenton group in its type region whereby beds now considered of earliest Trenton age be excluded from the Trenton group and returned to the Black River group, where they were orginally classified.

TRENTON LIMESTONE

Name.—In most of the Appalachian Valley of Virginia, beds of Trenton, Eden, and Maysville age are predominantly shale and have been grouped together into one formation, the Martinsburg shale. In the westernmost belts of exposure in extreme southwest Virginia and adjacent Tennessee, the beds of Trenton age are, however, predominantly limestone and have been called Trenton limestone, and the overlying shales of Eden and Maysville age have been called Reedsville shale. Application of the name Trenton to the limestone beds is confusing inasmuch as the underlying Eggleston limestone is believed by most to be of early Trenton age, and the still older beds here referred to the Hardy Creek and Ben Hur limestones are believed by some to be of earliest Trenton age. Hence the limestones (post-Eggleston) of Trenton age in Powell and Wallen Valleys of southwest Virginia and adjacent Tennessee should be given a new formation name. The old name Trenton limestone is retained in this report, however, because it is well established in the terminology of oil geologists and operators who are interested in the oil possibilities of these beds in the Jonesville district.

Distribution and topographic expression.—Because it is one of the thickest formations in the Jonesville district, the Trenton limestone forms relatively broad belts. One belt of the formation lies along the northern side of the Sugar Run lowland and on the lower slopes of adjacent Poor Valley Ridge. The corresponding belt on the southern side of the Powell Valley anticlinorium forms the lower and lower-middle slopes of Wallen Ridge. The formation is also present in a belt along the north side of the valley of lower Cane Creek and in a short belt inside the Bethel fenster.

The Trenton limestone is relatively weak, but it occurs in part or in toto on the mountain sides because it is overlain by the relatively resistant Reedsville shale, with the extremely resistant Clinch sandstone only a few hundred feet higher. As previously explained, the contact with the Eggleston limestone tends to be at or near the crests of low hills in the Sugar Run lowland, and the contact with the overlying Reedsville shale is at or near the break in slope where the steep-sided knobs of Reedsville shale begin. Outcrops of the Trenton limestone are few and far between, and both lower and upper contacts must in most places be mapped largely from float and from topographic expression.

Character.—The Trenton limestone is essentially a lithologic unit, clearly distinguished from the underlying and overlying formations in areas of good outcrops or abundant float. Despite its thickness of nearly 600 feet, the formation is not readily divisible into thinner lithologic members. Such lithologic variations as there are within the formation are not sharply defined and would be difficult to map for this reason and because of scarcity of exposures.

The formation consists predominantly of brown and dark gray limestone. In the lower part of the formation most of the limestone is medium- or coarse-crystalline with abundant fossils, and in the upper part most of it is fine-crystalline to fine-grained with a few abundantly fossiliferous beds. The beds of limestone are from 1 to 12 inches thick and average 2 or 3 inches thick. Partings and beds of gray to black shale are abundant throughout. In a few zones, shale accounts for almost half of the rock and the individual shale units may be as much as a foot thick. Separation of the beds of limestone by the partings and beds of shale emphasizes the bedding, as illustrated in figure 16, and causes well-exposed outcrops of the Trenton limestone to be very distinctive.

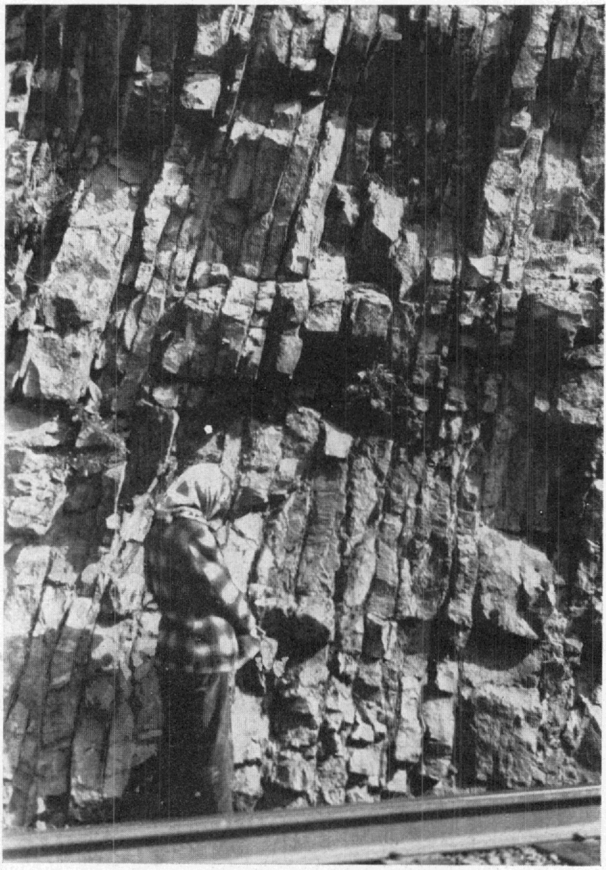

FIGURE 16.—Limestone beds separated by shale partings in the upper part of the Trenton limestone along the Louisville and Nashville Railroad half a mile west of the Ben Hur station.

Three bentonite beds have been seen in the Trenton limestone. All are thinner than the two big bentonite beds in the Eggleston limestone. In the excellent exposures of the Trenton at Hagan all three bentonite beds are visible. The oldest is greenish gray, 7 inches thick, and lies 31 feet above the base of the formation. The second, 69 feet above the base of the Trenton, is not well exposed but appears to be at least a foot thick. (See fig. 21*A*.) It consists of greenish-white bentonite which is underlain by partly silicified shale. The youngest, which has an average thickness of about 2 inches at Hagan, is a yellow clay bed that lies 12 feet from the top of the formation. None of these bentonites was found in the Sewell Bridge section (geologic section 14), where the exposures are poorer, but the bentonite 69 feet above the base of the Trenton has been seen in cuttings from numerous wells in and near the Rose Hill oil field, including the Anthony Ely well in the Jonesville district.

Stratigraphic relations and thickness.—Contacts at both base and top of the Trenton limestone are clearcut because of abrupt lithologic changes; but both contacts are apparently conformable. Where the contacts are visible, there is no evidence of any appreciable erosion of the underlying beds, but there is some variation in the position of the base of the Trenton limestone with respect to the upper big bentonite bed of Eggleston. At Hagan the base of the Trenton is 9 feet above the top of the bentonite, at Hurricane Bridge it appears to be 24 feet above the bentonite, and at Sewell Bridge it is apparently 15 feet above the bentonite. Whether this variation is due to pre-Trenton erosion or to variations in thickness of exactly equivalent units is not known.

The most reliable measurements of the thickness of the Trenton limestone at the surface and in wells are consistently between 500 and 600 feet, with an average figure of about 560 feet. Thicknesses greater than 600 feet, which were measured at several localities, are believed to be in error because of duplication of beds by reverse faults in covered intervals.

Paleontology.—Fossils are abundant in the Trenton limestone and are principally brachiopods, bryozoans, and gastropods. The lowest 50 feet of the formation is characterized by a great abundance of *Resserella* (*Dalmanella*) *fertilis* and *Sowerbyella curdsvillensis*. *Prasopora* is found about 35 feet above the base of the formation and is common in the next 100 feet of beds. A zone of abundant *Cyrtodonta* cf. *C. grandis* lies 284 feet above the base of the formation at Sewell Bridge and 293 feet above the base at Hagan.

The complete list of identified forms from collections made in the Jonesville district is given below:

- Corals:
  - *Foerstephyllum* sp.
  - *Lichenaria* cf. *L. grandis* Bassler.
- Bryozoans:
  - *Batostoma* sp.
  - *Calloporina* n. sp.
  - *Constellaria teres* Ulrich and Bassler.
  - *Constellaria* sp.
  - *Dekayia* sp.
  - *Eridotrypa* sp.
  - *Hallopora* sp.
  - *Homotrypa* sp.
  - *Mesotrypa* sp.
  - *Prasopora* sp.
  - *Prasopora* n. sp.
  - *Rhinidictya* sp.
- Brachiopods:
  - *Dalmanella* (s.s.) sp.
  - *Dinorthis pectinella* (Emmons).
  - *Dinorthis* sp.
  - *Hebertella frankfortensis* Foerste.
  - *Hebertella* sp.
  - *Hesperorthis* cf. *H. tricenaria* (Conrad).
  - *Platystrophia* sp.
  - *Rafinesquina trentonensis* (Hall).
  - *Rafinesquina* aff. *R. trentonensis* (Hall).
  - *Rafinesquina* sp.
  - *Resserella fertilis* Bassler.
  - *Resserella* cf. *R. fertilis* (Bassler).
  - *Rhynchotrema increbescens* (Hall).
  - *Rhynchotrema* cf. *R. increbescens* (Hall).
  - *Rhynchotrema* sp.
  - *Sowerbyella curdsvillensis* Foerste.
  - *Sowerbyella* cf. *S. curdsvillensis* Foerste.
  - *Sowerbyella* sp.
  - *Zygospira recurvirostris* (Hall).
  - *Zygospira* cf. *Z. modesta* (Say).
  - *Zygospira* sp.
- Pelecypods:
  - *Byssonychia* sp.
  - *Cyrtodonta* cf. *C. grandis* (Ulrich).
- Gastropods:
  - *Whiteavesia* sp.
  - *Hormotoma* sp.
  - *Loxoplocus* sp.
- Trilobite:
  - *Isotelus* sp.
- Ostracode:
  - *Leperditia* sp.

UPPER ORDOVICIAN SERIES

REEDSVILLE SHALE

Name, distribution, and topographic expression.—The Reedsville shale was named by Ulrich (1911, pl. 27) from Mifflin County, Pa. In Virginia it is recognized in the extreme southwest part of the State, where the underlying limestones and shales of Trenton age have been treated as a separate formation. Elsewhere beds equivalent to the Reedsville shale form the upper part of the Martinsburg shale.

The formation crops out on the middle slopes of Poor Valley Ridge, Wallen Ridge, and the unnamed ridge north of lower Cane Creek, and it is also present as a short belt in the Bethel fenster. The belts of Reedsville are characterized by rounded, steep-sided knobs on each of the three ridges. These are prominent on Poor Valley Ridge and on the ridge north of Cane Creek, but on Wallen Ridge they are conspicuous only where the ridge is low or of moderate height. The geologic map (pl. 1) shows the remarkable fidelity with which the base of the Reedsville follows the break in slope at the base of the knobs and the equal fidelity with which the top of the Reedsville lies in the sags that separate the knobs from the main mountain mass. The line of knobs of the Reedsville is well illustrated in the aerial photograph in figure 23.

Character.—The Reedsville shale is composed principally of gray shale. This is the only rock that is conspicuous in the float or in the average weathered exposure. In large fresh outcrops, however, considerable amounts of limestone and some sandy limestone may be seen to be interbedded with the shale. The limestone is gray and is both fine-grained and medium- to coarse-crystalline. The crystalline limestone is abundantly fossiliferous and some of it is coquinal, but the fine-grained limestone has few fossils. The sandy limestone is composed of fine-grained sand in a matrix of carbonate which dissolves readily, leaving a porous crumbly rock. The upper 20–40 feet of the Reedsville are composed almost entirely of limestone, which forms prominent ledges in road and railroad cuts. Other thinner zones of limestone locally produce ledges on the slopes of the knobs of Reedsville shale. The crests of the knobs appear to be formed by somewhat more massive, and hence more resistant, beds of limestone and sandy limestone, but these beds have very few natural outcrops, despite their greater resistance to erosion.

Stratigraphic relations and thickness.—The Reedsville shale conformably overlies the Trenton limestone and is conformably overlain by the Sequatchie formation. Good exposures of this contact are rare, but in most places where the beds in this part of the section are well exposed, the contact can be accurately located because of the abrupt lithologic change from relatively pure fossiliferous gray limestone of the top of the Reedsville to greenish-gray calcareous siltstone or argillaceous limestone of the lowest part of the Sequatchie. Along the railroad tracks half a mile east of Ben Hur the contact of the Reedsville with the overlying Sequatchie is extremely vague. At this locality a zone 19 feet thick is transitional in lithology between the limestones of the Reedsville and the siltstones of the Sequatchie. *Orthorhynchula linneyi* (James), which is persistent throughout the Appalachian Valley at the top of Reedsville (or Martinsburg) shale, was found in the lower part of this zone. Hence the zone was included with the Reedsville shale.

Accurate thicknesses of the Reedsville shale are extremely difficult to obtain because of the paucity of good sections and because the formation is incompetent and hence especially susceptible to deformation by folding or faulting. For example, in a section along the railroad tracks half a mile east of Ben Hur station the measured thickness of the Reedsville was 290 feet, and in another section half a mile northwest of Ben Hur the thickness was 460 feet. One or the other or both of these measurements are almost certainly in error, probably because of unobserved deformation of the beds. The only completely reliable measurement was obtained at Hagan, where the beds are continuously exposed and the errors due to folds and faults could be eliminated. Here the measured thickness was 358 feet. Along the Poor Valley Ridge belt of Reedsville all observed faults resulted in duplication of beds, and folding also has the effect of making the apparent thickness greater than the true stratigraphic thickness. Hence the measurement of 290 feet east of Ben Hur railroad station and a measurement of 282 feet along the road through the eastern of the two watergaps in Poor Valley Ridge near Hubbard Springs may be correct. If so, eastward from Hagan, the Reedsville shale has thinned appreciably.

Paleontology and age.—Bryozoans and brachiopods are the most abundant fossils of the Reedsville shale. Large bryozoans seen in cross-section in some beds superficially resemble pebbles of intraformational conglomerate. As previously noted, *Orthorhynchula linneyi* is persistent in the limestones at the top of the formation. The forms identified by G. A. Cooper from collections made by the writers from the Reedsville of the Jonesville district are listed below. Cooper refers all these forms to the Maysville, but the lower part of the Reedsville may be of Eden age.

Bryozoans:
- *Batostoma* sp.
- *Constellaria teres* Ulrich and Bassler.
- *Constellaria* sp.
- *Dekayia* sp.
- *Diplotrypa* sp.

- *Heterotrypa* sp.
- *Homotrypa* sp.
- *Homotrypella* sp.
- *Monticulipora* sp.
- *Monticuliporella* sp.

Brachiopods:
- *Hebertella* aff. *H. sinuata* (Hall).
- *Hebertella* cf. *H. frankfortensis* Foerste.
- *Hebertella* sp.
- *Orthorhynchula linneyi* (James).
- *Platystrophia* aff. *P. praecursor* Foerste.
- *Platystrophia* sp.
- *Rafinesquina* sp.
- *Rhynchotrema* sp.
- *Strophomena* sp.
- *Zygospira kentuckiensis* James.
- *Zygospira modesta* (Say).

Pelecypod:
- *Modiolopsis* sp.

Cephalopod:
- *Sactoceras* sp.

SEQUATCHIE FORMATION

Name and usage of name.—The Sequatchie formation, named by Ulrich (1913, pp. 593–667) from the Sequatchie Valley of southeast Tennessee and northern Alabama, has been used to include marine beds of supposed Richmond age in the southern part of the Appalachian Valley. The continental equivalents to the north and east have been called the Juniata formation. As used in southwest Virginia, the Sequatchie formation included the beds lying between the Reedsville shale of Eden and Maysville age and the Clinch sandstone of Silurian age. Miller and Fuller (in press) have recently shown, however, that in the Rose Hill district of Lee County the lower part of the Sequatchie formation, which is for the most part lithologically similar to the upper part, contains fossils of probable Maysville age. The presence or absence of beds of Richmond age in the Sequatchie of the Rose Hill district was not definitely established, as the upper part of the formation has very few and very poorly preserved fossils.

Distribution and topographic expression.—The Sequatchie forms belts adjacent to and on the downdip side of the belts of Reedsville shale. It crops out on the steep slopes above the line of knobs of the Reedsville and just below the crests of Poor Valley Ridge, Wallen Ridge, and the unnamed ridge on the north side of the valley of lower Cane Creek. In the south-central part of the Jonesville district, both the Sequatchie and the overlying ridge-making Clinch sandstone are absent because of over-thrusting along the Wallen Valley fault. A very small and poorly exposed patch of the Sequatchie formation is also preserved near the western end of the Bethel fenster, and a larger and better exposed area lies at the bottom of the deep valley along the headwaters of Wallen Creek at the eastern end of the district. Two small belts of Sequatchie also crop out in the faulted area at the east tip of the district.

Character.—Maroon and green, calcareous, even-laminated muddy siltstone composes most of the Sequatchie formation, but zones of greenish-gray nodular argillaceous limestone are everywhere present in the lower part of the formation. The maroon siltstone, which is the most distinctive rock type in the formation, is normally in zones from a few feet to 50 feet thick. Patches and beds of green siltstone may be included in the zones that are predominantly maroon. The green siltstone differs from the maroon siltstone only in color. Both types of siltstone are in thin even or wavy beds, but major bedding plane breaks are at intervals of several feet. Wavy bedding gives a nodular appearance to the weathered rock. The siltstones are practically unfossiliferous.

The zones of argillaceous limestone are composed of dense, hard, gray, fossiliferous limestone in fresh exposures, but the rock decomposes rapidly at the surface to a muddy-looking, nodular, crumbly rock from which large, poorly-preserved brachiopods may be picked out whole.

The lower part of the formation is excellently exposed in the Hagan section (geologic section 16) and there are good but not continuous exposures of the whole formation in the Wallen Ridge section (geologic section 17). Zones of fossiliferous limestone were observed higher in the Sequatchie formation in the Wallen Ridge section than anywhere else in the district.

Stratigraphic relations.—The Sequatchie formation conformably overlies the Reedsville shale. The contact is perfectly exposed at Hagan and is shown in a photograph of the report on the Rose Hill district (Miller and Fuller, in press). The uppermost Reedsville is a gray massive-bedded relatively pure limestone, whereas the lowermost Sequatchie is a yellow-weathering thinner-bedded calcareous siltstone. The existence of a transition zone between the two formations east of Ben Hur has previously been described in the section on the Reedsville shale. Figure 17 shows the contact as exposed along U. S. No. 58 on Wallen Ridge.

The Sequatchie formation is unconformably overlain by the Hagan shale member of the Clinch sandstone. This contact is described in the section on the Clinch.

Thickness.—The Sequatchie formation thickens from west to east across the Jonesville district. It is 274 feet thick at Hagan and 259 feet thick in the Anthony Ely well, but it thickens to 323 feet in the

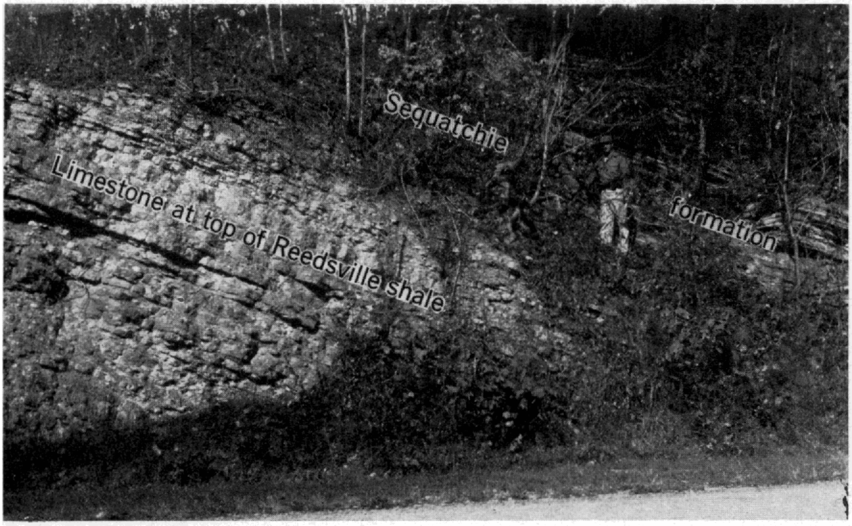

FIGURE 17.—Sequatchie formation conformably overlying limestones at the top of the Reedsville shale along United States Highway No. 58 over Wallen Ridge. Man's feet are almost exactly at contact.

section along the railroad west of Ben Hur and to 438 feet in the section on U. S. No. 58 over Wallen Ridge.

Paleontology and age.—Fossils, principally large globose brachiopods, abound in the argillaceous limestone zones of the Sequatchie and are practically absent from the siltstones. In the section on Wallen Ridge the fossiliferous zones are more numerous and are present higher in the formation than elsewhere. Thus, the measured section here (geologic section 17) has the most complete paleontologic record of the formation. The most significant forms collected at this locality are the brachiopods *Hebertella sinuata* (Hall) and *Platystrophia ponderosa* Foerste. These forms were also collected at Hagan from beds in the lowest 50 feet of the formation, and the faunule was provisionally dated as Maysville by G. A. Cooper and Charles Butts. In the Wallen Ridge section, however, *Hebertella sinuata* was found about 340 feet above the base of the formation and only about 100 feet from the top, and *Platystrophia ponderosa* was found in several zones in the middle part of the formation. G. A. Cooper states that these brachiopods appear to have stronger Maysville than Richmond affinities, but the evidence is not conclusive. In addition to *Hebertella* and *Platystrophia*, the brachiopods *Zygospira modesta* (Say) and *Zygospira recurvirostris* (Hall), the pelecypods *Byssonychia* sp. and *Whiteavesia* sp., and unidentified bryozoans have also been collected from the Sequatchie of the Jonesville district. It is to be hoped that additional fossiliferous localities of the Sequatchie can be found in southwest Virginia where more varied, more diagnostic, and better preserved faunas can be collected.

SILURIAN SYSTEM

CLINCH SANDSTONE

Name and distribution.—The type region of the Clinch sandstone is Clinch Mountain in northeast Tennessee. (Safford, 1856.) In Lee County the formation has been divided into the Hagan shale member below and the Poor Valley Ridge member above. (Miller and Fuller, in press.) The formation crops out along the crest and back slopes of Poor Valley Ridge and the unnamed ridge just east of Ben Hur. It also forms the crest and back slopes of Wallen Ridge along the high stretches of the ridge in the eastern and extreme western parts of the district but has been eliminated by overthrust faulting along the low part of Wallen Ridge. The Clinch sandstone also forms the crest of Powell Mountain, the tip end of which is just inside the eastern edge of the Jonesville district; and a very small area of Clinch is exposed inside the Bethel fenster.

Topographic expression.—The Clinch sandstone is the only prominent ridge-making formation of the Jonesville district. Sandstones at the base of the Poor Valley Ridge member normally form rocky ledges at the crests of the ridges mentioned above, and the remainder of the Poor Valley Ridge member is present but poorly exposed on the back slopes of the ridges. The Hagan shale member forms the highest slopes just below the ridge crests on the up-dip sides of the mountains. Being weak, the shale member has few outcrops, but shale float from the member can be found in most places above the Sequatchie formation and below the mountain crest.

Hagan shale member.—The lowest 65 to 130 feet of the Clinch is assigned to the Hagan shale member. The member consists largely of gray fissile shale with a few thin interbeds of fine-grained sandstone and locally a very few thin beds of impure fine-grained limestone. Figure 18 shows the typical appearance of the Hagan shale member, as exposed in the cut along the Louisville and Nashville Railroad at Hagan. The basal unit of the member is in some places a prominent bed 1-4 feet thick of medium-grained sandstone, but elsewhere only a few inches of weak sandstone or sandy shale are present at the base. Thicker-bedded sandstones become interbedded with the shale at the top of the member, and the contact with the overlying Poor Valley Ridge member is drawn at the base of the rock sequence in which massive-bedded, resistant sandstones are the dominant rock type. Undoubtedly the contact of the two members is not at the same stratigraphic horizon throughout the district, as the resistant sandstone units lens in and out. The Hagan member is from 65 to 83 feet thick at five localities in the Jonesville district, but is 129 feet thick along the railroad in the gap northwest of Ben Hur station.

FIGURE. 18.—Hagan shale member of the Clinch sandstone in the cut along the Louisville and Nashville Railroad at Hagan.

Poor Valley Ridge member.—The upper two-thirds of the Clinch sandstone is composed dominantly of sandstone and constitutes the Poor Valley Ridge member. The member begins with a zone of medium-grained massive-bedded sandstone several tens of feet thick, which forms the most resistant unit of the formation and almost everywhere forms the crests of ridges of the Clinch. Above this are thinner-bedded sandstones with occasional interbedded units of gray shale. Shale becomes increasingly abundant upwards and forms almost half of the rock in the uppermost part of the Poor Valley Ridge member. Some of the sandstone contains excellent ripple marks, impressions of fucoids, and oval patches or galls of clay or clay-shale. A few of the sandstone beds are coarse to pebbly and have subrounded pebbles as large as peas.

Stratigraphic relations.—An unconformity separates the Clinch sandstone from the underlying Sequatchie formation. This unconformity is excellently exposed at several places in the Jonesville district. In the cut along the curving spur of the Louisville and Nashville Railroad at Hagan, the top 2 feet of the Sequatchie are leached of their red color and are overlain by a basal sandstone of the Clinch that forms a ledge 15 inches thick (geologic section 16). On U. S. No. 58 at the crest of Wallen Ridge (geologic section 17), the basal bed of the Clinch, 1½ feet thick, is shaly sandstone with scattered larger sand grains. The underlying Sequatchie is reddish-purple shaly calcareous siltstone which shows small channels an inch or two deep filled with sand of the basal bed of the Clinch (fig. 19). The only place where the observed contact was not clear-cut was along the Louisville and Nashville Railroad in the gap northwest of Ben Hur station, where a transition zone of 8½ feet of beds separates typical Sequatchie from typical Hagan shale member. There is some evidence of minor erosion, indicating a hiatus, at the base of the transition zone, whereas the beds at the top of the transition zone are entirely conformable with the overlying typical Hagan shale. Hence the transition zone is believed to represent reworked Sequatchie deposited along with the sands and muds of Hagan lithology in earliest Clinch time. The Sequatchie and Clinch contact is also perfectly exposed along the dirt road that crosses Wallen Ridge through Lovelady Gap southeast of Dryden and also 2 miles northeast of where Wallen Ridge crosses the northern border of the Jonesville district.

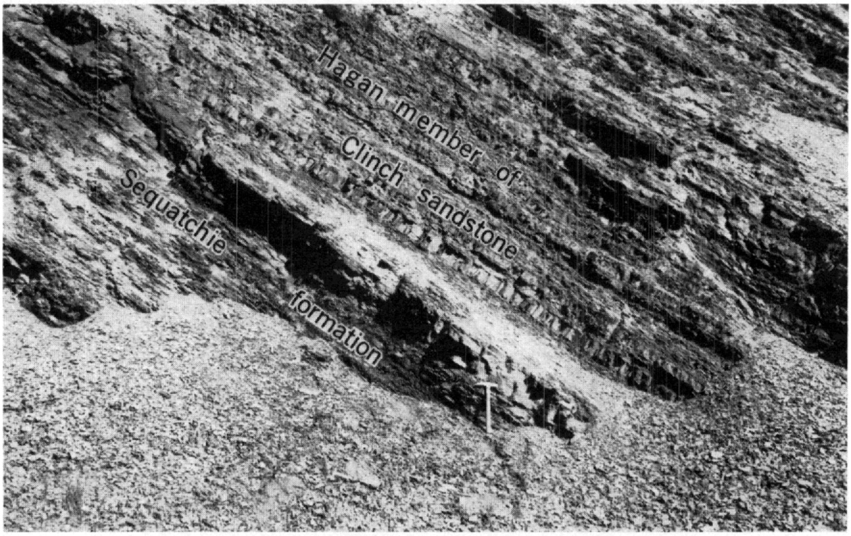

FIGURE 19.—Sandstone and shale of the Hagan shale member of the Clinch sandstone above the hammer head, overlying reddish-purple calcareous mudstone of the Sequatchie formation along U. S. No. 58 at the crest of Wallen Ridge.

The Clinch sandstone is overlain with slight disconformity by the Clinton shale. The contact is described in the section on the Clinton.

Thickness and paleontology.—The Clinch sandstone is 260 feet thick at Hagan, 309 feet thick at Ben Hur, and more than 333 feet thick along U. S. No. 58 over Wallen Ridge. It thus apparently thickens eastward.

Although most of the Clinch sandstone in Lee County is composed of marine strata, the formation is sparingly fossiliferous. A few pelecypods and linguloid brachiopods, gastropods, trilobites, cephalopods, and graptolites have been collected. The forms listed below have been identified by Frank M. Swartz and G. Arthur Cooper:

Hagan member:
  Ctenodonta (2 species).
  Liocalymene sp.
  Mendacella? sp.
Poor Valley Ridge member:
  Modiolopsis cf. *M. subcarinata* Hall.
  Bucanella aff. *B. trilobata* (Conrad).
  Hormotoma? sp.
  Stegerhynchus sp. cf. *S. neglectus* (Hall).
  Stegerhynchus sp.
  Lingula sp.
  Helopora sp. cf. *H. fragilis* Hall.

Correlation and age.—The Clinch sandstone correlates with the Tuscarora sandstone of northern Virginia, Maryland, and Pennsylvania. All of the Clinch in Lee County is believed to be of Brassfield age.

CLINTON SHALE

Name and distribution.—The Clinton shale was named in Oneida County, N. Y. (Conrad, 1842, pp. 229–230.) In Lee County, Va., it includes about 400 feet of shale and sandstone lying between the Clinch sandstone below and the Hancock dolomite above. The Clinton forms a continuous belt along the north side of the Jonesville district from the west edge of the district to a point near Ben Hur where it crosses the north edge of the district. In the Ben Hur region a shorter belt of Clinton is present which dies out against faults to the northeast and to the south. Clinton shale crops out in the bottom of Big Fleenortown fenster, and a much larger area of it is exposed in the Sulphur Springs fenster. In the southwest corner of the district along Wallen Ridge the Clinton forms a nearly continuous belt 3 miles long, lying between the Clinch sandstone and the Wallen Valley fault. It is absent for the next 9 miles to the northeast along Wallen Ridge because of over-thrusting along the Wallen Valley fault, but it comes in again southeast of Jonesville and forms a continuous belt from that point to the eastern tip of the district. The belt of Clinton is widest and also best-exposed in the area of gentle folding near the eastern tip of the district.

Character.—The Clinton contains a few beds of resistant sandstone, but in general it is nonresistant. The lower part of the formation nevertheless normally forms the middle and lower back-slopes of Poor Valley Ridge and Wallen Ridge because of its intermediate position between the ridge-making Clinch sandstone and the valley-making Upper Devonian shale north of Poor Valley Ridge and the valley-making Cambrian and Ordovician limestones and dolomites south of the Wallen Valley fault.

The formation is composed predominantly of red and greenish-gray marine shale. Red shale is more abundant in the lower half of the formation and greenish-gray shale more abundant in the upper half. The shale is fissile and disintegrates into small chips. Interbedded with the shale are numerous beds of dense fine-grained sandstone in even beds, most of which are from 1 to 6 inches thick. A few beds are considerably thicker. Many of the sandstone beds have excellent ripple-marked surfaces, and some also show rill marks and trail-like markings. In some parts of the district the top of the Clinton consists of a massive bedded zone of medium- to coarse-grained yellow sandstone more than 10 feet thick. Elsewhere this standstone is absent, probably because it was eroded in pre-Hancock time. A very few beds of coarse to pebbly sandstone have been seen in the Clinton, but beds of this type, which are common in the underlying Clinch sandstone, are extremely rare in the Clinton. The Clinton commonly contains one or more beds of low-grade hematitic iron ore in the lowest part of the formation. At Hagan the only well-exposed bed of iron ore is from 5 to 9 inches thick and lies 5 feet above the base of the formation. Despite its thinness this bed has been mined on the back slope of Poor Valley Ridge both east and west of the gap at Hagan. At Ben Hur, the same bed or a similar bed is 3 feet thick and lies 3 feet above the base of the Clinton. No beds of iron ore have been seen in place in the belts of Clinton along Wallen Ridge, but a little iron ore float was found in the broad Clinton area at the eastern tip of the district. The iron-rich beds consist mostly of flattened circular pellets of hematitic mud, coated with films of pure hematite. Much of the ore contains scattered grains of quartz sand, and some of the so-called ore is actually a hematite-stained and hematite-coated quartz sandstone.

The Clinton has fair exposures in the Jonesville district, but complete sections with even moderately good exposures are lacking. The only nearly complete section of the formation was pieced together from exposures along U. S. No. 58 on the southeast slope of Wallen Ridge (geologic section 18). At Hagan the lowest 83 feet of the formation is perfectly exposed.

Stratigraphic relations.—The Clinton shale overlies the Clinch sandstone with slight disconformity. The contact, wherever exposed, is sharp and clear. It may be recognized readily by the lithologic change from irregularly-bedded lenticular sandstones with clay galls and pebbles which comprise the upper part of the Clinch sandstone, to even-bedded shale with interbeds of even-bedded platy sandstone of the Clinton. The first red shale in the Silurian part of the section begins a few feet above the base of the Clinton, and the characteristic

Clinton brachiopod *Coelospira* [*Anoplotheca*] *hemispherica* is found in abundance a foot or two above the base. At most localities the basal beds of the Clinton shale are of greenish-gray shale and they appear to lie conformably on the Clinch. In the Wallen Ridge section (geologic section 18), however, the basal unit is a bed of friable pebbly sandstone 1 foot 4 inches thick containing conglomeratic oval pebbles of sandstone as much as 3 inches long in the lower part of the bed. The abrupt lithologic and faunal change indicates a hiatus of appreciable length between the close of Clinch deposition and the advance of the Clinton seas. Only locally, however, as at the locality described above, is there any evidence of significant erosion during the hiatus.

The Clinton is disconformably overlain by the Hancock dolomite, as described in the section on the Hancock.

Thickness.—The Clinton is one of the most difficult formations in the district from which to obtain reliable thickness measurements. In wells drilled in the Rose Hill district which penetrated flat-lying and unfaulted Clinton shale, the formation apparently is from 320 to 360 feet thick. In the Wallen Ridge section in the Jonesville district, it is at least 394 feet thick, with probably only a few feet of beds at the top unaccounted for. At Hagan, where both lower and upper contacts are exposed, a thickness measurement of 423 feet was obtained, but this is almost certainly too large because of the strong probability that reverse faults duplicate beds in the long covered interval between the lower and upper exposed parts of the section. The available evidence from wells in the Rose Hill district and from the one reasonably reliable measurement at the surface in the Jonesville district seems to indicate that the Clinton shale is thickening somewhat from west to east.

Paleontology.—Fossils are common in the Clinton and are very abundant in some beds. The lowest 100 feet of the formation contains abundant *Coelospira* [*Anoplotheca*] *hemispherica* (Sowerby), which is a reliable guide fossil to the Clinton in Lee County. *Brachyprion* is also common in the beds, as are ostracodes of the genus *Zygobolba.* In the zone of sandstone at the top of the formation, ostracodes and trilobites are common but are usually very poorly preserved. The middle part of the formation is sparingly fossiliferous, and no collections have been obtained from it.

The complete list of identified fossils from the Clinton of Lee County collected in part from the Jonesville district and in part from the Rose Hill district is given below. Starred fossils were identified by G. Arthur Cooper of the U. S. National Museum; all others were identified by Frank M. Swartz of Pennsylvania State College.

Clinton shale (upper 60 feet):
  Anoplotheca sulcata (Prouty) = *Coelospira sulcata* Prouty.
  Chonetes sp.
  Chonetes "novascoticus" Hall.
  **Howellella crispa* (Hisinger).
  Uncinulus sp.
  **Wilsonella* sp.
  **Pterinea* sp.
  Bucanella trilobata (Conrad).
  Hormotoma sp.
  Subulites sp.
  Tentaculites sp.
  cf. *Dalmanites clintonensis* Ulrich ms. sp. in C. K. Swartz (1923).
  Liocalymene clintoni (Vanuxem).
  cf. *Bonnemaia crassa* Ulrich and Bassler.
  **Bonnemaia* sp.
  Bonnemaia crassa.
  Dizygopleura loculata Ulrich and Bassler.
  **Mastigobolbina* sp.
  Mastigobolbina typus Ulrich and Bassler.
  Mastigobolbina new sp.
  Plethobolbina typicalis Ulrich and Bassler.
  Zygosella vallata Ulrich and Bassler.
Clinton shale (middle 165 feet):
  Coelospira sp.
Clinton shale (lower 100 feet):
  Crinoid stems, some round, some pentagonal.
  Brachyprion sp.
  Brachyprion pleuristriata (Foerste) = *Stropheodonta corrugata* var. *pleuristriata* Foerste.
  **Coelospira* sp. indet.
  **Camarotoechia* sp.
  Coelospira hemispherica (Sowerby).
  Coelospira hemispherica var.
  **Fardenia* sp.
  Lingula sp.
  Schuchertella sp.
  Pelecypods.
  Gastropods.
  Tentaculites sp.
  Calymene sp.
  Calymene sp. cf. *C. vogdesi* Foerste.
  Eophacops sp.
  Zygobolba anticostiensis Ulrich and Bassler.
  Zygobolba aff. *Z. excavata* Ulrich and Bassler.

Age.—The Clinton shale of Lee County appears to be identical in age with the Clinton elsewhere in the Appalachians. Ostracodes that mark the lowest and highest of the Clinton faunal zones in Maryland and Pennsylvania have been identified by Frank M. Swartz, from collections made by the authors from the lower part and upper part of the formation in Lee County. Since there is no indication of any break in sedimentation of the Clinton, the equivalence of the formation from Lee County to Pennsylvania is assumed.

HANCOCK DOLOMITE

Name.—The Hancock limestone was named by Keith (1896a) for a sequence of limestone and dolomite of late Silurian age occurring in Hancock County, Tenn., and mapped in the Morristown folio The name applied by Keith had been accepted and used by Campbell (1894) 2 years earlier in the Estillville folio, which covers an area northeast of the Morristown quadrangle and includes part of the Jonesville district. In the Estillville quadrangle, however, beds of Helderberg age, which are present above the upper Silurian beds, were included with the Hancock. More recently the upper Silurian beds have been called Cayuga limestone, and the beds of Helderberg age have been called Helderberg limestone. Because the name Hancock has priority in southwest Virginia and, as originally defined by Keith, does not cross a systemic boundary, it seems desirable to restore it to good standing, restricting it, as Keith did, to the carbonate beds of late Silurian age. In the Jonesville district, the formation is composed almost entirely of dolomite, except as noted later, so the formation will here be called the Hancock dolomite.

The Hancock dolomite is identical with the Cayuga dolomite as used by Miller and Fuller (1947) in the Rose Hill district, and with the "formations of Cayuga age" as used by Bates (1939, pp. 31–94) in eastern Lee County.

Distribution.—The Hancock dolomite forms a continuous but very poorly exposed belt along Poor Valley; however, most of it lies beyond the limits of mapping of the Jonesville district. East of Hubbard Springs, the belt has been mapped for a short distance. In the faulted area around Ben Hur a belt of steeply dipping Hancock, cut off at both ends by faults, lies in normal stratigraphic position between the Clinton shale and Upper Devonian shale. The Hancock is also exposed in Little and Big Fleenortown fensters, Town Branch fenster, and Sulphur Springs fenster. The outcrops of Hancock in the last-named fenster are the most extensive and best in the Jonesville district.

On the south side of Wallen Ridge the Hancock dolomite has been eliminated by overthrusting along the Wallen Valley fault except in a short belt south of Poteet Ferry bridge and in a complex area at the eastern tip of the district.

The Hancock dolomite has no consistent topographic expression, being neither particularly resistant nor particularly weak. In places, as along Poor Valley, it underlies the valley floor and has practically no outcrops. In the Sulphur Springs fenster, however, it rises up as

FIGURE 20.—Contact of Clinton shale and Hancock dolomite along State Route 70 in the east part of Ben Hur.

hogbacks on the slopes of fairly high hills and has abundant ledgy outcrops. In the other fensters the formation has few outcrops and its presence is not immediately apparent.

Character.—In all except the extreme eastern part of the Jonesville district, the Hancock dolomite has a three-fold lithologic division. At the base are a few feet of sandstone or limy sandstone in which the sand grains vary from medium to coarse and which in places contains larger conglomeratic pebbles. This sandstone is coarser than almost any sandstone in the Clinton and is readily distinguished from it in outcrop or in float. Overlying the basal sandy beds are 20–30 feet of dark-bluish-gray fine-crystalline limestone which is in thin, ribbon-like beds in the lower part and is irregularly mottled in the upper part. Ribboning and mottling are due to the presence of layers and patches of lighter-colored silty limestone in conjunction with darker-colored pure limestone. Weathering accentuates the ribboning and mottling, which are inconspicuous in the fresh rock. The weathered basal sandy zone and some of the overlying ribbon limestones are shown in the left half of the photograph in figure 20, taken along State Route 70 in the town of Ben Hur. The hammer is at the contact with the underlying Clinton, the top beds of which are a quartzitic sandstone. A small unmapped fault duplicates the beds in this vicinity so that the Clinton and Hancock contact is exposed again along the road a short distance to the right of the edge of the picture.

The third type of rock in the Hancock dolomite is brownish-gray fine-grained and fine-crystalline dolomite in beds from 6 inches to 2 feet thick that weather light gray to white with criss-cross grooves ("butcher-block structure"). This rock forms all of the middle and upper parts of the formation in most of the Jonesville district.

The Hancock dolomite changes facies within the Jonesville district. In the western half of the district all but the lowest 20–30 feet of the formation is dolomite. At Ben Hur a 15-foot zone of limestone has appeared in the upper part of the formation. In the exposures of the Hancock at the eastern end of the Jonesville district, practically all of the Hancock is limestone, with only a few beds of dolomite. This limestone facies was not studied in detail because it occurs in a strongly folded and faulted region where the proper sequence and thickness of units could not be determined. It is clear, however, that the lowest 20–30 feet are ribbon and mottled limestone identical to that farther west. The higher beds are brown fine-grained and fine-crystalline limestone in even and fairly thin beds that resemble some of the platy limestones of the Ordovician. A few small chert nodules were seen in the limestone, and occasional beds of dolomite from 6 to 18 inches thick are interbedded with the limestone.

This limestone facies persists into northeastern Lee County and Wise County, where Bates (1939) and Stose (1923, pp. 36–40) both describe the beds of Cayuga age as being predominantly limestone, although both note that some magnesian limestone and dolomite are included.

The only good section of the Hancock dolomite in the Jonesville district is the one along and near the highway on the east edge of Ben Hur (geologic section 19).

Stratigraphic relations.—The Hancock dolomite disconformably overlies the Clinton shale, as shown by the sharp contact between the two and by the persistent coarse to pebbly basal sandstone of the Hancock, which locally contains conglomeratic pebbles. Local absence—as at Hagan—of the sandstone zone that normally forms the top of the Clinton, is probably due to erosion of these beds in the Clinton and Hancock hiatus that spans all of Lockport time.

The black shale of Upper Devonian age unconformably overlies the Hancock dolomite with a hiatus between the two that includes all of Lower and Middle Devonian time.

Thickness.—The Hancock dolomite is 188 feet thick at Ben Hur. At Hagan, where the base and top of the formation are exposed but all the rest covered, the formation appears to be 158 feet thick. No other thickness measurements have been obtained in the Jonesville district, but at the eastern end of the district, where the formation is almost entirely limestone, it appears to be thicker than at Ben Hur.

Paleontology.—The dolomitic beds that compose most of the Hancock dolomite, except in the eastern end of the district, are unfossiliferous. The limestones in the lower part of the formation, however, contain a few very characteristic fossils. Most abundant is a fat stemlike coral, *Coenites sp.* Two other corals, *Favosites* sp., and *Halysites* sp. cf. *H. catenulatus*, were found in a few places, and a small stromatoporoid is also common. A few poorly preserved brachiopods and trilobites have been found in the basal sandy beds. The forms collected partly in the Jonesville district and partly in the Rose Hill district and identified by G. A. Cooper are listed below.

- Hancock dolomite
  - From limestone beds in the lower part:
    - Algal? structures.
    - *Stromatopora* sp.
    - *Coenites?* sp.
    - *Favosites* sp.
    - *Halysites* cf. *H. catenulatus* (Linnaeus).
    - Crinoid fragments.
    - Spiriferoid brachiopod.
    - *Whitfieldella* sp.
    - Orthoceratid.
    - *Calymene* sp.
    - *Leperditia?* sp.
  - From basal sandy beds:
    - *Liocalymene clintoni* (Vanuxem).
    - *Bonnemaia* cf. *B. oblonga* Ulrich and Bassler.
    - *Zygosella* cf. *Z. vallata* Ulrich and Bassler.

Age.—The fossils collected from the Hancock dolomite of the Jonesville and Rose Hill districts are not sufficiently numerous or distinctive to give a good age determination. The formation appears, however, to be exactly equivalent to the Cayuga limestone of Stose in Wise County, where the more limy beds contain fossils throughout the formation. Stose (1923) and also Butts (1940, pp. 258–259) believe the Cayuga limestone of Wise County to be of Wills Creek and Tonoloway age. G. A. Cooper, who identified the fossils from the basal sandstone of the Hancock at Hagan, states that these fossils appear to be of Rochester age, which indicates that the Hancock may contain some beds of pre-Cayuga age.

DEVONIAN SYSTEM

UPPER DEVONIAN SHALE (UPPER DEVONIAN SERIES)

Name.—Shale of Late Devonian age is the youngest consolidated rock in the Jonesville district. Knowledge about this gray and black shale, which was included in the Chattanooga shale by early workers in the Applachians, is still incomplete. In Lee and Wise Counties, Va., the beds mapped as the "Chattanooga" shale included the entire sequence between the top of the Hancock dolomite (limestone) or Helderberg limestone and the base of the Price sandstone. Recent opinion has been that the lower part of the "Chattanooga" is of Late Devonian age and the upper part of Mississippian (?) age. The names Genesee shale, Portage shale, Brallier shale, and Big Stone Gap shale have been applied to various parts of the sequence in Lee and Wise Counties. The distinctions between these formations are not, however, clear to the writers. In the Jonesville district, where the shale sequence is very poorly exposed and is commonly folded and faulted, the age and proper nomenclature of the shales was not resolved. Inasmuch as only the lower part of the "Chattanooga" shale is included in the mapped area, and this part of the "Chattanooga" is believed by all to be of Late Devonian age, this shale will be referred to as Upper Devonian shale.

Distribution.—The Upper Devonian shale forms a continuous belt along Poor Valley but was not mapped. Good exposures of the shale have, however, been indicated on plate 1. The best exposure of the shale is at the mouth of the railroad tunnel at Hagan.

The entire shale sequence lying between the Hancock dolomite and the Price sandstone is probably present in Poor Valley, but the shale has very few outcrops and the Price has none that was seen by the writers. Everywhere else in or near the Jonesville district the upper part of the "Chattanooga" shale has been removed by faulting and older formations lie in fault contact on the lower part, which is believed to be entirely of Late Devonian age.

The Upper Devonian shale crops out in a short belt that passes through the town of Ben Hur. Good exposures of the shale may be seen at the Ben Hur railroad station and on the valley walls near Sulphur Springs. Belts of the shale are also exposed around the rims of the Big Fleenortown, Town Branch, and Sulphur Springs fensters, but in no case are the belts continuous all the way around the fensters.

Upper Devonian shale is probably the weakest formation in the area. Along Poor Valley it normally lies at or near the lowest point of the valley. Elsewhere its topographic position is determined largely by the resistance of the beds which have been faulted over it. In many places it lies above the valley floors, and on steep slopes it has fairly numerous outcrops and produces a distinctive float of shale chips. The shale is in many places intricately folded.

Character.—The base of the Upper Devonian shale has been seen in the railroad cut at Hagan, in a gully along the northwest edge of the Big Fleenortown fenster, in a roadside ditch on the steep hill east of Sulphur Springs, and in the deeply weathered and slumped roadcut along State Route 70 on the west side of the Town Branch fenster. In each locality the basal bed consists of medium- to coarse-grained, porous friable sandstone which is 5 inches thick at Hagan, 3 inches thick at Fleenortown, 5 inches thick at Sulphur Springs, and as much as a foot thick in the Town Branch fenster. At Hagan the overlying beds are dark-gray shale which forms a unit 76 feet thick. This unit is overlain by 60 feet of carbonaceous black shale, above which is an overthrust fault that duplicates the section. Elsewhere the distinctive gray-shale unit was not recognized, and the beds above the basal sandstone are in part gray and in part black and carbonaceous. At most localities the association of severe folding and the presence of nearby major faults makes it impossible to determine the correct stratigraphic sequence.

The shales of the Upper Devonian are readily recognizable because they are the only carbonaceous shales in the column.

Stratigraphic relations.—The unconformity at the base of the Upper Devonian shale represents the longest hiatus in deposition in the Jonesville district. All of Early Devonian and Middle Devonian time is included. A few miles northeast of the Jonesville district, deposits of Helderberg age are present above the Hancock dolomite, and farther to the northeast are found deposits of Oriskany and Onondaga age.

Thickness.—The thickness of the Upper Devonian shale is known to be more than 137 feet at Hagan. The entire shale sequence, which probably includes beds of Mississippian age in the upper part, is undoubtedly considerably thicker. Butts (1940, pl. 45) indicates that it is 400–500 feet thick at Cumberland Gap west of the Jonesville district and nearly 1,100 feet thick at Big Stone Gap east of the Jonesville district.

Paleontology.—The Upper Devonian shale is sparingly fossiliferous in the Jonesville district. Spores were found in siderite concretions at Hagan, and a few chitino-phosphatic brachiopods probably belonging to the genus *Lingula* were seen. The shale probably also contains conodonts.

QUATERNARY SYSTEM

Mapped deposits of Quaternary age include terrace gravels of the Powell River, flood-plain alluvium along the larger streams, and talus and alluvial fans on the slopes of Wallen Ridge. All except possibly the highest of the terrace gravels, which are also the oldest, are of post-Pleistocene age. The character and origin of the Quaternary deposits is discussed in the chapter on physiography.

GEOLOGIC SECTIONS 1–20

GEOLOGIC SECTION 1.—*Maynardville limestone along Fourmile Creek beginning at the Virginia-Tennessee State line 3 miles south-southeast of Ewing, Va.*

[Measured by R. L. Miller and J. O. Fuller, in press]

	Feet
Copper Ridge dolomite:	
9. Dolomite, dark-gray, coarse-crystalline, massive-bedded, with petroliferous odor; contains interbeds of light-gray, fine-grained dolomite	20

	Feet
Maynardville limestone (302 feet):	
Chances Branch dolomite member (160 feet):	
8. Dolomitic limestone, light-gray, fine-grained, in even, angularly jointed beds; and dark-gray and brown, medium- to coarse-crystalline dolomite with petroliferous odor	55
7. Dolomitic limestone, light-gray, fine-grained, argillaceous, in beds 6 inches to 3 feet thick; some beds show laminae on weathered surfaces; interbeds of dark-gray limestone in lower part; tan chert in thin lenses; intraformational conglomerate locally	105
Low Hollow limestone member (142 feet):	
6. Limestone, dark-gray, massive-bedded, mottled, with thin interbeds of shale in lower part and of light-gray dolomite in upper part	47
5. Dolomitic limestone, light-gray, silty, with closely spaced laminae showing on weathered surfaces	22
4. Limestone, dark-gray, fine-grained, ribboned and mottled, with some oolitic beds; silty limestone layers separate ribbons, and silty limestone patches give mottled effect; trilobite fragments near base; ribbon limestone	73
Conasauga shale:	
3. Shale, dark fissile	3
2. Limestone, tan to gray, gnarled, ribbon bedding poorly developed; contains trilobite fragments; transitional from Conasauga to Maynardville type of limestone	8
1. Shale and limestone, in beds 1 inch thick; dark-gray shale; gray, fine-grained limestone	3

Geologic Section 2.—*Chances Branch dolomite member of the Maynardville limestone and Copper Ridge dolomite along Chances Branch half a mile southwest of Ewing, Va.*

[Measured by R. L. Miller and J. O. Fuller, in press]

	Ft.	*in.*
Chepultepec dolomite:		
24. Shale, interbedded with sandstone and dolomite	1	6
23. Dolomite, light-gray, fine- to medium-crystalline; some dark-gray medium-crystalline dolomite with petroliferous odor; oolitic chert	45	9
22. Shale, tan, calcareous; and dolomitic sandstone which is friable and limonite-stained when weathered	2	3
Copper Ridge dolomite (840 feet):		
21. Dolomite, light-gray and white, fine- and medium-crystalline; contains light to white oolitic chert in irregular masses and in beds several inches thick; occasional shale interbeds; forms light-brown soil	135	0
20. Covered; forms brown soil containing small cobbles of silicified dolomite	97	0
19. Dolomite, light- to medium-gray, coarse crystalline, saccharoidal, with some beds of fine-crystalline dolomite; bedding poorly developed; soil brown	70	0
18. Covered; brown soil containing white brecciated chert cobbles	92	0
17. Dolomite, light-gray coarse crystalline, and light brown, cryptocrystalline; forms deep red soil	12	0
16. Covered; soil contains chert and silicified dolomite cobbles	177	0

Copper Ridge dolomite (840 feet)—Continued	Ft.	in.
15. Dolomite, medium- and dark-gray, coarse-crystalline; vuggy, with abundant white dolomite veins and patches; gives strong petroliferous odor	172	0
14. Dolomite, medium-gray, mottled, coarse-crystalline; gives strong petroliferous odor, lower part contains possible algal reef	16	0
13. Covered	34	0
12. Dolomite, medium- to dark-gray, coarse crystalline, with strong petroliferous odor; contains several beds of light-gray cryptocrystalline dolomite typical of upper part of Maynardville	35	0
Maynardville limestone (229+ feet):		
Chances Branch dolomite member (209 feet):		
11. Dolomitic limestone, light-gray, fine-crystalline, even-bedded; and dark-gray, coarse-crystalline dolomite with petroliferous odor	56	5
10. Dolomitic limestone, light-gray, fine-crystalline, with several medium-crystalline beds; two shale beds, each 1 inch thick	35	9
9. Covered	26	10
8. Dolomite, dark-gray, medium-crystalline, with petroliferous odor; and light-gray, fine-crystalline, dolomitic limestone in one massive bed; lowest occurrence of Copper Ridge type of dolomite	6	9
7. Dolomitic limestone, light-gray, fine-grained, even-bedded	36	5
6. Limestone, bluish-gray, mottled; highest occurrence of Low Hollow member type of limestone	3	2
5. Dolomitic limestone, light-gray, fine-crystalline, laminated or mottled on weathered surfaces	25	2
4. Limestone, blue, fine-crystalline, with calcite eyes	3	0
3. Dolomitic limestone, light-gray, fine-grained, with fine laminae and indistinct intraformational conglomerate showing on weathered surfaces	10	5
2. Dolomitic limestone, gray, fine-grained, with intraformational conglomerate chips averaging one-eighth inch in length, formed by break-up of beds of thinly laminated dolomitic limestone similar to those in unit 3	4	9
Low Hollow limestone member:		
1. Partly covered; limestone, blue, mottled, massive-bedded; contains, at top, scattered tiny chips of white-weathering dolomitic limestone	20+	

GEOLOGIC SECTION 3.—*Upper part of the Copper Ridge dolomite, and Chepultepec, Longview, Kingsport, and Mascot dolomites along Long Hollow 3 miles southeast of Ben Hur, Lee County, Va.*

[Section begins at road junction a quarter of a mile south of Long Hollow School, follows the Long Hollow road to a point 1,500 feet northwest of Rock Castle School, thence extends northeastward uphill to the Mascot dolomite and Dot limestone contact. Measured by R. L. Miller]

Mascot dolomite (421 feet):	Feet
35. Dolomite, white, fine-crystalline, slabby, having scattered outcrops in field; top of unit is approximately at concealed contact of Mascot dolomite and overlying Dot limestone	52.0

Mascot dolomite (421 feet)—Continued	*Feet*
34. Dolomite, similar to unit 35, having scattered outcrops in field; abundant blocks of white chert on the surface	44.4
33. Covered interval in field	60.6
32. Dolomite, light-tan, medium-crystalline, saccharoidal, in massive beds, forms lowest 10 feet; medium-crystalline and fine-crystalline dolomite, with partings and thin beds of green shale, forms remainder of unit; has scattered outcrops in woods; produces an abundant chert float	85.4
31. Dolomite, light-colored, dense, cryptocrystalline and fine-crystalline, containing irregularly shaped nodules and lenses of white chert; bed of sandy dolomite near top, and a little sandstone in the float derived from this unit; unit has scattered outcrops on hillside; from the base of this unit to the top of the section, measurements were made up the hillside and across fields in a northeast direction	67.7
30. Dolomite, light-gray, fine crystalline, saccharoidal; and gray, fine-crystalline, silty, faintly laminated dolomite; banded chert in nodules and beds, particularly abundant in basal 6 feet; highest abundant chert in Mascot is in this unit	43.3
29. Dolomite, light-gray to white, dense, fine-grained, in beds 1 to 3 feet thick; some light-gray, medium-crystalline, saccharoidal dolomite; chert in irregular masses and beds, most abundant in lower half of unit	39.5
28. Dolomite, light-gray, dense, fine-crystalline; and light, fine- to medium-crystalline, saccharoidal dolomite; chert beds several inches thick; bed of green dolomitic shale 4 inches thick at top; basal bed 1 foot thick of gnarled chert containing tilted and broken nodules of chert and with bottom inch of deeply weathered porous chert	28.1
Kingsport dolomite (272 feet):	
27. Largely covered; a few ledges in hillside of light-gray and grayish-white medium-crystalline saccharoidal dolomite with patches and stringers of white secondary dolomite, weathering yellow	62.4
26. Covered along road, but exposed in hillside; dolomite, medium- and coarse-crystalline, grayish-white, saccharoidal, massive-bedded	68.4
25. Dolomite, grayish-white and flesh-colored, medium- and coarse-crystalline, saccharoidal, in massive beds; weathers with irregular surfaces and with solution cavities and pinnacles; top of unit directly opposite white house on southwest side of road	109.1
24. Partly exposed, gnarled mass of brecciated chert containing some rounded chert pebbles	29.5
23. Basal 6 inches are of limonite-stained sandy clay, overlain by 4 inches of pebbly weathered conglomerate containing both chert and dolomite pebbles; top 18 inches of massive, sandy, banded chert	2.4
Longview dolomite (222 feet):	
22. Dolomite, light-gray and grayish-white, medium- and fine-crystalline, saccharoidal, in beds 1 to 2 feet thick; abundant nodules, masses and beds of white and light-gray chalcedonic chert; a 4-inch bed of sandstone underlain by 6 inches of sandy dolomite with chert lenses lies 10 feet below top	26.6

Longview dolomite (222 feet)—Continued	*Feet*
21. Dolomite similar to unit 19, with abundant chert mostly in well shaped, banded nodules	109. 2
20. Covered interval	41. 4
19. Dolomite, light-gray and flesh-colored, fine-crystalline, faintly laminated; chert nodules and lenses in lower few feet only	38. 0
18. Dolomite, dark-gray, fine-crystalline, saccharoidal, sandy, grading upward into nearly white dolomite and then medium-gray dolomite; abundant oval and irregularly rounded nodules of banded, light-colored chert, weathering white; shaly layer at top	4. 8
17. Sandstone, grading upward into sandy dolomite and dolomite; abundant chert nodules; sharp wavy contact at base	1. 5
Chepultepec dolomite (775 feet):	
Argillaceous dolomite member (397 feet):	
16. Dolomite, medium gray, light-gray, and grayish-white, argillaceous, strongly laminated, in units 1 to 3 feet thick with shale partings; contains a few thin sandy lenses; almost no chert	130. 0
15. Dolomite, light, medium, and dark-gray, fine-crystalline, argillaceous; one zone of thick oval chert nodules	64. 2
14. Dolomite, light-gray, fine-, medium-, and coarse-crystalline, vuggy, saccharoidal, forms lowest third of unit; medium- to dark-gray, fine-crystalline, argillaceous, laminated dolomite forms upper two-thirds of unit; lenses and scattered grains of sand in basal 6 feet of unit; a very little chert	109. 3
13. Dolomite, light-gray and dark-gray, fine-crystalline, saccharoidal, in scattered outcrops with a 2-foot sandy zone at base; gray and black, banded, chalcedonic chert nodules in soil	33. 1
12. Covered interval	28. 5
11. Dolomite, medium- to dark-gray, fine-crystalline, laminated, argillaceous, with thin shale partings; light-gray, medium-crystalline dolomite at top; no chert	31. 6
Sandy dolomite member (378 feet):	
10. Dolomite, medium- and light-gray fine-crystalline, laminated and locally color-banded; 3-foot zone of interbedded sandstone, shale, and dolomite at top; base of this unit opposite northwest edge of long, unpainted house on southeast side of road	56. 7
9. Covered interval	23. 4
8. Dolomite, light-gray, dense, fine-crystalline; dolomite, medium- and dark-gray, fine-crystalline, laminated, argillaceous; and dolomite, white and tan, medium- to coarse-crystalline, saccharoidal; thin lenses, beds, and nodules of highly oolitic chert; oolitic grains have thin peripheral bands around central cores or cavities; sandy beds and lenses common	78. 2
7. Covered interval	14. 2
6. Dolomite, light-, medium-, and dark-gray, fine-crystalline, argillaceous, laminated; and dolomite, light-gray to white, medium- to coarse-crystalline, massive-bedded; abundant birdseyes of white, coarse-crystalline dolomite; beds and lenses of sandstone averaging 1 inch thick at numerous horizons; a few lenses and nodules of light- and dark-colored chert; nearly black chert common	118. 9
5. Covered interval, with some cobbles of sandstone and a little chert in soil	43. 6

	Feet
Chepultepec dolomite (775 feet)—Continued	
Sandy dolomite member (378 feet)—Continued	
4. Dolomite, light-, medium-, and dark-gray, fine-crystalline, faintly laminated, in beds a few inches to 2 feet thick; one bed of black chalcedonic chert	41.7
3. Sandstone, white, with well-frosted sand grains as much as 0.04 inch in size; contains a few oval pebbles of dolomite; contact at base wavy, and cuts across a few inches of underlying beds in exposure 10 feet long	1.7
Copper Ridge dolomite (254+ feet):	
2. Dolomite, light-gray and medium-gray, fine crystalline, with a few beds of light-gray medium-crystalline dolomite; much of dolomite silty and laminated on weathered surfaces; chert in nodules and lenses and a 1-foot-thick bed; chert is light- and dark-colored, banded, and oolitic	128.5
1. Dolomite, having a few outcrops in lower part of unit; remainder covered; outcrops consist of interbedded light-gray fine-crystalline dolomite, light-gray medium-crystalline dolomite, and dark-gray medium-crystalline oily-smelling dolomite	125.8

GEOLOGIC SECTION 4.—*Upper part of Copper Ridge dolomite, and Chepultepec, Longview, Kingsport, and Mascot dolomites along road paralleling Hardy Creek*

[Section starts at first outcrop south of axis of Powell Valley anticline, about 250 yards south of Anthony Ely well, and continues south past Carrol Mill (Grabeel Mill) and Lambs Chapel to junction of Little Yellow Branch and Hardy Creek. Measured by J. O. Fuller and R. L. Miller]

	Ft.	*in.*
Dot limestone (14+ feet):		
48. Dolomite, yellow to greenish-brown, argillaceous; breaks irregularly and weathers with rounded surfaces	10+	
47. Conglomerate, composed of greenish argillaceous dolomite with chert and fine-grained light-gray dolomite pebbles as much as 1½ inches in width	2	0
46. Conglomerate, coarse; composed of argillaceous dolomite with pebbles and cobbles of light-gray fine-grained dolomite, mottled dark-brown to black dolomite, and chert; largest conglomerate boulder 13 inches by 22 inches. The dark-brown to black dolomite is of the "stinkstone" type found in the Copper Ridge dolomite	2	4+
Mascot dolomite (462 feet):		
45. Dolomite, sandy, with a few scattered quartz pebbles; undulating erosion surface at top	0	8
44. Dolomite, light-gray, fine-crystalline, in thin beds from 2 to 15 inches thick; small lenses and some irregular masses of chert	18	4
43. Dolomite, light-gray to brownish-gray, fine-crystalline and medium-crystalline, saccharoidal; abundant chert nodules, lenses, and masses	348	11
42. Dolomite, light-grayish-white, fine-crystalline, with scattered small nodules of light-gray chert; beds thinner and more argillaceous near top of unit; chert beds 1 foot thick; green shale partings	93	7

Mascot dolomite (462 feet)—Continued	*Ft.*	*in.*
41. Conglomerate, in part intraformational; consisting of light-gray fine-crystalline dolomite with scattered rounded sand grains and rounded pebbles of chert and argillaceous dolomite	1	0
Kingsport dolomite (181 feet):		
40. Dolomite, light-gray, fine-crystalline, in even massive beds from 1½ to 4 feet thick; some beds argillaceous; some with scattered sand grains; blue chalcedonic chert in beds 6 to 13 inches thick	75	1
39. Dolomite, light-gray, fine-crystalline, argillaceous; in beds 1–3 feet thick, with some coarse-crystalline saccharoidal dolomite; lenses and nodules of blue chalcedonic chert; some green shale partings	75	5
38. Dolomite, light-gray, coarse-crystalline, saccharoidal; some mottled light- and dark-gray beds with vugs lined with dolomite crystals; beds from 1½ to 6 feet thick; irregular masses of light-blue to gray chalcedonic chert	30	0
37. Sand grains in matrix of chert ("chert-matrix sand"); known from float only	0	3
Longview dolomite (272 feet):		
36. Dolomite, brownish-gray, vuggy, medium- to coarse-crystalline, saccharoidal; chert masses and lenses; a few light-gray fine-grained dolomite beds; dark-blue chalcedonic chert with scattered oolitic spherules in beds 1 foot thick	155	4
35. Shale, light-green	0	3
34. Dolomite, interbedded white, fine-crystalline and light-gray, medium- to coarse-crystalline, saccharoidal; saccharoidal dolomite contains irregular masses, lenses, and nodules of light-bluish-gray to brownish-gray chert with scattered oolitic spherules; beds of chert as much as 4 feet thick	93	9
33. Dolomite, white, fine-crystalline, slightly argillaceous, laminated; with lenticular white chert nodules, half an inch thick and several inches long	6	0
32. Dolomite, brown, coarse-crystalline, saccharoidal, with scattered sand grains	2	2
31. Chert, oolitic; most oolites small with scattered lenses of larger oolites; bed 9–14 inches thick	1	0
30. Dolomite, light-gray, argillaceous, interbedded with gray, fine-crystalline, saccharoidal dolomite; top bed sandy with medium-sized grains in dolomite matrix	7	8
29. Chert, oolitic, light-blue-gray, with sandy lenses and irregular masses of non-oolitic chert	0	10
28. Dolomite, light-gray, fine-grained	5	0
Chepultepec dolomite (696 feet):		
Argillaceous dolomite member (413 feet):		
27. Sandstone, white, limonite-stained, medium-grained	0	6
26. Dolomite, gray, fine-crystalline, argillaceous, laminated, and brown, slightly coarser crystalline, saccharoidal dolomite; contains sandstone lenses and scattered chert lenses and nodules; numerous covered intervals	386	4

	Ft.	in.
Chepultepec dolomite (696 feet)—Continued		
Argillaceous dolomite member (413 feet)—Continued		
25. Dolomite, gray, fine-crystalline, argillaceous, laminated; and brown, slightly coarser crystalline, saccharoidal dolomite; one 5-foot bed similar to unit 23	20	0
24. Dolomite, light-gray and brown mottled, medium- to coarse-crystalline; irregular-shaped lenses and nodules of light-gray, chalcedonic chert	6	0
Sandy dolomite member (283 feet):		
23. Dolomite light-tan to light-gray, fine-grained, argillaceous, and light- to dark-brown, medium-crystalline, saccharoidal dolomite; contains sandy lenses	22	0
22. Chert, white, brecciated, chalcedonic	1	6
21. Sandstone, medium-grained, quartzitic, with a few thin shaly layers	1	8
20. Dolomite, light-gray to light-tan, fine-crystalline, argillaceous; and light-brown, fine- to medium-crystalline dolomite; scattered sand grains in top layer	40	0
19. Sandstone, impure, with coarse-crystalline dolomite cement, and silicified patches	2	6
18. Dolomite, brown to gray, fine-crystalline; and pinkish-gray, coarse-crystalline, saccharoidal dolomite	6	0
17. Covered interval; some sandstone and chert float	97±	
16. Sandstone, medium-grained, 5 to 8 inches thick; overlain by white mostly oolitic chert from 6 to 8 inches thick	1	2
15. Dolomite, dark-brown, fine-crystalline, saccharoidal, with a little argillaceous dolomite	7	8
14. Dolomite, brown, fine-crystalline, argillaceous; and white, medium-crystalline, saccharoidal dolomite; unit partly covered with abundant blocks of sandstone float from covered interval	12±	
13. Dolomite, light-tan, argillaceous with laminae showing on weathered surface, some fine-crystalline brown saccharoidal dolomite; light-gray to light-brown chalcedonic chert in irregular masses and nodules; *Cryptozoa*	37	0
12. Sandstone, white, medium-grained, platy, weathering limonite brown; a little interbedded shale	2	2
11. Dolomite, light-tan to dark-gray, fine- to medium-grained, argillaceous; white, saccharoidal dolomite; oolitic chert; shale partings	49	0
10. Sandstone, white, medium-grained, friable, limonite-stained	3	0
Copper Ridge dolomite (205+ feet):		
9. Chert, light-bluish-gray, with medium-sized, scattered to closely-packed oolitic spherules; 9–15 inches thick	1	0
8. Dolomite, light-tan, fine-grained, argillaceous, with purplish-brown impurities	4	8
7. Dolomite, dark-brownish-gray, medium-crystalline, cropping out in partly covered interval; light-gray chalcedonic chert and abundant small- to medium-sized *Cryptozoa*	86	2
6. Dolomite, interbedded light- to dark-brownish-gray, fine- to medium-grained, laminated, argillaceous; and dark-brownish-gray, medium-grained, oolitic chert; *Cryptozoa*	48	2

Copper Ridge dolomite (205+ feet)—Continued	*Ft.*	*in.*
5. Dolomite, light- to dark-brown, medium-crystalline, saccharoidal; 5 inches of bluish-gray shale at top	3	1
4. Conglomerate, consisting of light-gray fine-grained sandy dolomite with lenses of pure sandstone and of light-gray fine-grained dolomite; an undulatory surface at base indicates unconformity; contact with unit 3 in middle of massive ledge	3	0
3. Dolomite, interbedded, light-gray, fine-grained, laminated, argillaceous, and light-gray to brown, medium-crystalline, saccharoidal dolomite; scattered irregular dary-gray chert masses	48	10
2. Chert, white, with closely-packed, medium-sized oolitic spherules	0	10
1. Dolomite, light- to brownish-gray, medium-crystalline	9	4

Geologic Section 5.—*Upper part of the Chepultepec dolomite; Longview, Kingsport, and Mascot dolomites; and Dot limestone along State Route 70 north of Jonesville*

[Section begins at north end of roadcut 0.7 mile north of right-angle corner at east end of main street of Jonesville and ends at right-angle corner at east end of main street. Measured by R. L. Miller]

Poteet limestone (22+ feet):	*Feet*
33. Limestone, tan, dense, cryptocrystalline, with abundant individual and coalescing nodules of black chert, weathering with light-gray and orange outer rims	20+
32. Limestone, dark-brownish-gray, medium- to coarse-crystalline, fragmental; contains fragmented brachiopods and cystid plates, a few chert nodules, and several conglomeratic pebbles of limestone; unit ranges in thickness from 8 to 27 inches; contact with underlying beds sharp and has as much as 5 inches of relief	1.5
Dot limestone (122 feet):	
31. Limestone, brownish-gray, dense, cryptocrystalline, birdseye (also called vaughanite and calcilutite), in massive beds with numerous fossils; this is so-called 10-foot vaughanite	8.7
30. Limestone, tan, dense, cryptocrystalline, faintly laminated; some slightly dolomitic	18.8
29. Mostly covered; consists of interbedded argillaceous dolomite and dense cryptocrystalline limestone	72.6
28. Limestone, light-gray, dense; contains gastropods, ostracodes, and brachiopods	2.3
27. Dolomite, argillaceous, shaly, deeply weathered	9.5
26. Dolomite, light-gray, argillaceous, containing conglomeratic pebbles as much as half an inch in size in lower part	7.0
25. Conglomerate, consisting of pebbles of chert and dolomite as much as 6 inches long in fine-grained dolomite	3.0
Mascot dolomite (498 feet):	
24. Dolomite, green, medium-crystalline, saccharoidal; deeply weathered; green weathered color apparently due to copper carbonate	2.0
23. Dolomite, light-gray to grayish-white, dense, fine-crystalline and slightly coarser crystalline; occasional zones several inches to 1 foot thick of shaly dolomite and shale; almost no chert; two minor disconformities 25 feet and 40 feet from top	82

Mascot dolomite (498 feet)—Continued	*Feet*
22. Dolomite, light-gray, fine-crystalline; and medium- to coarse-crystalline, saccharoidal dolomite; one bed contains oval chert nodules	25
21. Sandstone, brown-weathering, friable, dolomitic	8.6
20. Dolomite similar to unit 22	76
19. Dolomite, light-gray, dense, fine-crystalline; and medium-crystalline, saccharoidal dolomite; upper part of this unit contains highest bedded chert and highest abundant nodular chert in Mascot dolomite	112
18. Dolomite, light-gray to white, medium- and coarse-crystalline, saccharoidal, with a little fine-crystalline dolomite; abundant white chert including bed 3.3 feet thick near middle	112
17. Mostly covered; a few ledges of fine-crystalline saccharoidal dolomite on east side of road; 6-foot chert zone at base containing tilted chert nodules in a gnarled chert matrix; this represents basal deformed zone of Mascot dolomite	80
Kingsport dolomite (156± feet):	
16. Covered zone, except for one outcrop of medium-crystalline saccharoidal dolomite; almost no chert in soil; location of contact with Longview dolomite estimated	156
Longview dolomite (222± feet):	
15. Covered	52
14. Dolomite, brown-weathering, slabby, slightly silty; outcrops on east side of road	90
13. Dolomite, brown and gray, fine-crystalline, containing zone of nodular chert at base and beds of chert from a few inches to more than a foot thick near top; top of unit is at south end of long road cut	35
12. Dolomite, light-brown, fine-crystalline; laminated on weathered surfaces, with abundant chert lenses in lower few feet	13
11. Dolomite, brown and gray, fine-crystalline, argillaceous; contains veins and vugs filled with coarse-crystalline dolomite; no chert	28
10. One-foot zone at base of gnarled conglomerate consisting of chert and dolomite pebbles ½ to 3 inches in size in a matrix of sandy dolomite; this grades upward into medium-crystalline saccharoidal dolomite with deformed bedding and then into similar regularly bedded dolomite; sharp contact at base, which transgresses a 6-inch bed of underlying unit	4.5
Chepultepec dolomite (86+ feet):	
9. Dolomite, brown, fine-crystalline, argillaceous, laminated	4.8
8. Sandstone, dolomitic, and nonsandy dolomite, in alternating layers ¼–1 inch thick, giving strongly banded aspect to weathered surfaces	7.4
7. Dolomite, gray, fine-crystalline, argillaceous, laminated; thin zones of dark to black chert; some dolomite in lower part is sandy	18.8
6. Conglomerate, intraformational, consisting of dolomite pebbles in a sandy matrix; some of sand cemented by chert; forms distinctive bed	.2
5. Dolomite, gray, platy-bedded, strongly laminated	4.2

Chepultepec dolomite (86+ feet)—Continued	*Feet*
4. Dolomite, gray and brown, mostly fine-crystalline, with sandy dolomite at base; other sandy zones higher up, and zone of gnarled, partly chertified dolomite at top	12
3. Dolomite, gray and brown, mostly fine-crystalline, strongly laminated; a little chert, mostly black, in thin lenses and larger masses; top 4-foot zone is massive dolomite with numerous thin sandy zones	18.4
2. Dolomite, partly chertified, containing intraformational conglomerate pebbles of dolomite as much as 2 inches long; most of chert is oolitic	.6
1. Dolomite, light-brown and flesh-colored, mostly fine-crystalline; a few lenses of white-weathering oolitic chert; base of unit is at north end of long road cut	20

GEOLOGIC SECTION 6.—*Uppermost part of Longview dolomite, Kingsport dolomite, and lower part of Mascot dolomite along U. S. No. 58 in bluff just west of Poteet Ferry bridge across Powell River*

[Section begins with oldest beds exposed along road and ends at sharp corner at top of hill where road turns away from bluff. Measured by R. L. Miller]

Mascot dolomite (63+ feet):	*Ft.*	*in.*
29. Sandy bed containing irregular lenses of gray chert; not well exposed	1	0
28. Dolomite, light-gray and tan, dense, fine-crystalline; slightly coarser, saccharoidal dolomite; and medium-crystalline, saccharoidal dolomite; contains lenses, nodules, and beds of white-weathering chalcedonic chert; occasional partings and thin beds of green shale	46	6
27. Chert, medium-brown and milky-white, mottled, intergrown with dolomite; as much as 10 inches thick	0	5
26. Dolomite, tan and greenish-gray, fine- and medium-crystalline, containing vugs, some hollow, some filled with coarse-crystalline dolomite; a few chert lenses; this unit displaced 3 feet along a small fault	13	1
25. Dolomite, nearly white, coarse-crystalline, saccharoidal in lower part, and gnarled, milky-white, brown, and light-gray chert in upper part; some parts of chert zone contain fractured, tilted and jumbled blocks of chert; undulatory surface at base and top of unit	1	9
24. Shale, green, and deeply weathered, coarse-crystalline dolomite interbedded; 3-8 inches thick	0	6
Kingsport dolomite (119 feet):		
23. Dolomite, light-gray to tan, dense, fine-crystalline, with patches of secondary, coarse-crystalline dolomite	3	1
22. Dolomite, light-gray, medium-crystalline, saccharoidal, with vugs; and patches and lenses of coarse-crystalline secondary dolomite; layers of irregularly-shaped chert nodules at base	4	1
21. Similar to upper part of unit 20 but with fewer vugs	6	3
20. Dolomite, light-gray to nearly white; fine-crystalline and medium-crystalline in lower part, grading upward into medium-crystalline dolomite with numerous vugs	13	2

Kingsport dolomite (119 feet)—Continued	*Ft.*	*in.*
19. Covered	8	0
18. Dolomite, light-gray, dense, fine-crystalline; and fine- and medium-crystalline, saccharoidal dolomite	13	10
17. Dolomite, gray, fine-crystalline, with numerous lenses, patches, and ramifying veins of chert	5	10
16. Dolomite, light-gray and tan, dense, fine-crystalline and medium-crystalline; no chert	9	0
15. Dolomite, tan, dense, fine-crystalline; highly jointed with some curving joints	7	8
14. Dolomite, gray, medium- and fine-crystalline, with a lensing branching bed of chert as much as 6 inches thick at base	3	4
13. Dolomite, light-gray, coarse, medium- and fine- crystalline, saccharoidal; no chert	18	2
12. Dolomite, light-gray, dense, fine-crystalline, with reddish-brown spots and blotches	1	3
11. Dolomite, light-gray, and speckled light-gray and white, medium- and coarse-crystalline, saccharoidal, friable; contains vugs, a few thin chert nodules, and patches and stringers of secondary dolomite; many saccharoidal crystals coated with thin films of white powder	14	0
10. Dolomite, light-gray, coarse-crystalline; in one bed; no chert	4	5
9. Dolomite, light-gray and light-tan, medium- and fine-crystalline, saccharoidal, with wavy bedding showing effect of disturbed zone beneath; chert content varies greatly, from none in some parts of exposure to abundant lenses and elongate nodules in other parts	4	6
8. Jumbled zone of masses and tilted lenses of white-weathering oolitic chert, and light-gray, medium-crystalline, saccharoidal dolomite containing chert veins; unit changes character rapidly in short distances from almost all dolomite to mainly chert; disturbed bedding diminishes upward; dolomite near base is sandy with ½- to 1-inch lens of sand at base; a little of oolitic chert is sandy; sharp, undulatory contact at base	2	9
Longview dolomite (31+ feet):		
7. Dolomite, light-gray, fine- and medium-crystalline, saccharoidal, in beds several feet thick, with thin partings of dolomitic shale; numerous thin lenses of chert, some oolitic	14	5
6. Dolomite, light-tan, medium-crystalline, saccharoidal, forming massive unit; numerous vugs in upper part; lenticular beds and nodules of chert as much as 4 inches thick; chert is white to gray, and weathers white	6	1
5. Dolomite, grayish-white, medium-crystalline, saccharoidal, in even beds from 7 to 18 inches thick; scattered masses of white chert at top	5	0
4. Chert, gray, chalcedonic, weathering white, in two beds; has numerous lunule-shaped cavities; some chert banded; loose *Lecanospira* believed to come from this unit	1	2
3. Dolomite, light-gray, medium-crystalline, saccharoidal, in one massive bed; chert nodules near top	2	6

Longview dolomite (31+ feet)—Continued	Ft.	in.
2. Chert, light-gray to milky-white, banded, chalcedonic; breaks along numerous joints into small splintery chips; bed lenses out in exposure	0	4
1. Dolomite, grayish-white, medium-crystalline, saccharoidal, in beds from 6 to 12 inches thick	1	7

GEOLOGIC SECTION 7.—*Dot, Poteet, and Rob Camp limestones along and near U. S. No. 58 about 2½ miles west of its junction with State Route 66 at Dot*

[Section begins in quarry on north side of road and ends on hill in right-angle bend of Station Creek 2,500 feet due east of the quarry. Measured by R. L. Miller]

	Feet
Martin Creek limestone (25+ feet):	
35. Limestone, tan, cryptocrystalline and fine-crystalline, with abundant chert nodules; some beds laminated on weathered surfaces; these are highest beds exposed on north side of Station Creek in this vicinity	12.6
34. Limestone, medium-gray at base, tan above, fine-crystalline, with abundant chert nodules; some beds laminated	12.0
Rob Camp limestone (153 feet):	
33. Limestone, identical with unit 29; contact with Martin Creek limestone not well exposed	64.0
32. Limestone, medium- and dark-gray, dense, fine-crystalline in platy beds with abundant chert nodules	3.1
31. Limestone, identical with unit 29	39.4
30. Limestone, dark-gray, dense, fine-crystalline, with very abundant knobby and coalescing chert nodules	4.5
29. Limestone, dove-gray and tan, dense, cryptocrystalline, pure, with numerous birdseyes of white calcite; in massive beds that weather blue-white with fluted and rough, pitted surfaces	42.4
Poteet limestone (56 feet):	
28. Limestone, tan, cryptocrystalline and fine-crystalline, in beds from a few inches to 1½ feet thick, containing chert nodules, large gastropods, and fragments of *Tetradium*; top bed well-laminated; contact with Rob Camp limestone conformable	21.0
27. Limestone, brown and gray, fine-crystalline, and some nearly cryptocrystalline limestone, in irregular beds, with abundant chert nodules, and with large gastropods and straight cephalopods	13.0
26. Limestone, light-brown and tan, some cryptocrystalline, some fine-crystalline; cryptocrystalline beds have calcite "birdseyes" and weather with fluted surfaces; abundant chert nodules in both types; zone of yellow-weathering slightly dolomitic shaly limestone near top	10.2
25. Limestone, dark-gray, medium-crystalline, fragmental, oily smellings, forms basal 2 feet; overlain by limestone, medium- and dark-gray, fine-crystalline, oily smelling; nodules and lenses of chert throughout	12.2
Dot limestone (193 feet): (type locality, but not type section.)	
24. Limestone, tan, cryptocrystalline, with calcite birdseyes, in massive beds from 1 to 2 feet thick; contains unidentifiable gastropods and a few ostracodes; this is so-called "10-foot vaughanite"	15.2

	Feet
Dot limestone (193 feet)—Continued	
23. Limestone, light-gray, laminated, and dolomitic limestone, light-gray, dense, with a 5-foot zone of dolomite at top; section crosses road at top of this unit and continues along slope overlooking Station Creek	20.0
22. Limestone, laminated, thin-bedded; shale, buff-weathering and calcareous; interbedded with dolomitic and earthy limestone; zone 1.4 feet thick at base is dark-gray, fine-crystalline limestone, slightly oily smelling with numerous chert nodules	12.6
21. Limestone, pure with calcite birdseyes; limestone, shaly; and dolomitic limestone, earthy; numerous poorly preserved small fossils; ostracodes, gastropods, brachiopods	4.8
20. Dolomite, light-gray, fine-grained, in beds 1–4 feet thick, with shaly layers from 1 to 2 inches thick between dolomite beds	19.8
19. Dolomite, yellow, argillaceous, with conspicuous spheroidal weathering; 4 inches of shaly limestone at base	6.2
18. Limestone, dolomitic, earthy, massive in lower part and shaly in upper part; small bryozoans near middle are oldest fossils seen in this section	14.0
17. Limestone, light-gray, dense, fine grained, in one bed	3.6
16. Limestone, dolomitic, yellow-weathering, massive to shaly, with a few zones of nondolomitic shaly limestone	22.8
15. Limestone, greenish-gray, fine-grained; weathers blue-gray; some beds laminated and weather shaly	18.5
14. Covered along road, but in woods are ledges of dolomite, light-greenish-gray with reddish tinges; in massive beds	12±
13. Dolomite, purple at base grading upward into maroon and gray shaly dolomite; unit comes down to road level at small wooden highway bridge across gully	1.5
12. Dolomite, reddish-purple, maroon and gray, both massive and shaly	5.8
11. Dolomite, yellow and orange, resistant, 8 inches thick, grading upward into green-orange and gray shaly dolomite	2.3
10. Dolomite, deep-maroon, earthy, breaking along numerous curving joints to a rubble of small chips	2.3
9. Dolomite, greenish-gray and yellow in lower part and lavender in upper part; scattered sand grains near base and slight disconformity at base; 2.0 to 3.5 feet thick	2.0
8. Dolomite, yellow, earthy; and brick-red, less resistant dolomite in zones about 1 foot thick	5.7
7. Dolomite, maroon with patches of green, earthy, deeply weathered	5.9
6. Dolomite, yellow, grading upward into red, soft, eathly dolomite	0.2
5. Dolomite, brick-red with green patches, very soft, argillaceous	3.0
4. Covered along road; partly exposed beds of dolomite in woods but beds not traceable to road	7.4
3. Dolomite, greenish-buff, earthy, with small indistinct pebbles of dolomite; this bed is at top of quarry; section continues 405 feet to east along highway; probable error due to offsetting is less than 5 feet	4.0

Dot limestone (193 feet)—Continued	*Feet*
2. Dolomite, buff-colored, weathering dirty yellow; basal few inches sandy, and scattered sand grains through basal foot; abundant small angular to subrounded pebbles of dolomite in basal foot and conglomeratic thin lenses higher in unit; a few angular chips of chert; this unit forms the top prominent bed of quarry face in northeast corner of quarry	3.6
Mascot dolomite (21+ feet):	
1. Dolomite, light-gray, dense, fine-grained; upper beds have faint bands and patches of pink dolomite; weathers with "butcher-block" grooved surfaces; contains no chert	21.0

GEOLOGIC SECTION 8.—*Dot limestone in cut at south end of spur of Louisville and Nashville Railroad at Hagan, Lee County, Va.*

[Section begins with oldest beds exposed in cut at south end of spur and ends with youngest beds exposed in second cut along spur. Measured by R. L. Miller and J. O. Fuller]

Poteet limestone (8+ feet):	*Ft.*	*in.*
22. Limestone, dark-brown, fine-crystalline, with asphaltic films along fracture surfaces, and with petroliferous odor; abundant oval and lenticular chert nodules; abundant fragmentary fossils	3	4
21. Limestone, medium- to dark-gray, fine- and medium-crystalline, with petroliferous odor; abundant fragmentary fossils; part is fragmental limestone	4	4
Dot limestone (178 feet): (Type section)		
Limestone member (57 feet):		
20. Limestone, light-brownish-gray, cryptocrystalline, with calcite birdseyes, in beds from 1 to 2 feet thick; this is so-called 10-foot vaughanite	7	10
19. Limestone, light-gray to brownish-gray, fine-grained; basal 20 inches silty and weather "wormy"; abundant fragmentary bryozoans and brachiopods in one bed	16	3
18. Dolomite, light-gray, fine-grained, argillaceous; highest dolomite in section	8	2
17. Limestone, light- to dark-gray, fine-grained, laminated; contains intercalated buff fine-grained argillaceous dolomite; thin shaly partings; fragmentary fossils in top bed	24	9
Dolomite member (121 feet):		
16. Dolomite, buff to gray, fine-grained, even-bedded, with shaly partings and a few siliceous nodules	17	11
15. Dolomite, medium- to dark-gray, fine-grained, shaly, with 1½-inch bed of limestone in lower part	8	8
14. Dolomite, buff, fine-grained, argillaceous, even-bedded, with zones of limestone 6 inches and 11 inches thick	12	4
13. Dolomite, argillaceous and shaly, and limestone, gray, fine-grained; massive bed of dolomite 2 feet thick near middle; ratio of dolomite to limestone is 3 to 1; unit is most prominent shaly zone in cut	15	8
12. Dolomite, buff, fine-grained, very argillaceous, in massive beds, rounded by weathering	5	6
11. Limestone, gray, fine-grained; purer and lighter in lower part, more argillaceous and darker in upper part	6	6

	Ft.	in.
Dot limestone (178 feet)—Continued		
Dolomite member (121 feet)—Continued		
10. Dolomite, buff and light-gray, argillaceous, massive-bedded; small scattered angular chert pebbles near top; thin zone of intraformational conglomerate	6	8
9. Limestone, brownish-gray, fine-grained, with calcite veinlets; lowest limestone in section	1	0
8. Dolomite, greenish-white, fine-grained, argillaceous, massive-bedded; shale partings as much as 6 inches thick	10	0
7. Shale, greenish-black	0	10
6. Dolomite, greenish-white with red zones and irregular areas, fine-grained, argillaceous; curving joints and rounded weathered surfaces; partings of green shale between massive dolomite layers; base of unit at beginning of long cut	16	3
5. Dolomite, buff to white with a reddish-purple bed 2 inches thick, and other mottled red patches; beds exposed in scrubby woods	14	3
4. Dolomite, greenish-white, fine-grained, containing chert pebbles as much as half an inch long in lower part; exposed in scrubby woods	5	0
3. Sandstone, buff, medium-grained, dolomitic, with patches of clay and pebbles of chert as much as half an inch long; exposed in scrubby woods	0	8
Mascot dolomite (122+ feet):		
2. Dolomite, light-gray, fine-grained and fine-crystalline, in even beds with occasional sandy lenses; partly exposed in woods	81	10
1. Dolomite, light-gray, fine-grained, with some white chert; partings and zones of green shale; beds continuously exposed in cut	39	11

GEOLOGIC SECTION 9.—*Dot, Poteet, Rob Camp, and Martin Creek limestones along bluff of Powell River north of Poteet Ford footbridge*

[Section begins in region of scattered outcrops on untimbered slopes a quarter of a mile north of footbridge, continues along lane about 40 feet above the river, and ends along farm road 220 feet north of footbridge. Measured by R. L. Miller]

	Feet
Hurricane Bridge limestone (26+ feet):	
40. Limestone, cryptocrystalline, weathering bluish white, and argillaceous limestone, weathering yellow and shaly	7.5+
39. Limestone, yellow-weathering argillaceous, shaly	6.2
38. Limestone, tan, dense, cryptocrystalline	.8
37. Limestone, yellow-weathering, argillaceous, platy to shaly, with a few beds of fine-grained, dense, purer limestone; no chert	12.0
Martin Creek limestone (182 feet):	
36. Limestone, tan and medium-brown, weathering bluish white; some beds cryptocrystalline, some fine-grained; moderately abundant chert nodules at numerous zones	50.2
35. Largely covered; two beds of light-brown and grayish-brown fine-grained limestone with abundant chert nodules; top of unit at junction of woods lane with farm road	47.7

Martin Creek limestone (182 feet)—Continued	*Feet*
34. Limestone, medium-brown, fine-grained and fine-crystalline, with petroliferous odor; chert at several horizons but not abundant; beds exposed on slope above lane	42.8
33. Limestone, medium-brown, fine-crystalline, with layers and patches of medium-crystalline fragmental limestone; chert nodules present throughout but very abundant in lower part	18.8
32. Limestone, brown, fine-crystalline and medium-crystalline, fragmental, in platy undulatory beds; scattered chert nodules along zones a few inches to 2 feet apart; fragmentary fossils	9.2
31. Limestone, dark-brown, medium-crystalline, fragmental; fragmentary fossils; no chert; contact with Rob Camp limestone is slightly undulatory bedding plane	13.8
Rob Camp limestone (7 feet):	
30. Limestone, tan, dense, cryptocrystalline, with calcite birdseyes; weathers with bedding planes at intervals of 1–2 feet; some bedding planes stylolitic; conformable contact with underlying unit	6.8
Poteet limestone (84 feet); (Type section)	
29. Limestone, tan, cryptocrystalline, in beds from a few inches to 1½ feet thick; some beds laminated	9.2
28. Limestone, light- and medium-brown, dense, fine-grained, with lenses and lenticular beds of brown and gray chert; upper half laminated	3.0
27. Limestone, tan, cryptocrystalline, with calcite birdseyes	4.2
26. Limestone, light-brown, fine-grained in lower part, grading upward into medium-brown limestone with petroliferous odor; several zones of chert nodules	9.4
25. Covered; probably similar to unit 24	10.4
24. Limestone, light-brown, dense, fine-grained, in even beds, with abundant nodules of black chert (flint)	13.2
23. Limestone, yellow-weathering, fine-crystalline, dolomitic; no chert	3.6
22. Covered	6.3
21. Limestone, tan, cryptocrystalline, with thin nodules and lenses of chert	1.4
20. Limestone, tan, cryptocrystalline, in one massive bed, with abundant large irregular-shaped nodules of chert	3.0
19. Limestone, dark-gray and dark-brown, fine-crystalline and fine-grained, with petroliferous odor and with abundant nodules of flint	13.8
18. Limestone, dark-brown, medium-crystalline, fragmental, with one zone of chert nodules	2.5
17. Limestone, dark-gray, fine- and medium-crystalline, in platy beds 1–4 inches thick, with petroliferous odor, and with abundant flint nodules and lenses; contact with underlying unit sharp but tight, and undulatory	3.6
Dot limestone (188 feet):	
16. Limestone, tan, cryptocrystalline, with calcite birdseyes; zone of chert nodules near middle; forms prominent small cliff; contains *Tetradium syringoporoides;* this is so-called 10-foot vaughanite	8.5
15. Limestone, dolomitic, like unit 13	1.0

Dot limestone (188 feet)—Continued	*Feet*
14. Limestone, tan, fine-grained, laminated	1.8
13. Limestone, yellow-weathering, fine-grained, dense, dolomitic, with curving joints	0.9
12. Limestone, tan, cryptocrystalline in beds from 6 inches to 1 foot thick with wavy incipient bedding showing on weathered surfaces; one line of chert nodules 2 inches above base	5.8
11. Limestone, light-brown, cryptocrystalline, pure, in two beds; zone of weathered rotten chert nodules in lower bed; base of this unit at beginning of continuous outcrops along woods lane	2.5
10. Limestone, platy to shaly, slightly dolomitic, with curving joints, and pure cryptocrystalline limestone in even beds a few inches thick; zone of shale 3 inches thick near middle; unit more than half covered	40.6
9. Limestone, cryptocrystalline, pure, and limestone, fine-grained, slightly dolomitic; two-thirds of unit covered; offset along top bed of unit downhill to lane 30 feet above river	37.7
8. Limestone, tan, cryptocrystalline, in two beds, forming prominent ledge	3.5
7. Limestone, greenish-buff, platy, in lower part; upper three-fourths of unit covered	16.6
6. Covered; probably largely limestone	19.1
5. Limestone, yellow-weathering, dolomitic, in rounded beds; and buff and greenish-gray limestone, weathering light gray to white, in even beds from a few inches to 1 foot thick; about half of unit exposed	28.4
4. Dolomite, mottled maroon and green, massive, weathering with rounded surfaces, forms basal bed; remainder covered	16.2
3. Dolomite, buff speckled with pink, fine-crystalline, weathering yellow, has curving joints and well-rounded outer surfaces; contains widely scattered chips of gray and white, conglomeratic chert	4.9
2. Dolomite, greenish-gray, fine-crystalline, containing scattered subrounded, conglomeratic pebbles of dolomite, and scattered chips of white-weathering chert	1.0
Mascot dolomite (64+ feet):	
1. Dolomite, light-gray, medium-gray, and greenish-gray, fine-crystalline and cryptocrystalline, in both platy and massive beds; one zone containing nodules and lenses of white-weathering, chalcedonic chert	63.6

Geologic Section 10.—*Dot, Poteet, and Rob Camp limestones along road and through woods half a mile north of Rob Camp Church, Hancock County, Tenn.*

[Section begins in open woods 150 feet uphill east of point on road 200 feet north of junction of main road with small dirt road coming in from west. Section ends on edge of woods on east side of road where outcrops of massive bedded limestone cease. Measured by J. O. Fuller and R. L. Miller]

Martin Creek limestone:	*Ft.*	*in.*
23. Limestone, dark-colored, coarse-crystalline, poorly exposed; a few feet thick, overlain by unexposed beds that produce a soil containing abundant chert cobbles	(?)	

	Ft.	in.
Rob Camp limestone (137 feet): (Type section)		
22. Limestone, light-brownish-gray, dense, cryptocrystalline, with calcite birdseyes in massive beds forming prominent ledges in woods; weathers nearly white with fluted surfaces	136	9
Poteet limestone (58 feet):		
21. Limestone, partly covered, light-brown, fine-grained to dense, with birdseyes; top bed shaly	6	10
20. Limestone, brownish-gray, dense, with birdseyes; weathers light blue-gray; nodules and lenses of dark-gray chalcedonic chert; *Tetradium*	4	0
19. Limestone, argillaceous; light-brown, fine-grained in platy or nodular beds; mud cracks	16	8
18. Limestone, brownish-gray, dense, birdseye, with dark-gray chalcedonic chert in nodules and lenses; argillaceous partings; *Tetradium cellulosum*, gastropods, ostracodes	11	1
17. Limestone, brown to dark-gray, medium-crystalline; and argillaceous, greenish-gray limestone; thin-bedded, with mud cracks	12	2
16. Mudstone, greenish-brown, fine- to medium-grained, limy, with dendrites; cross-bedding	0	10
15. Limestone, partly covered, argillaceous, greenish-gray, fine- to medium-crystalline; abundant fossils; *Tetradium*, bryozoans, ostracodes; one bed with black chert nodules	5	6
14. Limestone, argillaceous, mottled, brownish-gray with greenish-gray streaks and patches; abundant fossils; some dark chalcedonic chert	1	3
Dot limestone (152 feet):		
Limestone member (118 feet):		
13. Limestone, partly covered, brown, dense; and greenish-gray, argillaceous limestone; abundant ostracodes	17	3
12. Limestone, partly covered, argillaceous, fine-grained, brown to greenish-gray, with dendrites and some argillaceous dolomitic limestone	13	6
11. Limestone, light-tan to brown, dense, with birdseyes; thin-bedded, mud-cracked; colonial type of *Tetradium*	36	6
10. Limestone, light-tan, dense with birdseyes; fluted	3	11
9. Limestone, light-brownish-gray, fine-grained with calcite birdseyes; some argillaceous beds	8	5
8. Limestone, dark-gray, fine-crystalline; dark-gray chalcedonic chert in nodules and layers; abundant ostracodes	4	0
7. Limestone, largely covered, light-blue-gray to brownish-gray, fine-grained; some intraformational conglomerate; interbedded argillaceous, buff, fine-grained dolomite	29	0
6. Limestone, light-tan to greenish-tan, dense with irregular purple partings; thin-bedded; *Tetradium* sp. cf. *T. cellulosum;* abundant ostracodes	5	3
Dolomite member (34 feet):		
5. Dolomite, argillaceous, buff, fine-grained, weathering with rounded surfaces and dendrites; interbedded light brownish-gray, fine-grained mottled, argillaceous limestone; ostracodes	15	8

	Ft.	in.
Dot limestone (152 feet)—Continued		
Dolomite member (34 feet)—Continued		
4. Dolomite, partly covered, argillaceous, fine-grained, with light-brown and purplish splotches; weathers buff with rounded surfaces	8	5
3. Dolomite, partly covered, conglomeratic; greenish-gray fine-grained dolomite with pebbles less than 1 inch in length and larger pebbles typical of Mascot dolomite	9	3
2. Conglomerate made of chert and dolomite pebbles from Mascot dolomite averaging 3 inches in diameter in matrix of light-gray fine-grained dolomite	0	7
Mascot dolomite (10+ feet):		
1. Dolomite, light-gray, fine-grained; beds from 1 to 2 inches thick; some oval chert nodules	9	10

Geologic Section 11.—*Rob Camp, Martin Creek, Hurricane Bridge, Woodway, Ben Hur, and Hardy Creek limestones, and lower part of Eggleston limestone on north slope of Elk Knob 1¾ miles northeast of Woodway and ½ mile east of Huff Cemetery*

[Section begins along ravine and lane 600 feet north of hard surface county road, crosses road and continues southeastward up hill to crest of flat-topped spur at elevation of 1,795 feet, offsets 500 feet to southwest to prominent ledges in gully, and continues due south uphill to end of exposures at elevation of 1,860 feet. Measured by R. L. Miller]

	Feet
Eggleston limestone (52+ feet):	
Middle member (10+ feet)	
35. Limestone, brown, fine-grained, dense, with patches and bands of fine-crystalline limestone; fairly abundant fossils	10+
Lower member (42 feet):	
34. Mudstone, yellow-weathering, calcareous, with birdseyes; poorly exposed	42.0
Hardy Creek limestone (123 feet):	
33. Limestone, greenish-tan and medium-brown, cryptocrystalline, very dense, in platy beds; fractures like glass; a few beds of yellow-weathering, shaly limestone in lower part; more massive beds from 1 to 2 feet thick in upper part; zone of flattened, coalescing or digitate nodules of chert 20 feet below top	60.6
32. Limestone, greenish-tan, glassy, in platy beds less than an inch thick at base, overlain by yellow-weathering argillaceous limestone with a few platy interbeds similar to basal beds	22.7
31. Limestone, medium-brown, fine-grained, dense, weathering with closely spaced faint laminae, forming shelving ledges a foot or two high; zone of chert nodules near base and another near middle of unit	40.0
Ben Hur limestone (133 feet):	
30. Limestone, yellow-weathering, argillaceous, and limestone, weathering bluish gray, in platy beds	20.6
29. Limestone, gray-weathering, argillaceous, forms 2-foot zone at base, overlain by yellow-weathering, argillaceous and shaly, mudcracked limestone	19.7
28. Limestone, yellow-weathering, argillaceous, shaly, mudcracked, with a few interbeds of light-gray, less-argillaceous limestone	49.6
27. Limestone, gray, in beds several inches thick, containing streaks and splotches of yellow-weathering argillaceous limestone	19.7

	Feet
Ben Hur limestone (133 feet)—Continued	
26. Limestone, gray, weathering yellow, fine-grained, argillaceous, nodular at base; grading upward into laminated earthy and shaly yellow-weathering limestone with numerous mudcracks; base of this unit at very large dead tree stump in ravine	23.1
Woodway limestone (289 feet): (Type section)	
25. Limestone, blue-weathering, platy, and similar limestone with silty laminae; abundant bryozoans; this bryozoan zone very persistent at top of Woodway limestone; offset from crest of flat-topped spur 500 feet to southwest to steep gully	24.7
24. Limestone, gray, fine-grained, platy, becoming slightly argillaceous upward; contains *Camarocladia*	17.3
23. Limestone, fine-grained and fine-crystalline, in massive beds but showing thinner wavy and nodular beds on weathered surfaces; weathers bluish white; contains abundant *Camarocladia*	74.7
22. Limestone, gray, fine-grained, dense, with some brown cryptocrystalline nodular limestone; a few beds of coarse-crystalline limestone with fossils; faint *Camarocladia*-like markings near top, and zone of chert nodules at top	34.4
21. Limestone, tan, cryptocrystalline, in beds as much as 6 inches thick, forming small ledges, overlain by fine-grained and fine-crystalline limestone in thin nodular beds; *Cryptophragmus* a few feet below top	68.8
20. Limestone, tan, brown, and gray, fine-grained, but with some fine-crystalline and coarse-crystalline limestone near top; in platy beds; zone of *Stromatocerium rugosum* at base, with which are associated a colonial *Tetradium*, chertified bryozoans, and straight cephalopods; chert nodules in *Stromatocerium* zone; zone of *Öpikina* 15 feet above base	68.8
Hurricane Bridge limestone (288 feet):	
19. Limestone, brown and gray, fine-grained; some beds weather with yellow laminations; numerous chert nodules in top 20 feet	51.1
18. Limestone, weathering blue gray, platy, forming zone 5 feet thick at base, overlain by yellow-weathering argillaceous and shaly limestone, becoming less argillaceous upward	23.0
17. Limestone, dove-gray, cryptocrystalline, in very massive beds, with pitted and fluted weathered surfaces; beds from 1 to 4 feet thick	64.0
16. Limestone, yellow-weathering, argillaceous, shaly	7.8
15. Limestone, medium-crystalline, marble-like, in lower part, and fine-crystalline limestone with abundant individual calcite crystals in upper part	18.4
14. Limestone, brown and gray, fine-grained, in beds a few inches thick, with very abundant chert nodules at numerous horizons; a few beds at top of argillaceous limestone, weathering yellow	39.8
13. Limestone, medium- and light-brown, fine-grained, dense, in fairly massive beds forming conspicuous ledges; numerous silty, wavy laminae give rock a nodular appearance on weathered surfaces; abundant *Tetradium* and gastropods	25.2
12. Limestone, tan, weathering bluish white, cryptocrystalline, in bed 1½ feet thick at base, overlain by poorly exposed, thin-bedded, tan, cryptocrystalline limestone; some beds are argillaceous and weather yellow, especially in lower part	58.3

	Feet
Martin Creek limestone (69 feet):	
11. Limestone, medium-brown, fine-grained, dense, containing a layer of coarse-crystalline fragmental limestone in middle; abundant small gastropods	1.7
10. Limestone, light-brown, fine-grained, dense, with silty laminations conspicuous on weathered surfaces; some laminae wavy giving nodular appearance to rock; chert nodules and lenses abundant in lower part, and present in middle and upper parts	25.3
9. Limestone, tan, cryptocrystalline, in bed 2 feet thick, at base; remainder of unit concealed beneath hard surfaced county road	17.0
8. Limestone, gray, fine-grained, in beds a few inches thick; contains chert nodules and lenses at several horizons	9.4
7. Limestone, brown, coarse-crystalline, fragmental, in irregular beds a few inches thick	11.7
6. Limestone, brownish-gray, fine-grained, with slight petroliferous odor; patches of crystalline limestone in upper part; *Tetradium* and small gastropods	3.8
Rob Camp limestone (91 feet):	
5. Limestone, tan, cryptocrystalline, with calcite birdseyes, in beds from 1 to 4 inches thick; several layers with abundant chert nodules; bed near top with abundant birdseyes, which are probably sections of *Tetradium*, and also gastropods and straight cephalopods	9.7
4. Limestone, tan, cryptocrystalline, with calcite birdseyes, in beds from 6 inches to 1½ feet thick; weathers bluish white; contains stylolites	10.8
3. Limestone, tan, cryptocrystalline, in beds about 1 foot thick, with abundant chert nodules at several horizons	19.5
2. Limestone, dove-gray, cryptocrystalline, with calcite birdseyes, in massive beds from 1 to 5 feet thick; weathers bluish white, with channeled and fluted surfaces	51.1
Poteet limestone (66 feet—top 46 feet described):	
1. Limestone, light-gray, fine-grained and fine-crystalline, with abundant nodules, lenses, and occasional beds of chert; highest chert seen is 10 feet from top of unit; unit poorly exposed; unit overlies 19 feet of well-exposed limestone of lower part of Poteet, which in turn overlies 122 feet of moderately well exposed limestone and dolomite of the Dot limestone; contact of Mascot dolomite and Dot limestone is duplicated along lane by a reverse fault up on the south	46.3

GEOLOGIC SECTION 12.—*Rob Camp and Martin Creek limestones along Powell River road at mouth of Martin Creek, Hancock County, Tenn.*

[Section begins along lane 135 feet north of hairpin curve on county road just west of Martin Creek bridge, and ends at right angle bend of county road at top of hill. Measured by J. O. Fuller, with additions and changes by R. L. Miller]

	Ft.	*in.*
Hurricane Bridge limestone:		
15. Limestone, buff-weathering argillaceous, laminated		
14. Limestone, greenish-buff, cryptocrystalline, very dense, without chert, in one massive bed	2	0

Martin Creek limestone (101 feet): (Type section)	*Ft.*	*in.*
13. Limestone, cryptocrystalline, dense, in beds from a few inches to 18 inches thick; prominent zone of chert nodules at top; contact with Hurricane Bridge limestone is 30 feet north (downhill) from corner fencepost on inside of road curve at top of hill	3	0
12. Limestone, buff-weathering argillaceous, laminated; without chert but otherwise similar to unit 11	2	0
11. Limestone, interbedded, light-brown, argillaceous, laminated, dense, fine-grained, with black chert nodules and lenses; and brownish-gray, fine-crystalline limestone; *Tetradium*	14	0
10. Limestone, mottled, brownish-gray, fine-grained, with shale partings and black chert	0	11
9. Limestone, light-brown, dense, birdseye, interbedded with light-gray, fine-grained limestone; both with chert nodules and lenses	24	9
8. Limestone, light-brown, dense, birdseye, interbedded with light-gray, fine-grained, laminated limestone	17	8
7. Limestone, dark-gray, fine-crystalline; abundant black chert nodules; silicified bryozoans and brachiopods weathering in relief; black chert lenses several feet long	26	8
6. Limestone, dark-brown, dense, fine-grained, with brachiopods and black chert nodules	3	4
5. Limestone, dark, mottled, fossiliferous, with a few chert nodules	2	5
4. Limestone, dark-gray, fine- to medium-grained, with dark carbonaceous streaks; a few limestone pebbles; sealed contact with Rob Camp is exposed in field to west of road; base of unit is 160 feet south (uphill) from hairpin turn of road	6	0
Rob Camp Limestone (84 feet):		
3. Limestone, brownish-gray, dense, fine-grained, with birdseyes, thick-bedded; fluted weathering; large gastropods	37	1
2. Limestone, greenish, argillaceous, dolomitic; weathering with rounded surfaces	1	5
1. Limestone, brownish-gray, dense, fine-grained, with birdseyes; thick-bedded and fluted; some brown calcite eyes; gastropods	45	1

GEOLOGIC SECTION 13.—*Hurricane Bridge, Woodway, Ben Hur, Hardy Creek, and Eggleston limestones along road south from Hurricane Bridge 3 miles southwest of Jonesville*

[Section begins along road 1,700 feet east of Hurricane Bridge and 150 feet south of right-angle bend in road, continues south along road, and ends 2,200 feet south of starting point. Measured by R. L. Miller and W. P. Brosgé]

Trenton limestone:	*Feet*
22. Limestone, gray, medium-crystalline, well-bedded, with abundant *Dalmanella* and *Sowerbyella*	5+
Eggleston limestone (181 feet):	
Upper member (80 feet):	
21. Largely covered; a few feet of argillaceous yellow-weathering limestone exposed near top	24.4±

	Feet
Eggleston limestone (181 feet)—Continued	
Upper member (80 feet)—Continued	
20. Bentonite, not exposed but was dug out; underlain by 2 inches of bedded chert; thickness approximate	4.0
19. Mudstone, dark-yellow, platy to shaly, calcareous, with some brown fine-grained and crystalline limestone	51.9
Middle member (60 feet):	
18. Bentonite, yellow-weathering, without visible mica flakes, underlain by 3 inches of bedded chert	2.5
17. Limestone, tan and brown, cryptocrystalline, fine-grained, and fine-crystalline, in platy beds from 1 to 7 inches thick, with several zones of yellow-weathering argillaceous limestone	57.6
Lower member (40 feet):	
16. Mudstone, yellow, earthy and crumbly, calcareous, with white calcite birdseyes; bedding planes irregularly spaced and undulatory	40.3
Hardy Creek limestone (124 feet):	
15. Limestone, greenish-yellow, dense, cryptocrystalline, in platy beds from 1 to 3 inches thick in lower two-thirds of unit; and brown and gray, fine-grained to fine-crystalline limestone, in beds as much as 6 inches thick in upper one-third; zone of thin elongate oval chert nodules 15 feet from top	53.2
14. Limestone, yellow-weathering, earthy and shaly	14.4
13. Limestone, medium-gray, fine-grained, even-bedded, weathering light blue-gray with faint laminae; some brown, dense, cryptocrystalline limestone; zone containing oval and lens-shaped chert nodules (fig. 12) is 8 feet thick and lies about 20 feet above base of unit	56.2
Ben Hur limestone (99 feet):	
12. Limestone, greenish-brown, fine-grained, argillaceous, weathering yellow, earthy and shaly; zone of hard laminated limestone 9 feet thick lies 10 feet below top	99.4
Woodway limestone (251 feet):	
11. Limestone, brown and gray, fine-grained, thin-bedded; with some crystalline lenses and beds; *Camarocladia* present throughout but most abundant in upper half	159.3
10. Limestone, tan and brown, fine-grained to cryptocrystalline, thin-bedded; argillaceous yellow-weathering zone at base, and beds and zones of medium-crystalline limestone in middle and at top; *Cryptophragmus* at top	80.2
9. Limestone, dark-gray, medium-crystalline and fine-crystalline, in undulatory beds a few inches thick; chert nodules a foot above base, and *Stromatocerium rugosum* common 3 feet above base; *Öpikina* at top	11.5
Hurricane Bridge limestone (327 feet): (Type locality but not type section)	
8. Limestone, tan and brown, cryptocrystalline and fine-crystalline, with a few argillaceous and nodular beds; unit starts at beginning of cut on east side of road	52.9
7. Covered along road; unit includes a zone of massive-bedded birdseye limestone	90.0
6. Limestone, fine-grained, some pure and platy bedded, some argillaceous and shaly; several beds weather salmon pink	16.5

Hurricane Bridge limestone (327 feet)—Continued	*Feet*
5. Limestone, dove-gray, cryptocrystalline, dense, with abundant calcite birdseyes, in massive beds from 6 inches to 3 feet thick	46.4
4. Limestone, argillaceous, fine-grained; weathering salmon pink and greenish yellow; a few beds of purer white-weathering limestone	13.5
3. Limestone, dense, cryptocrystalline and fine-grained, weathering bluish white, in thin platy beds; massive bed of birdseye limestone 1.1 feet thick at base, overlain by 4.5 feet of yellow-weathering argillaceous limestone	100.7
2. Limestone, yellowish-brown, fine-grained, impure, without chert; weathers yellow; placed in Hurricane Bridge limestone because of argillaceous character and absence of chert	7.0
Martin Creek limestone (25+ feet).	
1. Limestone, tan and light-brown, dense, cryptocrystalline, with zones of dark-gray chert nodules at intervals a few feet apart	25

GEOLOGIC SECTION 14.—*Hurricane Bridge, Woodway, Ben Hur, Hardy Creek, Eggleston, and Trenton limestones along State Route 70 in vicinity of Sewell Bridge south of Jonesville*

[Section of Hurricane Bridge and Woodway limestones measured on west side of Powell River, other formations measured on east side of river. Section begins on northwest side of State Route 70 at a point 100 feet southwest of large unpainted barn, crosses highway and continues due south down spur between highway and river bluff to a point 200 feet north of U-turn of highway, offsets across river to a point on farm road 70 feet south of large tobacco barn and 250 feet north of highway, and continues southeastward along highway, ending at a point 125 feet northwest of beginning of long highway curve to the east. Measured by R. L. Miller]

Reedsville shale (136+ feet):	*Feet*
70. Shale, gray, with platy beds of siltstone and silty limestone every few inches. Section ends where dip steepens in wavy fold. Remainder of exposed Reedsville shale folded and possibly faulted owing to proximity to Wallen Valley fault	115.7
69. Shale, gray, weathering yellowish brown, with platy interbeds of light-gray fine-crystalline limestone and dense fine-grained siliceous limestone	20.7
Trenton limestone (599 feet):	
68. Limestone, light-gray, fine- and coarse-crystalline, and brown-weathering shale; unit is transitional into Reedsville shale	4.0
67. Limestone, light-gray, fine- and coarse-crystalline, with wavy shale partings, forming massive ledge; contains *Rafinesquina*, *Rhynchotrema*, and abundant big bryozoans	7.7
66. Limestone, gray, medium-crystalline, with shale zones several inches thick; unit poorly exposed	40.9
65. Covered interval caused by stone retaining wall	42.7
64. Limestone, gray, fine-grained, with some beds of fossiliferous crystalline limestone; zone of thin coalescing lenses of dark-gray chert; numerous bryozoans, gastropods, and brachiopods	55.8
63. Limestone, gray, medium- and coarse-crystalline, with a few beds of dense fine-grained limestone; abundant large bryozoans appearing in cross-section as prominent white oval patches on edges of beds; also *Hebertella frankfortensis*	40.3

Trenton limestone (599 feet)—Continued	Feet
62. Limestone, gray, fine-grained and crystalline, in both thin and massive beds; irregular-shaped nodules and thin lenses of chert in basal beds	55.8
61. Covered interval at curve in road	23.1
60. Limestone, gray, fine-grained and crystalline, in beds as much as a foot thick; abundant large crinoid stems; one bed of intraformational conglomerate; *Constellaria* sp., *Zygospira* cf. *Z. modesta*, *Platystrophia* sp	45.0
59. Limestone, gray, fine-crystalline, with fossils; and gray, fine-grained limestone, without fossils; abundant *Cyrtodonta* sp., *Rafinesquina* sp., *Zygospira* sp., and *Hebertella* sp	14.1
58. Limestone, gray, fine-grained, with some gray medium-crystalline limestone; *Rafinesquina* aff. *R. trentonensis*, *Zygospira recurvirostris*, *Dalmanella* sp., *Sowerbyella* sp., *Rhynchotrema* sp.; top of unit at junction of highway with farm lane	97.0
57. Limestone, light-gray, fine- and medium-crystalline, fossiliferous; and gray, fine-grained, blocky, unfossiliferous limestone; shale partings; these beds involved in small flexure	6.4
56. Limestone, gray, medium-crystalline, fine-crystalline, and fine-grained, in beds from 1 to 6 inches thick, with shale partings; *Rafinesquina* sp., *Hebertella* or *Dinorthis* sp., *Sowerbyella* sp., *Zygospira* cf. *Z. modesta*	47.8
55. Limestone, similar to unit 54	7.9
54. Limestone, gray, medium-crystalline, in beds from 2 to 6 inches thick, with thin interbeds of shale; abundant fossils; *Lichenaria* cf. *L. grandis*, *Rhinidictya* sp., *Batostoma* sp., *Dekayia* sp., *Mesotrypa* sp., *Rafinesquina trentonensis*, *Resserella fertilis*, *Rhynchotrema increbescens*	33.1
53. Limestone, gray, coarse-crystalline; interbedded gray shale accounts for half the rock in upper part of unit; unit partly covered	23.9
52. Limestone, gray, coarse-crystalline; lowest *Prasopora* 17 feet above base; *Eridotrypa* sp., *Prasopora* sp., *Homotrypa* sp., *Dinorthis pectinella*, *Sowerbyella curdsvillensis*, *Rhynchotrema increbescens*, *Resserella fertilis*, *Hesperorthis* cf. *H. tricenaria*	29.5
51. Limestone, gray, coarse-crystalline, in wavy beds from 2 to 4 inches thick; *Resserella fertilis* very abundant throughout, and *Sowerbyella curdsvillensis* starting 10 feet above base	24.2
Eggleston limestone (164 feet):	
Upper member (51 feet):	
50. Limestone, tan, laminated, wormy, forming ledge 3 feet thick at base, overlain by interbedded platy beds of argillaceous nodular limestone, shaly limestone, and shale	10.4
49. Mudstone, yellow-weathering, calcareous, with a few zones of tan fine-grained impure limestone with white calcite birdseyes, and several beds of gray-weathering purer limestone; upper big bentonite bed of the Eggleston not exposed, but some dug out in ditch 5 feet below top of unit	40.8
Middle member (69 feet):	
48. Limestone, brown, fine-grained, forms lowest foot, overlain by a foot of medium-gray, partly-silicified limestone with very blocky angular joint pattern; top inch of silicified zone is bed of chert; lower big bentonite bed of Eggleston forms upper half of unit but is not exposed	4.7

	Feet
Eggleston limestone (164 feet)—Continued	
Middle member (69 feet)—Continued	
47. Limestone, brown, fine-grained, and fine- to medium-crystalline, with fragmentary fossils; *Camarocladia* prominent in middle of unit	24.9
46. Limestone, yellow-weathering, argillaceous, shaly, with poorly developed mudcracks	3.8
45. Limestone, brown, fine-grained, nodular, in beds from 1 to 2 inches thick; abundant *Zygospira*, bryozoans, and crinoid stems	8.6
44. Limestone, yellow-weathering, argillaceous, shaly	3.7
43. Limestone, brown, fine-grained, forming massive ledge; abundant poorly preserved pelecypods, gastropods and bryozoans	2.0
42. Limestone, yellow-weathering, very argillaceous, shaly	10.1
41. Limestone, brown, fine-grained, nodular, in resistant beds from 1 to 4 inches thick; some surfaces appear wormy possibly because of dissolved *Camarocladia;* abundant bryozoans, large brachiopods, and crinoid stems	10.9
Lower member (44 feet):	
40. Mudstone, yellow-weathering, calcareous, crumbly, with small calcite stringers and "birdseyes"; uniform from base to top	43.7
Hardy Creek limestone (151 feet):	
39. Limestone, brown, fine-crystalline, silty, in platy beds; contains abundant *Tetradium* sp. and *Camarocladia;* also bryozoans, ostracodes, and trilobite fragments	2.5
38. Limestone, brown, fine-grained, weathering bluish gray in slabby beds with laminated surfaces; contains zone of chert nodules at top	20.8
37. Limestone, gray-weathering, fine-grained, resistant, with yellow-weathering silty wavy layers forms basal 2 feet, overlain by interbedded yellow-weathering shaly limestone and bluish-gray weathering dense pure limestone; this unit exposed opposite gate at junction of farm lane and State Route 70	35.5
36. Limestone, yellow-weathering, argillaceous, shaly, with a few beds of tan fine-crystalline limestone weathering bluish gray	28.3
35. Limestone, brown, dense, cryptocrystalline; three zones of chert nodules in basal 12 feet	41.2
34. Limestone, brown, dense, fine-grained, laminated; slightly shaly in some zones	22.7
Ben Hur limestone (127 feet):	
33. Siltstone, yellow-weathering, calcareous, shaly; upper beds less argillaceous than most of unit; basal beds are 18 inches of tan ledgy limestone with silty partings	14.4
32. Limestone, yellow-weathering, argillaceous; and yellow-weathering, calcareous siltstone; basal beds brown laminated slightly argillaceous limestone	73.8
31. Limestone, yellow-weathering, argillaceous, in laminated shaly beds, with major bedding planes less than 3 inches apart; unweathered limestone is tan, fine-grained, and dense; several beds of purer limestone; abundant bryozoans and small gastropods	38.6
Woodway limestone (268 feet):	
30. Limestone, brown, cryptocrystalline and medium-crystalline, slightly argillaceous; abundant bryozoans; section continued on east side of river	14.0

Woodway limestone (268 feet)—Continued	*Feet*
29. Limestone, brown, cryptocrystalline and fine-grained, with a few beds of fine-crystalline limestone; abundant irregular-shaped nodules of chert in lower half; small shed on crest of spur is in middle of unit	51.4
28. Limestone, brown, cryptocrystalline, with a few beds of fine-crystalline limestone. *Camarocladia* abundant	12.0
27. Limestone, light-brown, cryptocrystalline, pure; forms prominent ledge	1.6
26. Limestone, tan, cryptocrystalline, nodular, in platy beds, weathering light gray; zone of irregular-shaped chert nodules at base; section crosses fence near base of unit	22.7
25. Limestone, tan, cryptocrystalline, with some fine- and medium-crystalline limestone interbedded in middle and upper parts of unit; basal beds contain *Cryptophragmus*, *Öpikina* sp., *Camarocladia*, and gastropods	73.1
24. Limestone, brown, cryptocrystalline at base, fine- and coarse-crystalline above, in platy beds; *Öpikina*, *Columnaria*(?), and large bryozoans	23.2
23. Limestone, brown, coarse-crystalline, marblelike, with a few beds of gray fine-crystalline limestone and tan cryptocrystalline limestone	27.1
22. Limestone, greenish-tan, cryptocrystalline, with scattered calcite birdseyes; and a few beds of fine- and medium-crystalline limestone	31.8
21. Limestone, tan, cryptocrystalline, with abundant *Stromatocerium rugosum* in basal 5 feet, and abundant *Öpikina* at top; also *Tetradium* cf. *T. cellulosum*, and a radially-branching large coral	10.6
Hurricane Bridge limestone (368 feet): (Type section)	
20. Limestone, tan, cryptocrystalline, with a few beds of fine-crystalline limestone and of slightly yellow argillaceous limestone; numerous chert nodules near top and also large gastropod identified as *Holopea* sp	52.8
19. Limestone, thin-bedded to shaly, coarse-crystalline, weathering slightly pinkish in lower part, fine-crystalline, and weathering gray in upper part	10.6
18. Limestone, tan, cryptocrystalline, dense in lowest 2 feet; and coarse-crystalline limestone with marblelike texture in upper part; unit crops out at highest point of spur overlooking Sewell Bridge	13.9
17. Partly covered zone; some outcrops of yellow-weathering, fine-grained, argillaceous limestone	19.3
16. Limestone, brown, medium-crystalline, nodular, forming massive ledge 5 feet thick at base, and thinner bedded above	44.0
15. Partly covered interval; limestone, brown, fine-grained; top of unit a few feet from northwest corner of quarry	17.0
14. Limestone, brown, fine-crystalline in lower part, medium- and coarse-crystalline in upper part, nodular, in platy beds	19.6
13. Limestone, greenish-tan and tan, cryptocrystalline, with small and big calcite birdseyes, in massive beds from 6 inches to 3 feet thick that weather with fluted surfaces; forms prominent ledges; *Tetradium* and poorly preserved gastropods	54.6

Hurricane Bridge limestone (368 feet)—Continued	*Feet*
12. Limestone, tan, cryptocrystalline, thin-bedded, platy to nodular	4.7
11. Limestone, tan, cryptocrystalline, massive, with white calcite birdseyes in beds more than 1 foot thick	6.5
10. Limestone, yellow-weathering, argillaceous, shaly; in a few places weathers salmon pink	11.2
9. Limestone, greenish-tan, cryptocrystalline, in thin beds; slightly more massive with fluted surfaces near top	15.3
8. Limestone, brown, cryptocrystalline, massive, with calcite birdseyes; weathers with pitted and fluted surfaces	3.0
7. Limestone, tan, cryptocrystalline and fine-grained, weathering bluish white in lower part and medium brown and nodular in upper part	20.7
6. Limestone, fine-grained, nodular, weathering bluish white, with thin silty partings and yellow silty patches showing on weathered surfaces; abundant *Tetradium* cf. *T. cellulosum*	13.9
5. Limestone, tan and medium-brown, cryptocrystalline and fine-crystalline, nodular; abundant *Tetradium* cf. *T. cellulosum*; unit partly covered	30.0
4. Limestone, light-brown, cryptocrystalline, with large white calcite birdseyes; forms prominent ledge; contains *Tetradium*, and small brachiopods (*Zygospira ?*), small ostracodes, and gastropods	0.6
3. Limestone, tan and light-brown, cryptocrystalline, pure, and fine-grained, argillaceous, with yellow-weathering silty layers; gastropods visible in cross-section are abundant near top; offset at top of unit 250 feet to east, across highway	22.3
2. Limestone, light-brown, fine-grained, dense, argillaceous, weathering yellow, with abundant small elongate patches of calcite, possibly replaced *Tetradium*	8.2
Martin Creek limestone (38+ feet):	
1. Limestone, greenish-tan, cryptocrystalline, with small white calcite crystals, and abundant small chert nodules at several horizons; several argillaceous yellow-weathering beds near top	38.2

GEOLOGIC SECTION 15.—*Ben Hur and Hardy Creek limestones, and lower and middle members of Eggleston limestone in cut on big curve of Louisville and Nashville Railroad 1,000 feet west of Ben Hur station*

[Measured by R. L. Miller and J. O. Fuller]

Eggleston limestone (111+feet):	*Ft.*	*in.*
Upper member (17+feet):		
21. Limestone, yellowish-brown, argillaceous, with indistinct calcite birdseyes, weathering a mottled light yellowish-gray	10+	
20. Limestone, buff, weathering shaly; and bluish-white, platy limestone; this unit is transitional between lithology of middle member and lithology of upper member	6	11
Middle member (61 feet):		
19. Bentonite, yellow and yellowish-white, mottled; poorly exposed	3±	

Eggleston limestone (111+ feet)—Continued

Middle member (61 feet)—Continued	*Ft.*	*in.*
18. Limestone, brownish-gray, argillaceous, laminated, weathering mottled; top 3 inches silicified; unit has blocky fracture	1	6
17. Covered	2	0
16. Limestone, brown, fine-grained, with irregular lenses of chert near top and 9 inches of argillaceous limestone at base	8	1
15. Clay, yellowish-brown, believed not a bentonite	0	2
14. Limestone, brown, fine-grained and medium-crystalline, with zones of buff-weathering, shaly limestone; resistant 2-foot bed at base	26	9
13. Limestone, medium-brown, argillaceous; forms prominent weak unit between more resistant underlying and overlying beds	10	2
12. Limestone, brown, fine-grained and medium-crystalline; weathers bluish white and "wormy"	9	1
Lower member (34 feet):		
11. Mudstone, medium-brown to yellowish-brown, calcareous, with small calcite birdseyes; no sign of bedding	33	6
Hardy Creek limestone (134 feet):		
10. Limestone, brownish-gray, thin-bedded, fine-grained, with several beds of fine-crystalline limestone; lower part contains beds and coalescing nodules of chert from 1 to 3 inches thick	14	0
9. Limestone, brownish-gray, fine-grained, laminated, resistant; contains a few chert nodules	3	8
8. Limestone, brownish-gray, fine-grained, thin-bedded, with a 6-foot zone of argillaceous, buff-weathering limestone 9 feet above base; oval chert nodules 4 feet from top	44	0
7. Limestone, yellow-weathering, argillaceous, shaly with a few platy beds, weathering bluish white; poorly exposed	15	0
6. Limestone, brownish-gray, fine-grained, laminated, in beds from a few inches to 1 foot thick; zones of chert nodules at 12 feet, 25 feet, and 30 feet above base	57	0
Ben Hur limestone (126 feet): (Type section)		
5. Limestone, yellow-weathering, argillaceous and shaly, with less argillaceous zones forming ledges at base and 33 feet and 54 feet above base	75	0
4. Limestone, yellow-weathering, argillaceous and shaly; some beds with nodular appearance; abundant mud cracks; 4-foot zone of less argillaceous limestone forms small ledges in upper part of unit	50	6
Woodway limestone (21+ feet):		
3. Limestone, brown, platy, in beds 1 inch thick or less, with indistinct markings like *Camarocladia*	4	0
2. Limestone, light-gray, fine-grained, dense, in thin, gnarled beds; weathers buff	17	0
1. Limestone, brown and gray, weathering bluish white, with abundant *Camarocladia* markings; crops out in woods below railroad; not measured	(?)	

GEOLOGIC SECTION 16.—*Hardy Creek, Eggleston, and Trenton limestones, Reedsville shale, Sequatchie formation, Clinch sandstone, and lower part of Clinton shale along spur of Louisville and Nashville Railroad at Hagan, Lee County*

[Section begins at south end of nearly continuous railroad cut, continues north along tracks to top of Sequatchie formation, offsets westward to beginning of cut on curving spur connecting main line with tunnel line, and continues westward around curve to last cut. Measured by R. L. Miller and J. O. Fuller]

	Ft.	*in.*
Clinton shale (85+ feet):		
72. Shale, red	79	7
71. Iron ore, hematitic, made up of flattened pellets; contains brachiopods		5-9
70. Shale, greenish-gray, with sandstone beds ½ inch to 2 inches thick; ripple marks and fucoids abundant	5	4
Clinch sandstone (260 feet):		
Poor Valley Ridge member (183 feet): (Type section)		
69. Sandstone, greenish-white, fine-grained, in lenticular beds from 6 inches to 2 feet thick; shale interbeds as much as 2 feet thick in upper part; ripple marks; trails possibly of trilobites on one bed	15	2
68. Shale, dark-gray, with thin lenticular standstone interbeds	16	0
67. Iron ore, hematitic, fair-grade, consisting of numerous flattened pellets	0	4
66. Shale, greenish-gray, with thin ripple-marked interbeds of sandstone; one 2-inch bed of gravel with pebbles as much as half an inch; unit includes reverse fault which duplicates 4 feet of beds	32	11
65. Sandstone, white, fine- to medium-grained, quartzitic; and shale, reddish-gray; ripple marks; *Lingula* sp., *Helopora* sp., *Paraechmina* sp., *Paraechmina* n. sp., ostracode n. gen., n. sp	17	4
64. Sandstone, white, fine-grained, quartzitic, in massive unit, with thin shale interbeds in upper part	8	11
63. Shale, dark-gray; and white and yellow, fine- to medium-grained sandstone; ripple marks; *Lingula* sp	23	10
62. Sandstone, greenish-white, medium-grained, massive in lower part; contains abundant pellets and patches of red clay; abundant *Helopora* cf. *H. fragilis*, small medium-spired gastropods, *Lingula* fragments, orthoceratids	7	1
61. Shale, gray, and greenish-white, fine-grained sandstone	4	2
60. Sandstone, medium-grained, greenish-gray; forms massive unit; most resistant unit in the Clinch sandstone	8	7
59. Shale, greenish-gray, becoming sandy in upper part	31	10
58. Sandstone, fine- to medium-grained, and shale, greenish-gray; red clay pellets and pebbles in some sandstone beds	17	1
Hagan shale member (77 feet): (Type section)		
57. Shale, greenish-gray, containing platy beds of siliceous limestone; fucoids	55	1
56. Iron ore, hematitic, siliceous, composed of oval pellets; contains small, poorly preserved brachiopods	0	5
55. Shale, greenish-gray, with platy beds of siliceous limestone, from 1 to 3 inches thick	19	10
54. Sandstone, buff, medium-grained, with numerous patches of clay; forms prominent bed at base of Clinch sandstone	1	3

	Ft.	*in.*
Sequatchie formation (274 feet) :		
53. Mudstone, maroon, calcareous, with top 2 feet bleached yellow	10	0
52. Largely covered; several outcrops of maroon calcareous mudstone; section offset to west and continues at beginning of cut on curving spur connecting main line of railroad with the line through tunnel	93	5
51. Mudstone, calcareous, mainly maroon with some greenish beds having mottled green patches, abundant mudcracks	85	5
50. Limestone, greenish-gray, fine-crystalline, massive-bedded, argillaceous; most massive unit in Sequatchie; probable top of beds of Maysville age in lower part of Sequatchie	13	11
49. Limestone, greenish-gray, argillaceous, *Platystrophia ponderosa*, *Sactoceras* sp	33	8
48. Limestone, greenish-gray, argillaceous, in massive beds; abundant bryozoans and *Hebertella sinuata*, *Platystrophia ponderosa*, *Byssonychia radiata*, *Lophospira tropidophora*		
47. Mudstone, maroon, mottled, with shaly interbeds in lower part; abundant bryozoans in upper part; *Hebertella sinuata*	24	2
Reedsville shale (358 feet) :		
46. Limestone, medium-gray, fine-crystalline, siliceous; some coarse-crystalline coquina; shaly partings abundant; *Hebertella sinuata*, *Orthorhynchula linneyi*, *Platystrophia ponderosa*, *Plectorthis* sp., *Zygospira kentuckiensis*, *Z. modesta*, *Byssonychia radiata*	72	10
45. Shale, deeply weathered, yellow-brown	3	6
44. Shale, greenish-gray, fine-grained, siliceous; and coarse-crystalline limestone interbedded in equal amounts	14	10
43. Limestone, massive, brownish-gray, coarse-crystalline, coquinal; a few green shale and platy siliceous limestone beds; stony bryozoans	21	2
42. Shale, greenish-gray, interbedded with coarse-crystalline coquinal limestone; a few fine-grained siliceous limestones; *Rafinesquina fracta*, *R. nasuta*	33	5
41. Limestone, light-gray, coarse-crystalline, coquinal; small amounts of interbedded greenish-gray shale and fine-grained siliceous limestone; faulted	14	7
40. Shale, greenish-gray, weathering yellowish brown; fine-grained gray siliceous limestone; some beds of coarse-crystalline coquina; *Hebertella sinuata*, *Holtedahlina halli*, *Plectorthis fissicosta*, *Rafinesquina fracta; Resserella emacerata*, *Sowerbyella rugosa*, *Zygospira kentuckiensis*, *Z. modesta*, *Modiolopsis* sp	197	5
Trenton limestone (562 feet) :		
39. Limestone, brown and brownish-gray, coarse-crystalline, highly fossiliferous, forming one massive unit; *Hebertella* sp., *Rafinesquina trentonensis*	11	8
38. Clay, yellow, probably a bentonite; mica flakes present in the Brooks well but not seen here	0	2

Trenton limestone (562 feet)—Continued	*Ft.*	*in.*
37. Limestone and shale; limestone mainly gray, coquinal, with some fine-grained siliceous beds; shale amounts to about one-third of the rock in lower part of unit, less in upper part	33	8
36. Limestone, fine-crystalline and coarse-crystalline interbedded, with shaly partings; pink coquinal limestone near top; abundant gastropods in lower part; a few chert nodules and lenses in fine-grained limestone	54	7
35. Limestone, not exposed along railroad but scattered outcrops at base of hill to east; contains white chert in irregular thin masses; lithologically similar to unit 34; *Glyptocrinus* sp., *Rhynchotrema increbescens*, cephalopods; large stony bryozoans in beds near top	168	0
34. Limestone, fine- to medium-crystalline, in beds as much as 8 inches thick; most is sparingly fossiliferous but some coquinal beds; chert nodules in one bed; top of unit is highest bed exposed in railroad cut near water tower; *Cyrtodonta* cf. *C. grandis*	32	4
33. Limestone, gray, interbedded fine- and medium-crystalline; fine-crystalline beds siliceous; no coquinal limestones; abundant shaly partings	26	5
32. Limestone, bluish-gray, fine-crystalline in even beds with shaly partings; fewer fossils than underlying units; *Zygospira recurvirostris*, *Rafinesquina trentonensis*, *Ceraurus pleurexanthemus*	24	7
31. Limestone, gray, coarse-crystalline fossiliferous and fine-crystalline, unfossiliferous, interbedded, with fine-crystalline beds increasing in abundance upward; shaly partings between beds; ripple marks; unit includes a reverse fault; *Resserella* (*Dalmanella*) *fertilis*, *Sowerbyella curdsvillensis*, *Rafinesquina trentonensis*, *Zygospira recurvirostris*, *Prasopora* sp	77	6
30. Limestone, gray, coarse-crystalline; abundantly fossiliferous; sinkhole in this unit on east side of railroad tracks	63	4
29. Bentonite, greenish-gray, poorly exposed	1±	
28. Limestone, gray, coarse-crystalline; abundantly fossiliferous; 8-inch zone of partly silicified shale at top; abundant shale partings and shale beds except in lowest 10 feet; *Resserella* (*Dalmanella*) *fertilis*, *Dinorthis pectinella*, *Rafinesquina trentonensis*, *Prasopora* sp	37	4
27. Clay, greenish-gray, probably bentonitic	0	7
26. Limestone, gray and white mottled; highly fossiliferous; a few vugs lined with asphalt; abundant *Resserella* (*Dalmanella*) *fertilis* and *Sowerbyella curdsvillensis*; *Rhynchotrema increbescens*, *Dinorthis pectinella*, *Rafinesquina trentonensis*	31	4
Eggleston limestone (146 feet):		
Upper member (53 feet):		
25. Limestone, gray, cryptocrystalline and coarse-crystalline, with shaly partings; forms transition zone with Trenton lithology	9	0
24. Bentonite, greenish-white; weathers yellow; gritty; abundant flakes of brown mica	3	4

	Ft.	*in.*
Eggleston limestone (146 feet)—Continued		
Upper member (53 feet)—Continued		
23. Chert, brownish-black; represents silicified zone beneath bentonite; oscillation ripple marks on top surface	0	2
22. Limestone, gray, cryptocrystalline and medium-crystalline; *Rhinidictya* sp., *Rhynchotrema* sp., *Leperditella* sp	6	6
21. Mudstone, calcareous, dark-gray, massive-bedded, with abundant white calcite patches as much as half an inch in length; weathers blue gray	4	7
20. Bentonite(?)	0	1
19. Mudstone, calcareous, dark-gray, argillaceous, massive-bedded, with abundant white calcite patches as much as half an inch in length; weathers to blue-gray color	15	0
18. Limestone, light-brown, cryptocrystalline, with shaly partings	6	7
17. Clay, gray to buff, slightly gritty, bentonite(?)	0	1½
16. Limestone, gray, cryptocrystalline, with abundant shaly partings as much as 1 inch thick	7	8
Middle member (57 feet):		
15. Bentonite, greenish-white but weathers yellow	2	2
14. Chert, gray; represents silicified zone at base of bentonite	0	2
13. Limestone, gray, cryptocrystalline and medium- to coarse-crystalline, with fossils; thin shaly partings; unit includes two small faults; *Camarocladia* sp., *Doleroides* sp., *Öpikina* sp., *Strophomena* sp., *Zygospira* sp	33	1
12. Limestone, gray, thin-bedded, cryptocrystalline, with a few crystalline fossiliferous beds; a little argillaceous limestone; shaly partings and one zone of clay-shale 6 inches thick; *Pionodema minuscula*, *Rhynchotrema* sp	21	6
Lower member (36 feet):		
11. Mudstone, calcareous, weathers greenish yellow and gnarled, with no visible bedding; contains small patches of white calcite	35	10
Hardy Creek limestone (138 feet):		
10. Limestone, brown, cryptocrystalline and fine-crystalline, in even beds from 2 inches to 3 feet thick; includes shale bed 1 foot thick; unit spans fault having 19 feet of displacement	10	8
9. Clay, gray, gritty; probably not a bentonite	0	1½
8. Limestone, brown, cryptocrystalline and fine-crystalline, siliceous, in even beds from 2 inches to 2 feet thick; laminated on weathered surfaces; includes one chert bed and one bed containing oval chert nodules; several beds with intraformational conglomerate	14	6
7. Bentonite(?), gray, 2 inches thick, overlain by 3 inches of fissile white shale	0	5
6. Limestone, brown, cryptocrystalline with silty laminae	2	0
5. Bentonite(?)	0	¼
4. Limestone, brown, cryptocrystalline, with silty laminae; several beds of intraformational conglomerate, and several crystalline, fossiliferous beds	31	1

Hardy Creek limestone (138 feet)—Continued	*Ft.*	*in.*
3. Limestone, brown, cryptocrystalline, in even beds 6 inches to 3 feet thick; silty laminations show on weathered surface; large oval chert nodules in several beds; unit includes fault having 21 feet of displacement	64	3
2. Limestone, brown, in even beds, with partings and thin beds of yellow-weathering shaly limestone; forms transition zone with underlying Ben Hur limestone	15	0
Ben Hur limestone (141 feet):		
1. Limestone, yellow-weathering shaly and earthy; only topmost beds exposed in railroad cut	141	0

GEOLOGIC SECTION 17.—*Upper part of Reedsville shale, Sequatchie formation, and Hagan shale member of Clinch sandstone along U. S. No. 58 over Wallen Ridge*

[Section begins just uphill from a brushy ravine, where platy beds of Reedsville shale are folded into a prominent anticline, and ends in the gap at the crest of Wallen Ridge. Measured by R. L. Miller]

Clinch sandstone:	*Feet*
Poor Valley Ridge member (42+ feet):	
44. Sandstone, white, and light-colored, medium- and fine-grained, in massive beds as much as 5 feet thick, with a few zones of shaly sandstone; very massive unit 9 feet thick at top has been quarried and crushed for sand	29.0
43. Sandstone, yellow, earthy, shaly, with a bed of resistant sandstone 5 inches thick at base and a zone of maroon shaly sandstone 1 foot thick at top	4.5
42. Sandstone, reddish-brown, medium-grained, earthy, hematitic	3.1
41. Sandstone, dense, fine-grained, in beds as much as 11 inches thick, separated by shaly sandstone partings	5.8
Hagan shale member (83 feet):	
40. Sandstone, fine-grained, platy, with zones and partings of green shale in lower part; and greenish-gray shale with a few platy beds of fine-grained sandstone in upper part	20.8
39. Sandstone, gray and greenish-gray, fine grained, slightly quartzitic, with specks of limonite, in beds 1 to 4 inches thick separated by shale and shaly sandstone partings; exposed on southwest side of highway only	8.7
38. Shale and sandstone, not exposed on northeast side of cut and poorly exposed on southwest side of cut	9.0
37. Shale, light-green, slick, containing interbeds of fine-grained sandstone from 1 to 7 inches thick; top of unit at highest beds exposed on east side of roadcut	36.9
36. Shale, greenish-gray, earthy, containing interbeds of impure fine-grained sandstone from 1 to 4 inches thick; contains small brachiopods, pelecypods, trilobites and gastropods	5.9
35. Sandstone, shaly, fine-grained, with scattered medium-sized sand grains	1.5
Sequatchie formation (438 feet):	
34. Mudstone, maroon, shaly, calcareous, with zones of green shale and several beds of greenish-gray calcareous siltstone; at top, channel 1 inch deep filled with sand of overlying unit	12.0

Sequatchie formation (438 feet)—Continued	*Feet*
33. Siltstone, yellow-weathering, crumbly, calcareous	1.6
32. Mudstone, maroon, shaly, with a few patches and bands of green mudstone; and several beds of green dense calcareous siltstone; numerous mudcracks	59.0
31. Covered interval along highway; 10 feet of beds belonging in this interval exposed in ravine are greenish calcareous siltstone with limy lenses and beds containing abundant *Hebertella sinuata* (Hall)	73.9
30. Mudstone, maroon, calcareous, platy to shaly, speckled, mottled and interlayered with green mudstone	31.0
29. Mudstone, greenish-gray, calcareous, mottled with maroon	5.2
28. Covered interval between highest beds exposed along road and lowest beds exposed north of quarry above road	5±
27. Mudstone, green, calcareous, containing bryozoans	7.9
26. Siltstone, green, nodular, calcareous, with layers of shaly siltstone; contains bryozoans, *Zygospira modesta* (Say), *Hebertella* sp., *Platystrophia* sp	9.0
25. Siltstone, greenish-gray, limy, more resistant than enclosing units; contains abundant bryozoans	2.3
24. Siltstone, greenish-gray with maroon bands, even-bedded in beds as much as a foot thick, with grooves parallel to bedding on weathered surfaces	38.0
23. Siltstone, green, calcareous, with lenses of gray, harder, more calcareous siltstone; contains brachiopods (*Platystrophia ponderosa* Foerste) and bryozoans	18.2
22. Limestone, impure, nodular, and calcareous siltstone, both weathering greenish gray; abundant large brachiopods (*Platystrophia ponderosa* Foerste) and a few bryozoans	7.0
21. Siltstone, gray, calcareous, in beds 1 to 6 inches thick, separated by layers of green shaly calcareous siltstone averaging 2 inches thick; brachiopods (*Platystrophia* sp.) in a few beds	39.0
20. Limestone, gray, nodular, in beds from 1 to 3 inches thick, separated by equally thick layers of green shaly siltstone; abundant brachiopods (*Hebertella sinuata* (Hall) and *Platystrophia ponderosa* Foerste) and bryozoans	17.8
19. Siltstone, green calcareous, in gnarled beds, with large bryozoans	2.3
18. Siltstone, red, calcareous, in beds from 1 to 2 feet thick; large bryozoans at top	4.7
17. Siltstone, greenish-gray in lower part, with maroon bands in upper part; forms fairly resistant ledge	5.7
16. Limestone, impure, nodular, interlayered with shaly calcareous siltstone in lower part; gray calcareous siltstone, showing spheroidal weathering in upper part; numerous bryozoans and brachiopods	12.0
15. Covered interval	75±
14. Siltstone, maroon, calcareous, with greenish-gray patches	4.4
13. Limestone, greenish-gray, impure, dense; forms ledges that weather with ridges and grooves parallel to bedding, a distinctive feature of Sequatchie lithology; contains poorly preserved pelecypods and brachiopods; 2 inches of clay at base (fig. 17)	7.5

Reedsville shale (231+ feet):	*Feet*
12. Limestone, gray, medium- and coarse-crystalline, with some gray calcareous shale; *Orthorhynchula linneyi* (fig. 17)	18.5
11. Shale, greenish-brown, calcareous; and deeply weathered limestone, largely decomposed to reddish-brown soil	2.5
10. Limestone, gray, medium- and coarse-crystalline, in beds from 1 to 6 inches thick, separated by layers of gray calcareous shale from 1 inch to 1 foot thick; slightly more limestone than shale; abundant fossils	19.2
9. Covered zone	45±
8. Shale and silty shale, greenish-gray, weathering yellow, with zones from 2 to 6 inches thick at intervals of 1 to 2 feet, consisting of reddish soil derived from weathered coquinal limestone	26.0
7. Limestone, gray, coquinal, forming prominent ledge in part of cut and zone of reddish silty and gritty soil elsewhere	1.5
6. Shale, gray, and zones of reddish-brown gritty soil derived from coquinal limestone	7.8
5. Limestone, gray, fine- and medium-crystalline, forming massive ledge; contains abundant bryozoans and brachiopods	5.8
4. Shale, gray, and silty sandstone interbedded in units several inches thick	19.0
3. Limestone, deeply weathered, sandy in lower part and silty in upper part, in zones as much as a foot thick, separated by layers of gray shale several inches thick	10.5
2. Shale, greenish-gray, containing platy beds of fine-grained impure silty sandstone from 1 to 4 inches thick; even-layered; unit two-thirds shale	56.7
1. Sandstone, silty, greenish-gray speckled with brown; greenish-gray shale; and gray, fine-crystalline, fossiliferous limestone; upper part of unit resistant, probably forms crests of knobs of Reedsville above and below road	18.2

GEOLOGIC SECTION 18.—*Poor Valley Ridge member of Clinch sandstone and Clinton shale along U. S. No. 58 on south slope of Wallen Ridge*

[Section begins at back of abandoned loop of highway near log shed half a mile east northeast of high point of highway on ridge, continues southward (uphill) along highway to highest beds exposed at right-angle bend, offsets to next deep highway re-entrant a quarter of a mile to the east, and continues southward along road (downhill) to highest beds exposed at near right-angle bend in highway. Measured by R. L. Miller]

Clinton shale (394+ feet):	*Feet*
43. Sandstone, yellow, medium-grained, deeply weathered, somewhat shaly at top; contains numerous crumbly brachiopods and trilobites	13.0
42. Sandstone, coarse-grained, pebbly, deeply weathered; contains two zones of mottled greenish-gray and reddish-purple sandstone	14.2
41. Sandstone, coarse-grained and pebbly at base, overlain by interbedded fissile gray shale and pebbly sandstone	2.9
40. Sandstone, medium-grained, massive, glassy, quartzitic	7.4
39. Sandstone, fine-grained, soft, shaly with limonitic layers and nodules	.5
38. Shale, green and greenish-gray, slick, fissile, with numerous beds less than 3 inches thick of dense fine-grained sandstone; 2-foot zone of red shale near middle	33.0

Clinton shale (394+ feet)—Continued	*Feet*
37. Shale, red, with numerous platy beds of greenish-gray, fine-grained sandstone	9.1
36. Shale, green and red, with a few platy beds of dense, fine-grained sandstone	38.4
35. Covered	61.9
34. Shale, greenish-gray, fissile, with a few zones of red shale and a few beds as much as 8 inches thick of fine-grained sandstone	27.1
33. Shale, greenish-gray and greenish-yellow, with a zone of sandy shale containing abundant *Coelospira hemispherica* at base; beds of fine-grained sandstone as much as a foot thick in middle and upper parts, and a little red shale near top	16.3
32. Sandstone, yellowish-brown, fine-grained, deeply weathered, with abundant *Coelospira hemispherica*	1.9
31. Shale, red, pink, and greenish-gray, fissile, containing platy beds of dense fine-grained sandstone	10.0
30. Shale, red, with a few beds of fine-grained sandstone with fucoid markings	22.3
29. Covered	17.7
28. Shale, red; greenish-gray in upper part; covered with gray shaly float in lower part; *Coelospira hemispherica* at top; exposures on uphill side of highway loop stop at top of this unit; offset along strike to downhill side of loop	35.4
27. Shale, red, some reddish-gray and greenish-gray; *Coelospira hemispherica*	23.0
26. Shale, brown-weathering, silty, fissile, with beds of fine-grained sandstone	9.2
25. Covered, but base of Clinton almost exposed; thickness of unit is thickness of beds in covered interval less thickness of units 22 to 24	39.9
24. Shale, red, crumbly; contains *Coelospira hemispherica;* these are top beds exposed along highway at right-angle bend; section continues on next highway re-entrant downhill a quarter of a mile to the east	4.1
23. Sandstone, fine-grained, platy, stained yellow and red; and shaly and earthy sandstone; contains *Coelospira hemispherica*	5.3
22. Sandstone, pebbly, massive, with oval conglomeratic pebbles as much as 3 inches long in lower half; contains *Coelospira hemispherica* on top surface	1.3
Clinch sandstone:	
Poor Valley Ridge member (250+ feet):	
21. Sandstone, hematite-stained, and green shale, with a little maroon shale at top	3.4
20. Sandstone, yellowish-brown, pebbly, deeply weathered	.4
19. Sandstone, fine-grained, in platy and wavy beds, with partings and thin layers of shale	18.9
18. Shale, greenish-gray; small fault cuts unit, stratigraphic displacement eliminated	8±
17. Sandstone, platy and shaly, hematite stained in lower part, greenish-gray in upper part	6.8
16. Sandstone, maroon, medium-grained, hematite-cemented, forming ledges	10.9
15. Shale, green, weathers yellow	6.0

Clinch sandstone—Continued

Poor Valley Ridge member (250+ feet)—Continued	*Feet*
14. Sandstone, medium-grained, with prominent rounded ridges on under surface	1.9
13. Shale, greenish-gray, with a few thin beds of sandstone; small fault in this unit; displacement eliminated	7.5
12. Sandstone, massive in lower part, thinner-bedded with some shale in upper part; many clay galls	28.0
11. Shale, gray, with a few beds of platy sandstone	7.4
10. Sandstone, fine-grained, dense, forming ledge	1.4
9. Shale, greenish-gray, with thin wavy beds of sandstone in lower part and even beds of resistant sandstone in upper part	12.0
8. Sandstone, fine-grained, in wavy beds, with massive unit 3 feet thick at base, and several shaly zones	13.7
7. Shale, green and greenish-gray, fissile	1.9
6. Sandstone, fine-grained; in wavy and lumpy beds 2 or 3 inches thick; with abundant patches of green clay	4.5
5. Shale, greenish-gray, fissile; with one 5-inch bed of resistant sandstone	6.8
4. Sandstone, fine-grained, slabby, pitted; in wavy beds	18.0
3. Covered	12.3
2. Sandstone, massive, resistant; in beds from 1 to 3 feet thick	20.8
1. Sandstone, gray, fine-grained; shaly sandstone; and green shale; unit largely covered; base of unit at log shed at back of abandoned loop of highway	59.5

GEOLOGIC SECTION 19.—*Hancock dolomite along State Route 70 on east edge of Ben Hur*

[Measured by J. O. Fuller and R. L. Miller]

Upper Devonian shale:	*Ft.*	*in.*
22. Shale, dark-brown to black, fissile; weathers light gray; slickensides; few outcrops, but abundant shale chips in soil	(?)	
Hancock dolomite (188 feet):		
21. Dolomite, fine-crystalline, light-brown; weathers light blue-gray to gray with medium- to fine-"butcher-block structure"; upper half medium- to dark-brown, fine-crystalline, with petroliferous odor	26	9
20. Limestone, dense to fine-crystalline, dark- to medium-brown, with petroliferous odor; weathers light blue-gray with smooth rounded surfaces	15	2
19. Dolomite, dense to fine-crystalline, light-brownish-gray; weathers light gray with a few red streaks and "butcher-block structure"	30	8
18. Dolomite, fine-crystalline, dark-brownish-gray; "butcher-block structure" on weathered surfaces	24	10
17. Covered	12	8
16. Dolomite, fine-crystalline, light-brownish-gray; weathers light tan to light gray with "butcher-block structure"	14	0
15. Dolomite, fine-crystalline, brownish-gray; weathers buff to bluish gray with "butcher-block structure;" some limy zones, which are laminated	24	10

Hancock dolomite (188 feet)—Continued	*Ft.*	*in.*
14. Limestone, fine-crystalline, dark-blue-gray; weathers buff; laminated in lower part, pitted in upper part; brachiopods and abundant corals including *Favosites* sp	4	9
13. Covered	4	4
12. Limestone, dark-blue-gray; with scattered zones of intraformational conglomerate, whose pebbles are more silty and weather buff	1	4
11. Limestone, massive-bedded, ribboned, medium- to dark-blue, with scattered sand grains and pebbles; ribbons weather silty, buff and light blue-gray; indeterminate fossil fragments; see left side of photograph, figure 20	12	2
10. Sandstone, medium-grained, medium-blue-gray, laminated, with lime cement; a few scattered pebbles; weathers light blue-gray and then to a brown earthy sand; some shale partings	3	2
9. Sandstone, medium to coarse, friable, with pebbles as much as half an inch in length; some silicified areas	1	6
8. Sandstone, medium to coarse, friable; fucoids and fossil fragments	3	7
7. Limestone, fine-crystalline, medium-blue, with scattered sand grains and some clay which produce irregular indistinct banding; weathers medium brown; calcite veins	2	0
6. Shale, greenish-gray; upper part fine-grained white limonite-stained quartzitic sandstone	0	6
5. Sandstone, fine-grained, with lime cement, scattered pebbles, weathers porous and friable	1	4
4. Shale, brown, highly weathered; interbeds of thin quartzitic sandstone, some with cross-bedding	2	1
3. Sandstone, irregularly bedded, medium- to coarse-grained and pebbly, some quartzitic; largest pebble one-fourth inch long	1	6
2. Weathered zone; white silicified rock at base with rounded medium to coarse sand grains and molds of calcite rhombohedrons; upper part yellowish-brown clay derived from weathering of limestone; see photograph, figure 20	1	0
Clinton shale:		
1. Sandstone, massive, fine-grained, white, limonite-stained, in beds from 6 to 33 inches thick; lime cement; interbedded thin bluish-gray sericitic shale; some quartzitic sandstone; fucoids; fault duplicates about 50 feet of beds, including Clinton and Hancock contact	13	11

GEOLOGIC SECTION 20.—*Upper Devonian shale in cut leading to tunnel of Louisville and Nashville Railroad at Hagan*

[Section begins at north edge of covered interval filled with slump into a sinkhole, and ends at major underthrust fault, beyond which beds are repeated. Measured by R. L. Miller and J. O. Fuller]

Upper Devonian shale (137+ feet):	*Feet*
4. Shale, black to greenish-black, weathering black, brown, and yellow; contains large concretions of siderite in lower part; top of unit is at underthrust fault, north of which units 3 and 4 seem to be repeated. (See fig. 21 *B*)	60.0

Upper Devonian shale (137+ feet)—Continued	*Feet*
3. Shale, dark-gray, weathering light gray	76.0
2. Sandstone, fine-grained, earthy, slightly carbonaceous, stained with sulfate, forms lowest 5 inches, overlain by 3 inches of shiny black carbonaceous shale stained with sulfur	.7
Hancock dolomite (158 feet):	
1. Dolomite, brownish-gray, fine-grained, in beds several feet thick; abundant lenses of small-scale intraformational conglomerate; this unit well exposed at top of formation; remainder of Hancock covered except lowest 10 feet	34.7

PHYSIOGRAPHY

PHYSIOGRAPHIC PROVINCES

The Jonesville district is entirely within the Valley of Virginia. This is not a single valley, but comprises many parallel valleys which form a belt extending northeast along the western boundary of Virginia between the Blue Ridge Upland and the Appalachian Plateau (fig. 1). The southeastern part of the belt which comprises the Valley of Virginia is a broad lowland generally more than ten miles wide, and interrupted by few ridges. The northwestern part of the belt is characterized by linear ridges separated by narrow valleys. These ridges are about 1,500 feet lower than the mountains of the Blue Ridge and of the Appalachian Plateau, and, together with the narrow valleys and the broad lowland, form a trough between the mountains. The Valley of Virginia is part of the Valley and Ridge province of Fenneman (1928), which extends from Alabama to Canada. (See fig. 1.)

In southwest Virginia and northeast Tennessee the rocks of the Valley and Ridge province are faulted along a series of major overthrusts. The formations crop out in parallel belts which strike northeast. Because of the faulting, the same lower Paleozoic formations are repeated in successive belts across the province. Streams have eroded the weak formations of these belts more rapidly than the resistant formations, thus forming the alternating valleys and ridges that give the province its name.

Most streams of the province follow the strike of the weak rock belts for long distances and cross the resistant rock belts in short stretches almost normal to the strike. This gives a pronounced trellis pattern to the regional drainage. Near the Jonesville district all the master streams of the province are subsequent and flow along the strike of weak formations.

For most of its length the Valley and Ridge province is bordered on the west by the Appalachian Plateau. The plateau is underlain by relatively flat-lying rocks of Pennsylvanian and Permian age that include much sandstone, conglomerate, and coal. They are younger than the rocks of the Valley, which dip below them along the steep escarpment that separates the plateau from the Valley and Ridge province. The dendritic stream pattern developed on the flat-lying rocks of the plateau contrasts sharply with the pattern of the streams controlled by the folds and faults of the Valley and Ridge province.

Near the Jonesville district the crest of the plateau escarpment stands about 1,500 feet higher than the lowland at its base. It is breached by the North Fork of Powell River at Pennington Gap just northeast of the Jonesville district. Through this water gap the drainage of the Lee County section of the plateau flows southward into the valley. Six miles southwest of the gap the crest of the escarpment is the divide between plateau and valley drainage, and the divide follows the crest thence into Tennessee. Where the escarpment forms this major drainage divide, it is called Cumberland Mountain, and along the section of the plateau drained by Powell River it is called Stone Mountain.

Although the plateau escarpment near the Jonesville district separates two physiographic provinces of sharply distinct topography and rock types, there is no strong contrast in regional structure of the provinces, as there is farther to the northeast. The rocks of the Jonesville district and those of the adjacent plateau are both part of the Cumberland overthrust block, which extends 15 miles northwest of the escarpment to Pine Mountain. This part of the plateau between the escarpment and Pine Mountain is structurally continuous with the Jonesville district but is classed as part of the plateau on the basis of topography.

RELATION OF TOPOGRAPHY TO GEOLOGY

The major topographic divisions of the Jonesville district are directly related to the gross lithologic divisions of the rocks of the area. The stratigraphic column is roughly divisible into four groups of formations on the basis of differing resistance to erosion. These are:

4. Upper part of Clinton shale, Hancock dolomite, and Upper Devonian and lower Mississippian (?) black shale.
3. Reedsville shale, Sequatchie formation, Clinch sandstone, and lower part of the Clinton shale.
2. All formations from the limestone member of the Dot limestone to the Trenton limestone, inclusive. Almost entirely limestone.
1. All formations from the Maynardville limestone to the dolomite member of the Dot limestone, inclusive. Almost entirely dolomite.

1. The oldest of these gross lithologic divisions is the thick sequence of Cambrian and Lower Ordovician carbonate beds, which includes the Maynardville limestone, the five formations of the Knox group, and the lower or dolomite member of the Dot limestone. This sequence, which is more than 2,500 feet thick, is composed almost

entirely of dolomite. Where these dolomites have been brought to the surface along and near the axes of the Chestnut Ridge and Sandy Ridge anticlines (pl. 1), they form hilly upland areas which rise 300–600 feet above the adjacent limestone lowlands. In the region of gentle dips the upland is dissected by transverse streams, whose tributaries have a dendritic pattern. In these areas the hills have no particular trend or shape. Some are gently sloping and are circular or oval or form short ridges. Others that lie near the major stream courses may be steep-sided and have their trend determined by the pattern of the nearby stream valleys. Sinkholes abound in those parts of the upland that are not directly tributary to deeply incised streams. Along the north flank of the Chestnut Ridge anticline, where the dips are steep, the abundantly cherty beds of the Longview dolomite and lower part of the Mascot dolomite form a nearly continuous ridge, named Chestnut Ridge, which rises 100–300 feet above the general level of the dolomite upland to the south and 300–600 feet above the limestone lowland to the north.

Throughout the upland areas the dolomite weathers to a yellow or orange sticky clay soil which forms a nearly continuous deep mantle over the flat and gently-sloping areas. Outcrops of bedrock are mostly confined to the walls of the more sharply incised stream valleys and to the bottoms of sinkholes that have not been clogged with alluvium. The dolomite formations of the Knox group have nodules, lenses, masses, and beds of white-weathering chert at many horizons. Pieces of this chert are scattered over the surface of almost all of the dolomite upland, and locally they are so abundant that great rock piles and rock fences have been built by the farmers from the chert cobbles picked up in the fields.

2. In order of age, the second group of formations that has a distinctive topographic expression is a sequence of Middle Ordovician limestones about 2,000 feet thick. This includes all formations from the upper or limestone member of the Dot limestone through the Trenton limestone. These limestones crop out in continuous belts along both flanks of the major anticlinorial uplift of the area, and they also form an embayment along The Cedars syncline that separates the Sandy Ridge anticline from the Chestnut Ridge anticline.

Subsequent lowlands have been eroded along the limestone belts. The southern limestone lowland is occupied throughout most of its length by the Powell River, the master stream of the region. The corresponding limestone lowland on the north flank of the Chestnut Ridge anticline is occupied by various small streams in different parts of the area, the longest of which is Sugar Run. A sketch showing the appearance of this lowland at Hagan and the relation of the topographic features to the Ordovician formations is given in figure 21*A*. This limestone lowland is continuous with the limestone lowland referred to as the Indian Creek lowland in the Rose Hill district. In some stretches the drainage of the lowland is entirely underground.

The upper part of the limestone sequence is little more resistant to erosion than is the lower part, but it is overlain by the ridge-forming formations of the third lithologic sequence. Hence, these upper limestones crop out on the lower slopes of Wallen Ridge on the south side of the Powell Valley lowland and, to a lesser extent, on the lower slopes of Poor Valley Ridge on the north side of the Sugar Run lowland (fig. 21*A*).

In the eastern part of the district, the southern belt of limestone laps around the nose of the east-plunging Sandy Ridge anticline and forms a broad limestone area having gentle dips. This area, known as Hickory Flats, has very low relief. Sinkholes are abundant, and almost all of the drainage is by underground passages. Hickory Flats has rich, fertile soil and is probably the best farming area in the Jonesville district. Cedar Knob is a prominent, isolated hill rising more than 300 feet above the western part of Hickory Flats. It is an unreduced remnant of the lower slopes of Wallen Ridge, formed by the almost flat-lying limestones near the axis of The Cedars syncline.

The limestone embayment along The Cedars syncline is named The Cedars lowland. It is underlain by gently dipping beds of about the lower third of the limestone sequence. Few streams cross this area, and almost all of the drainage is by way of sinkholes to underground channels. Hence, The Cedars lowland is much less dissected than either the Powell River or Sugar Run lowlands.

3. The third lithologic sequence in the Jonesville district consists of shales and sandstones of Late Ordovician and Silurian age. This sequence includes the Reedsville shale, Sequatchie formation, Clinch sandstone, and the lower part of the Clinton shale, and it totals about 1,300 feet of beds. The Clinch sandstone is by far the most resistant formation of the district, and it forms the crest of Poor Valley Ridge on the north side of the Sugar Run lowland and the crest of the high reaches of Wallen Ridge on the south side of the Powell River lowland. Resistant beds in the upper part of the Reedsville shale form a prominent series of knobs on the upper slopes of both ridges. The front slopes of the knobs are steep, but the side slopes are even steeper and are consistently at angles very close to 30°.

Poor Valley Ridge is irregular in height, rising to maximum elevations of about 800 feet above the Sugar Run lowland. Elsewhere it is only about 400 feet above the lowland. A short, curving, unnamed ridge near Ben Hur is formed by duplication of the Clinch sandstone outcrop in the Ben Hur fault slice.

FIGURE 21A

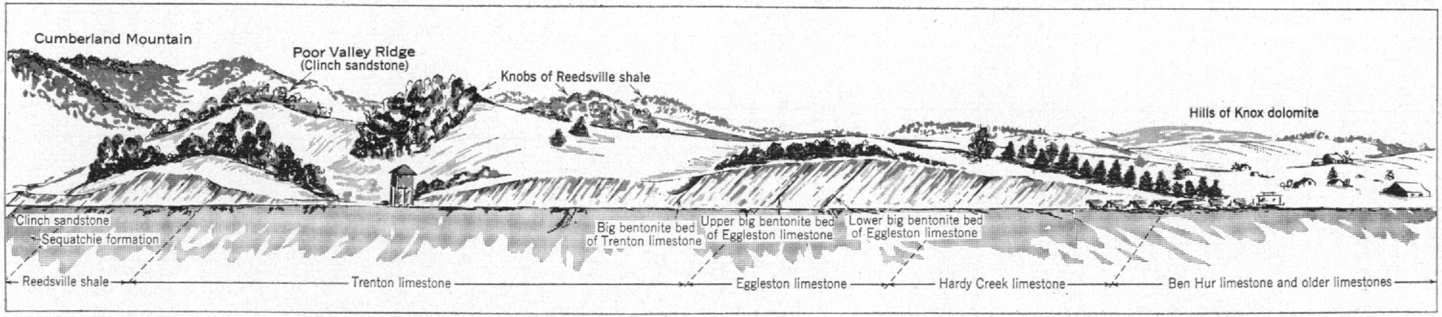

FIGURE 21B

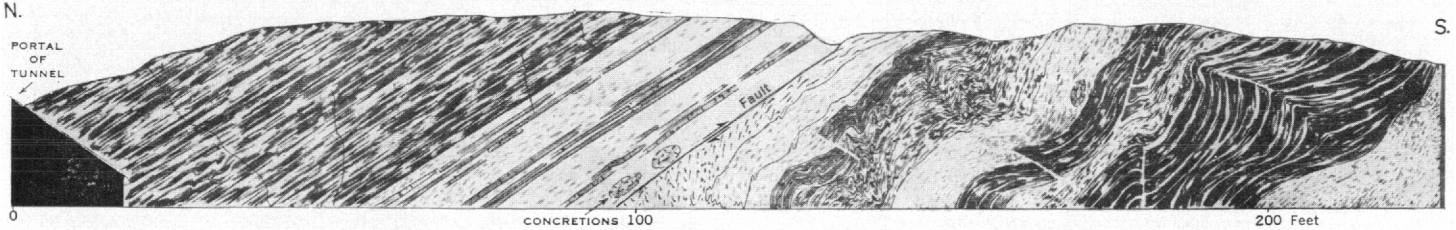

FIGURE 21.—*A,* Sketch of railroad cut at Hagan showing topographic expression of Ordovician formations. *B,* Geologic section of Upper Devonian shale in the cut leading to the portal of the Louisville and Nashville Railroad tunnel at Hagan. Fault in middle of section is an underthrust.

Wallen Ridge has considerably more relief than Poor Valley Ridge. Along part of its course, the Clinch sandstone is absent because of overthrusting along the Wallen Valley fault, and here the crest line is low and is very irregular. Where the Clinch is present, however, the ridge is sharp and linear and the northwest slopes of the ridge rise steeply above the Powell River lowland.

The highest point along Wallen Ridge and the highest point of the Jonesville district is Buzzard Roost, where the Poor Valley Ridge member of the Clinch sandstone curves around the end of the synclinal point of a zigzag fold. The gently dipping Clinch sandstone on the synclinal axis stands 500 feet higher than the steeply dipping sandstone on the ridge crest less than 2 miles away. Older and weaker formations also have unusually high elevations in the area of low dips. A long high spur extends westward from Buzzard Roost for more than a mile along the synclinal axis. The Clinch sandstone that formerly capped this point has been stripped away; the Sequatchie formation is also largely gone; and the Reedsville shale lies at the crest of the spur for most of its length. Elk Knob, the second-highest summit along the synclinal axis, stands near the end of this spur. The knob is capped by the Sequatchie formation, which generally forms steep hillside slopes rather than summits. The Sequatchie formation forms the summit here only because Elk Knob is a high remnant left after erosion of the Clinch sandstone that formerly capped the spur. This synclinal point of Wallen Ridge forms the skyline in the photograph (fig. 26) across the cut-off meander at Woodway. Buzzard Roost is the high point at the center, from which the ridge crest declines gradually to the left, where the sandstone outcrop diverges from the synclinal axis. To the right of Buzzard Roost the main escarpment descends into the sag that separates Buzzard Roost from the broad, lower summit of Elk Knob.

4. The fourth lithologic division of the stratigraphic column consists of the upper part of the Clinton shale, the Hancock dolomite, and the upper Devonian and lower Mississippian (?) black shale. These rocks, which total about 1,000 feet of beds, are weak. Along the northwest edge of the district they form a persistent valley named Poor Valley. Poor Valley is very narrow, as the sequence of rocks which forms it is relatively thin and also steeply dipping. Just north of the edge of the Jonesville district Cumberland Mountain and Stone Mountain rise about 1,500 feet above the floor of Poor Valley. Talus from the resistant conglomerate and sandstone beds of Pennsylvanian age that form the crest of the mountain has partially choked Poor Valley in many places. This, combined with the infertility of the soil derived from the black shales, causes the valley to be unsuitable for agriculture, but there is some pasture land on the floor and lower slopes of the valley.

On the southeast edge of the district, Hancock dolomite and Devonian black shale are almost everywhere eliminated by the overthrusting along the Wallen Valley fault, which brings Maynardville limestone or Copper Ridge dolomite in contact with the belt of Clinton shale on the back side of Wallen Ridge. The Clinton shale and Maynardville limestone are less resistant than either the Clinch sandstone of Wallen Ridge to the north or the dolomitic formations of the Knox group to the south. Hence a distinct but discontinuous lowland has developed approximately along the trace of the Wallen Valley fault. This is manifested by the flaring valleys of the transverse streams and the low divides between the transverse streams along this belt. Locally this lowland is named Back Valley.

At the eastern tip of the area this indistinct lowland opens out into a broad basin, where the belt of Clinton becomes broader in the area of flat dips east of the zigzag bend of Wallen Ridge. This basin is intricately dissected by the headwaters of Wallen Creek, is heavily timbered, and is the wildest, most rugged, and least accessible of the lowland areas in the Jonesville district.

EROSIONAL HISTORY

The topography near the Jonesville district shows evidence of at least three cycles of erosion. During the first two of these cycles, partial peneplains were produced; and the cycles were ended by regional uplift. Erosion in the third cycle is still active. The peneplains of the earlier cycles are more perfect, more extensive, and better preserved in New Jersey and Pennsylvania than near the Jonesville district. From its type region in New Jersey the older is named the Schooley peneplain, and from its type region in Pennsylvania the younger is called the Harrisburg peneplain.

PRE-SCHOOLEY EROSION

In the southwest Virginia and northeast Tennessee sections of the Valley and Ridge province there is no trace of any erosion surface older than the Schooley peneplain. East of the province the summits of the Great Smokies at an elevation of nearly 6,000 feet present an even skyline that may possibly represent a higher peneplain, but within the province no ridges rise far enough above the Schooley level to preserve remnants of any higher surface.

The major streams responsible for pre-Schooley erosion probably followed approximately the same courses as those of today. The master streams near the Jonesville district follow subsequent courses along belts of weak rocks for most of their length, but parts of their courses cross belts of resistant rock through which they have cut water gaps. Powell River, for example, flows along a belt of limestone and dolomite for 70 miles of its lower course, but its two main branches are transverse to the strike and cross Stone Mountain in Pennington Gap and Big Stone Gap. The transverse parts of these courses are inherited from the Schooley peneplain, on which the streams found their way across reduced barriers of resistant rock. The parts of the major stream courses that are now subsequent must also have existed in approximately their present positions before the completion of the Schooley peneplain. The present great lengths of these subsequent courses can hardly have resulted from any structurally controlled reorganization of the stream pattern on the Schooley peneplain at the end of the Schooley cycle, and there is no evidence that any major stream has changed its course since that time.

SCHOOLEY PENEPLANATION

The Schooley peneplain has been identified throughout most of the length of the Valley and Ridge province and in neighboring provinces as well. The type region of the Schooley peneplain is in the New England province of New Jersey, where it is represented by the broad, flat top of Schooley Mountain. Summit levels from there to Birmingham, Ala., have been correlated with this peneplain surface. However, the surface is difficult to recognize in the Valley and Ridge province southwest from Wytheville, Va., because ridge crests are more irregular and high ridges less numerous. Nevertheless, the generally accordant level of high summits is taken to represent somewhat-reduced remnants of the peneplain.

In most places the summits that represent the peneplain remnants are not broad and flat, and representative elevations are not constant. This is partly because the peneplain was not flat. Monadnocks rose above the surface, and shallow valleys were below the general level. Despite subsequent reduction in post-Schooley time, these irregularities are still to some extent exhibited on the ridge crests by local high points that rise above the general crest level and by the downward slope of the ridge crests toward the major transverse streams.

The peneplain surface sloped gently in the direction of major drainage, and summit elevations indicate that the slope was southwest in the southern section of the Valley and Ridge province. Typical summit levels are: 3,000 to 3,300 feet on the mountains adjacent to New River northwest of Wytheville, Va.; 2,100 to 2,500 feet on Powell and Clinch Mountains south of Cumberland Gap; 1,500 to 2,000 feet on Walden Ridge and Sand Mountain near Chattanooga, Tenn.; and 1,000 feet near Birmingham, Ala.

Present elevations of summits identified as remnants of the peneplain surface are lower than those of a true restored surface, for the ridge crests have been degraded since the uplift of the Schooley peneplain. The amount of degradation is not known and probably varies with local differences in the resistance and attitude of the rocks; so elevations given for the peneplain are only approximations.

REMNANTS IN THE JONESVILLE DISTRICT

In the Jonesville district only a small part of one ridge rises to the approximate height of the Schooley peneplain; but the peneplain has been identified on nearby ridges, and it may be inferred within the district. Pine Mountain, 17 miles northwest of Jonesville, has an elevation of 2,500–2,700 feet. Just southeast of the Jonesville district, stretches of Powell Mountain and Newman Ridge have fairly level crest lines at elevations of 2,300 to 2,500 feet and 2,400 to 2,500 feet respectively. About 13 miles southeast of Jonesville, Clinch Mountain rises to 2,200–2,400 feet. These crest lines roughly define a peneplain surface at an elevation of 2,300–2,400 feet in the Jonesville district.

Several summits rise above the peneplain surface. Just north of the Jonesville district Cumberland Mountain and Stone Mountain have elevations of about 2,600–2,900 feet. Farther north in the Cumberland plateau the Black Mountains stand at 3,300–4,100 feet, and just east of the district the plateau ridge named Powell Mountain stands at 3,400–4,000 feet. These mountains must have been monadnocks on the Schooley peneplain. The Black Mountains owe their height to their position along the divide in the plateau between Powell River and Cumberland River drainage. Cumberland Mountain and the Powell Mountain of the plateau are capped by conglomerate of the Lee formation, the most resistant rock of the region. The conglomerate dips steeply northwest in Cumberland Mountain and is relatively flat-lying in Powell Mountain, with the result that Cumberland Mountain was reduced to a linear ridge rising only a few hundred feet above the Schooley peneplain, while Powell Mountain remained as a broad-topped mountain.

Within the Jonesville district the crest of Wallen Ridge rises above the peneplain level where the crest crosses the axis of The Cedars syncline. The ridge crest has an elevation greater than 2,600 feet for about 5 miles, and it culminates in Buzzard Roost at an elevation of 3,190 feet. On the Schooley peneplain this part of Wallen Ridge was a V-shaped monadnock capped by gently dipping Clinch sandstone that probably extended west of Buzzard Roost over the summit of Elk Knob.

Where U. S. No. 58 crosses Wallen Ridge, the crest elevation drops sharply from 2,600 feet to 2,300 feet. From here almost to Blue Hollow, where the Clinch sandstone is cut out by the Wallen Valley fault, the ridge crest has an elevation of 2,250 to 2,400 feet or more.

This elevation corresponds closely to the 2,300- to 2,400-foot elevation of the Schooley peneplain deduced from summit elevations outside the Jonesville district. Except for this stretch of Wallen Ridge no summit in the Jonesville district stands at the summit level that marks the Schooley peneplain. The ridges of Clinch standstone do, however, retain a fairly uniform summit level, even where degraded 200 to 400 feet below the approximate peneplain level.

Between Blue Hollow and Fitts Gap, the Wallen Valley fault block has overridden the Clinch sandstone, and the crest of Wallen Ridge is either on dolomite of the overthrust block or on Reedsville shale of the stationary block. This part of the ridge is less than 2,000 feet in elevation. From Fitts Gap to the southern edge of the Jonesville district Clinch sandstone again forms the crest of Wallen Ridge, and the crest elevation varies from about 2,100 to 2,200 feet.

Poor Valley Ridge is also made by the outcrop of Clinch sandstone but is generally lower than Wallen Ridge because the ridge-forming beds are thinner and dip more steeply. The summit rises above 2,100 feet in only one stretch of 1½ miles where the dip of the Clinch sandstone flattens to 25°–35°.

The dolomite uplands of Chestnut Ridge and Sandy Ridge-Tanbark Ridge have also been eroded below Schooley peneplain level. Dissection has destroyed any continuous even skyline they may have inherited from the peneplain level, but the Chestnut Ridge divide does have a general summit level of about 1,900 feet from Pennington Gap to 1 mile east of Hardy Creek.

DRAINAGE SYSTEM IN SCHOOLEY TIME

The Schooley erosion cycle was ended and a new cycle begun by uplift and tilting of the peneplain. The restored peneplain surface now slopes at an average rate of more than 6 feet per mile from Wytheville, Va., to Birmingham, Ala. (Wright, 1936, pp. 93–142.) This slope is too steep to be the original downstream slope of the peneplain and must be in part the result of deformation. The uplift rejuvenated the Schooley streams. They deepened their valleys below the peneplain, cutting water gaps and gorges across belts of resistant rock and wider valleys where they followed the strike of weaker rocks. Meanders that had formed on the peneplain were intrenched by rapid down cutting. The water gaps and intrenched valleys that were cut below the Schooley surface are a record of the main stream courses of the late Schooley cycle.

About half the surface drainage of the Jonesville district enters Powell River through Hardy Creek, Dry Creek, Cane Creek, and Wallen Creek. Within the district, Powell River and each of these creeks flows from one subsequent lowland to another across an intervening ridge of resistant rock. These transverse courses are cut into erosion surfaces that rise several hundred feet above any known peneplain younger than the Schooley, and thus they must have been inherited from the Schooley cycle. No wind gaps can be identified on the ridge crests or in the Chestnut Ridge upland, so there is no evidence that any major stream courses connecting the minor parallel lowlands with the main Powell River lowland have been abandoned since the end of the Schooley cycle.

In the northeast corner of the district, Powell River flows along the foot of Wallen Ridge. At Woodway the river turns south, flows across the structure, and cuts through the end of the dolomite ridge along the axis of Sandy Ridge anticline. Thence the river follows the strike of the limestone belt to the west edge of the district, but its meander belt is not restricted to the limestones. As far west as the dolomite is exposed along the Sandy Ridge anticline, the meanders are intrenched in both the narrow limestone lowland and the slopes of Sandy Ridge-Tanbark Ridge. Dolomite intermeander spurs reach elevations of 1,500–1,600 feet, and dolomite cliffs at the meander ends rise in places to 1,700 feet. These elevations are from 100 to 300 feet higher than the elevation of the Harrisburg peneplain, and so the parts of the meanders in the dolomite upland could not have been inherited from the Harrisburg surface.

HARRISBURG PENEPLANATION

The Harrisburg erosion cycle began when the Schooley peneplain was uplifted and streams thus rejuvenated began trenching the old surface. The uplift and trenching of the Schooley surface has continued into the present erosion cycle but not without interruption. A pause in the movement checked the rapid down cutting of the streams and enabled them to broaden their valleys and to produce a limited or partial peneplain. This surface has been named the Harrisburg (Butts, 1940, pp. 507–510) peneplain and has also been called the valley floor (Stose, 1922, pp. 16–24) peneplain. The period during which it was cut was so brief that the peneplain generally is restricted to the valleys of only the larger streams and, in the Valley and Ridge province, to the belts of weaker rocks. In each drainage system the peneplain rises upstream at a rate dependent upon the gradient of the stream. Where circumstances were unfavorable for even partial peneplanation, contemporaneous erosion surfaces such as straths or mature valleys have in places been formed.

In the Valley and Ridge province the peneplain is generally on either limestone or shale. Its original altitude is probably better preserved on the shale, for on highly soluble rocks the surface may have been lowered by solution since peneplanation, without appreciably destroying the original flatness.

In the Jonesville district the Harrisburg peneplain is clearly recognizable only in the limestone belt along Powell River. This belt is only about half a mile wide where restricted between Wallen Ridge and Sandy Ridge-Tanbark Ridge, but it is more than 2 miles wide at Hickory Flats, in the synclinal embayment at The Cedars, and in the area of gentle dips across the Sandy Ridge anticlinal axis southwest of The Cedars. Within the belt the peneplain is present only on the limestones below the Woodway limestone, and locally even some of these lower limestones rise above the peneplain. Part of the Hurricane Bridge limestone crops out on the lower slopes of Wallen Ridge and in remnant knobs beyond the foot of the ridge. Cedar Knob, which is capped by Woodway limestone, is the highest of these knobs. On the west and north sides of Hickory Flats both the Dot limestone and the Poteet limestone rise to elevations of 1,500 feet or more on the flanks of the dolomite upland.

Except for Powell River and Station Creek, which skirt the edges of the area, there are no streams in Hickory Flats. A large part of the peneplain surface has been pitted by sinkholes, which are most numerous in the Poteet and Rob Camp limestones near the center of the area. Streams flowing toward the flats from Wallen Ridge disappear in a second zone of sinkholes near the top of the Hurricane Bridge limestone. The abundant sinkholes and gentle slope of Hickory Flats make it difficult to approximate a level for the Harrisburg peneplain, but several high flat divides are at 1,460 feet. Five nearby intermeander spurs of Powell River also have summits or benches at this elevation, and three more are at 1,400 feet.

In the limestone embayment of The Cedars the Harrisburg peneplain is best preserved on the Hurricane Bridge limestone along the axis of the syncline. No streams cross The Cedars, and only two streams, Beatty Creek and Sims Creek, flow out of the area. Solution has deeply dissected the erosion surface, but the flat-lying ledges of the Hurricane Bridge limestone make prominent flat divides between the sinkholes at an elevation of about 1,420 feet. The upper part of the Martin Creek limestone is the main locus of sinks, and its belt of outcrop forms a marginal lowland 80–120 feet below the peneplain level.

In the limestone belt southwest of The Cedars, the lowland underlain by limestone older than the Woodway has a generally flat surface, but the elevation is not constant. The lowland rises to about 1,500 feet just across Powell River from The Cedars, where the Poteet limestone crops out along the axis of the Sandy Ridge anticline. From there the surface slopes down to an elevation of 1,300 feet on the flat-topped intermeander spurs of Powell River near the mouth of Hardy Creek. Southwest from Hardy Creek, however, a general level can be identified. Except for one stream, the limestone lowland has no surface drainage southwest of Hardy Creek, and sinkholes obscure the Harrisburg surface; but the divides back from Powell River are at elevations of about 1,340–1,360 feet. The summits of intermeander spurs are almost all at elevations between 1,300 and 1,340 feet. Using the approximate elevations of 1,460 feet, 1,420 feet, and 1,340 feet for the peneplain at Hickory Flats, The Cedars, and southwest of The Cedars, the height of the peneplain above the Powell River at these places is 170 feet, 180 feet, and 150 feet, respectively.

In the narrow limestone belt between Wallen Ridge and Sandy Ridge, the area of outcrop of the limestones below the Woodway is occupied largely by the meanders of Powell River, which swing back and forth from the limestone belt to the dolomite belt. The dolomite on the intermeander spurs has hindered the migration of the meanders and the development of the Harrisburg peneplain. However, half a dozen intermeander spurs of present and abandoned meanders have summits at elevations from 1,380 to 1,460 feet that probably represent isolated remnants of areas reduced to base level during the Harrisburg cycle.

Most of the Sugar Run limestone lowland on the north side of the Jonesville district is occupied by short tributaries of transverse streams rather than by a major through-going subsequent stream. Some of the drainage is by subsurface channels.

A composite longitudinal profile of the part of Sugar Run lowland underlain by limestones older than the Woodway shows no clear evidence of a peneplain surface. From Ben Hur almost to Dry Creek there is a dissected erosion surface about 100 feet above present stream level, but this surface has a gradient the same as that of the present ungraded streams, about 200 feet per mile along the tributary of Cane Creek and about 80 feet per mile along Sugar Run.

From Dry Creek westward, however, a general erosion level is discontinuously recognizable on limestones below the Woodway. Occasional knobs and benches along the sides of the lowlands have elevations of about 1,500–1,560 feet. Long stretches on the divides across the lowland between the head of Martin Creek and the short subsequent tributaries of Hardy Creek and Dry Creek rise from 1,500 to 1,580 feet. These areas on the divides have only subsurface drainage and are pitted with sinkholes, but they have gentle, fairly continuous slopes from the divides towards the streams. Except for Martin Creek, the streams have trenched fairly steep walled valleys against the sinkhole areas and probably receive the subsurface drainage from them.

The stream pattern of the Harrisburg cycle differed appreciably from that of the present cycle only in the limestone areas, where the Harrisburg peneplain is now found. Many of the streams which now disappear into sinkholes upon entering the wide parts of the limestone belt of the Powell River probably flowed on across the belt during the Harrisburg cycle, for streams must have crossed and eroded these areas during the Harrisburg cycle unless solution of the limestones produced the peneplain. The possibility that solution caused the peneplanation is not likely; for although the dolomites of the Chestnut Ridge upland are soluble and have numerous sinkholes, no part of the peneplain was developed on dolomite. It therefore is probable that stream erosion was much more effective than solution in peneplaning the limestone areas.

POST-HARRISBURG DOWN CUTTING

The streams of the Jonesville district resumed down cutting at the end of the short standstill during which the Harrisburg partial peneplain was cut. The intrenchment of Powell River 150–180 feet below the Harrisburg peneplain is the most conspicuous result of this new down cutting.

Major tributaries have kept pace with Powell River. Dry Creek and Hardy Creek are now trenched more than 100 feet below the peneplain level where they flow on the limestone belt of Powell River. In the Sugar Run lowland these creeks and their tributaries are from 100 to 140 feet below the probable Harrisburg erosion surface. In places this difference in elevation is almost all taken up in steep valley walls bordering the streams.

Subsurface streams drain most of the central parts of the dolomite uplands. The areas of subsurface drainage lie 200 feet or more above the Harrisburg level, and the regime of subsurface drainage was probably inherited from the Schooley peneplain. Streams are now extending their network of tributaries by advancing their headwaters into these central areas and capturing the drainage from the sinkholes. Just west of Dry Creek and along Caney Hollow and Kinzer Hollow there are good examples of the encroachment of surface drainage into areas formerly drained underground.

On the other hand, surface drainage has been displaced by subsurface drainage on the Harrisburg peneplain and on the divides in the Sugar Run lowland. These surfaces, which were probably cut and drained by streams, are now crossed by only a few. Subsurface drainage probably gained superiority during the final stages of peneplanation because streams flowing across the peneplain before the uplift had such small gradients that erosion by solution became more rapid than mechanical erosion.

SURFACE DRAINAGE

The streams of the Jonesville district form a trellis pattern over most of the area. In the section on relation of topography to geology, four lithologic units, each of which has a distinctive topographic expression, have been described. The two lowland-making units are separated by the main ridge-forming unit, which includes the Clinch sandstone. Much of the outcrop area of these three units is in regions of moderate to steep homoclinal dips. Along both the north and the south sides of the district these three units form parallel belts consisting of two relatively narrow lowlands separated by a sharp ridge. Between the northern and southern belts are the dolomite uplands formed by the fourth lithologic unit. On the drainage map of the Jonesville district (pl. 6), the stippled pattern represents these dolomite uplands. The unpatterned area between the foot of Powell Mountain and the foot of Cumberland Mountain-Stone Mountain comprises the belts of the other three units.

Within each belt the drainage of the pair of lowlands is connected by streams that cross the narrow separating ridge in short stretches normal to the strike. Except for Cane Creek, the streams of the northern belt also cross the dolomite upland in courses normal to the strike to reach Powell River. The subsequent streams of the lowlands and the transverse courses across the ridges form the basic trellis pattern of the district.

The fourth and thickest lithologic unit, which forms the dolomite uplands, crops out mostly in areas of gentle dips near the anticlinal axes. The dolomites are fairly uniform in their resistance to erosion, so no continuous lowlands have been developed along the strike except on the margins of the limestone belts. The largest streams flow directly across the uplands in entrenched valleys and are part of the general trellis pattern. Most of the streams that rise in the uplands are also part of the trellis system. They flow down the side slopes of the dolomite arches in courses roughly normal to the strike and are tributary to subsequent streams in the adjacent limestone lowlands. However, the branches of these tributary streams form a dendritic pattern on the relatively flat-lying and uniformly resistant dolomites within the uplands. The streams that make this dendritic pattern are lengthening and ramifying by capture of the subsurface drainage from sinkhole areas on the broad divides.

Much of the cleared land of the Jonesville district is on the slopes of Wallen Ridge, Poor Valley Ridge, and the dolomite uplands. Soil erosion on all these slopes is a serious problem, but it is most acute in the dolomite uplands where most of the slopes are cleared and many steep fields have been ploughed. The residual clays of the dolomites of the Knox group and of the Hancock dolomite seem particularly susceptible to gullying, and many fields in the dolomite uplands have been washed out even though not ploughed. Figure 22 shows a gullied pasture on cherty clay soil of the Copper Ridge dolomite, which here lies just above the Wallen Valley fault 1¼ miles south of Hurricane Bridge. On Wallen Ridge and Poor Valley Ridge the upper slopes have been left in timber or brush. The knobs of Reedsville shale, although cleared, are mostly in pasture, and their steep sides are cut by few gullies. Conspicuous soil erosion along these ridges is mainly confined to the lower slopes and the gentle spurs in front of the ridges proper. The belts of Eggleston limestone are more abundantly gullied than are the other formations along the ridges.

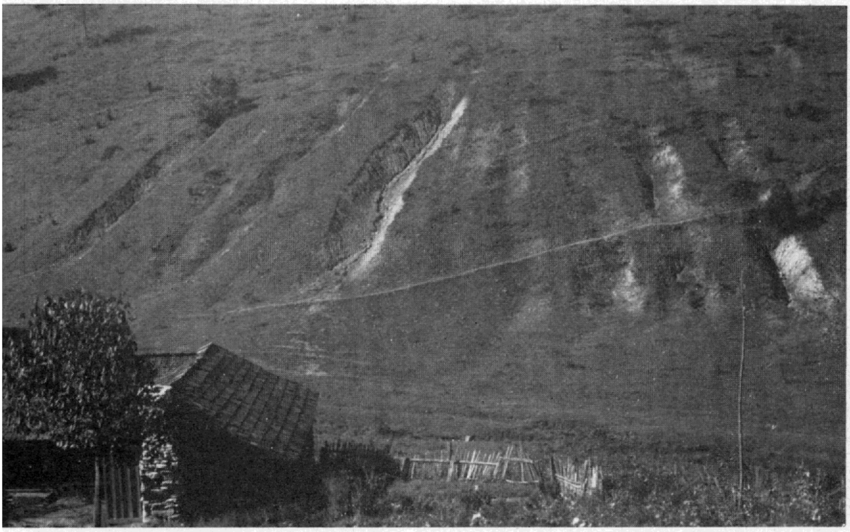

FIGURE 22.—Gullies in the clay soil of the Copper Ridge dolomite on Wallen Ridge, 1¼ miles south of Hurricane Bridge.

Organized and individual attempts to stop the gullying have been made. During the 1930's the Civilian Conservation Corps planted soil-retaining cover and built check dams of stone and timber. Local farmers have blocked some gullies with piles of brush, trash, or rubble, and, unintentionally, with undermined fences. All these efforts probably retard the growth of the gullies, but they have not begun to heal even where a thick stand of locust saplings covers the gullies.

POWELL RIVER

Powell River is one of four parallel rivers that flow southwest through the Valley and Ridge province in southwest Virginia and northeast Tennessee. These rivers, the Powell, the Clinch, the Holston, and the French Broad, carry to the Tennessee River all drainage of the province south of the Holston-New River divide near Tazewell, Va.

The headwaters of Powell River are not in the valley but in the Virginia section of the Appalachian Plateau. The main stem of the stream rises near Norton, Va., and enters the valley through Big Stone Gap. The North Fork of the Powell enters the valley through Pennington Gap and joins the Powell River in the Jonesville district at Woodway. Thence the river follows the limestone and dolomite lowland known as the Powell Valley to its junction with the Clinch River at Norris Reservoir in Tennesee. The Clinch River carries the Powell River drainage from Norris Reservoir to the Tennessee River. By way of the Tennessee and Mississippi Rivers the rain that falls in the Jonesville district eventually reaches the Gulf of Mexico.

The Powell River has a water distance of 36 miles across the Jonesville district. In this distance it falls 125 feet from an elevation of 1,320 feet to 1,195 feet at an average gradient of 3½ feet per mile. The gradient does not vary appreciably from this average whether the river flows on limestone or on dolomite.

INTRENCHED MEANDERS OF POWELL RIVER

The Powell River swings in large intrenched meanders throughout its course on the dolomites and limestones. The high cliffs bordering these meanders are the boldest features of the valley floor. In the Jonesville district the meanders are intrenched only 150–180 feet below the Harrisburg peneplain surface as developed on the limestones; but where the river has cut into the edge of the dolomite uplands, intermeander spurs rise to 300 feet and cut-back cliffs rise to more than 450 feet above the river.

In the narrow limestone lowland between Wallen Ridge and Sandy Ridge-Tanbark Ridge many individual meanders lie across the contact between the limestone and the dolomite. In that area the slip-off slopes on the limestone are generally long, flattened, and low, many of them 100 feet below the elevation of the Harrisburg peneplain. Slip-off slopes on the dolomite are generally steep and rise 100 feet or more above the Harrisburg level.

Of the limestones the most persistent cliff-maker is the 10-foot vaughanite at the top of the Dot limestone. The coarse fragmental beds immediately above this in the base of the Poteet limestone and again in the base of the Martin Creek limestone are also conspicuous, and in areas of gentle dips the outcrop of one or another of these three forms the rim of many cliffs.

The cliff bases are covered with talus or, near the beginning of the meander bend, are rimmed with narrow, low, alluviated terraces. The cliffs at Tyler Bend are an exception. There the cut-back cliff at the end of the meander, one of the sharpest loops in this part of the river, descends to water level and is partly undercut. Elsewhere the Powell River is now attacking the products of weathering of the cliffs, rather than the cliffs themselves, and is falling behind in its work.

The size of the meanders and the width of the meander belt are influenced by the differences in lithology. The original meanders of the Powell River were developed on the Schooley peneplain, which levelled dolomite and limestone alike. The size of those meanders was proportional to the size, gradient, and load of the river in the Schooley cycle. These characteristics of the river changed when the Harrisburg cycle began; and when the Harrisburg peneplain had been cut, the river readjusted the size of its meanders on the peneplain to fit the new conditions. However, the peneplain was cut only on limestones. The dolomite and even some limestone were left as uplands, and where the river flowed on them it remained intrenched. The meanders that were wholly or in part intrenched throughout the Harrisburg cycle could not migrate or be cut off and relocated as easily as those on the limestone peneplain, and many of these Schooley meanders lasted through the Harrisburg cycle. Thus, the meanders intrenched by the Powell River during the present erosion cycle are the product of two earlier cycles. Most meanders on the limestone are of the Harrisburg cycle, but the oversized meanders on the dolomite are of the Schooley cycle.

On the broad stretches of the limestone lowland the meander belt maintains a fairly constant width of about 3,500 feet. The exceptionally narrow and the exceptionally wide parts of the meander belt both lie in the narrow lowland between Wallen Ridge and Sandy Ridge-Tanbark Ridge. From the mouth of Station Creek to Cheek Spring, about 3 miles to the west, the limestone belt is at its narrowest because of steep dips. The meander belt there is less than 2,000 feet wide and the meanders are open rather than recurved. The meanders are confined mostly within the narrow belt of Woodway and older limestones. The adjustment of meander size to fit the narrow limestone belt must have occurred long before Harrisburg peneplanation because the lowland is so narrow and its walls so steep that there is not room enough for Schooley-size or even Harrisburg-size meanders below a level about 200 feet above the Harrisburg peneplain.

From Cheek Spring to near the mouth of Wallen Creek the meander belt is over 4,000 feet wide, and one of the meanders about 6,000 feet wide. The belt of Woodway and older limestones is only about 500–1,000 feet wider here than it is upstream, but the meanders reach beyond it into the dolomite to the north and into limestones as high as Trenton on the south. Not only the dolomites of Sandy Ridge and the higher limestones of Wallen Ridge, but also in places the lowland-making limestones below the Woodway rise above the Harrisburg peneplain level. The meanders are intrenched in all these rocks. Little evidence of erosion to the Harrisburg level can be found except in a discontinuous depression which follows the strike of the base of the Hurricane Bridge limestone. The intrenchment of most of the meanders in dolomite prevented their free migration during the Harrisburg cycle and prevented the river from levelling the intermeander spurs and withdrawing from these oversize meanders.

The contrast between the meanders here and those just to the east is striking. East of Cheek Spring the river adjusted its meanders to fit a very narrow limestone lowland before the end of the Harrisburg cycle. West of Cheek Spring, oversize meanders that overlap both margins of a somewhat wider lowland have been retained in the present cycle. An explanation may lie in the character of the crest of Wallen Ridge, which east of Cheek Spring is capped by Clinch sandstone and is less than half a mile from the lowland, but west of Cheek Spring is capped by shale or dolomite and is almost a mile from the lowland. The abundant talus from the sandstone section of the ridge may have choked the valley at its foot and forced the Powell River there into a narrower meander belt either during the Schooley or the Harrisburg cycle.

The oversized meanders west of Cheek Spring are conspicuously rectangular, and the cliffs that follow their long dimensions are almost parallel. Of 12 of these cliffs between Cheek Spring and Wallen Creek, 8 strike between N. 8° E. and N. 19° E. They intersect the general strike of the rocks at an average angle of 48°. This rectangular pattern of the meanders and parallelism of the long cliffs suggests joint control.

The aerial photograph (fig. 23) shows all the described features of the Powell River in the narrow limestone belt. The Clinch sandstone on the crest of Wallen Ridge is cut out by the Wallen Valley fault about one-third of the way from the right (east) edge of the photo. The meanders to the east of the spring are typical of the undersized meanders, and those to the west are typical of the oversized meanders. The two western meanders display the closest approach to parallelism and rectangularity of any in the district.

Constant ratios of width of meander belt to width of stream have been determined empirically for freely meandering streams and for intrenched streams. According to Bates (Bates, R. E., 1939, pp. 819–880) the ratio is 41 to 1 for intrenched streams 100 feet wide. The average of 38 map measurements of the width of the Powell River in

FIGURE 23.—Aerial photograph of intrenched meanders of Powell River in the narrow lowland between Wallen Ridge and Sandy Ridge-Tanbark Ridge. To the east sandstone caps Wallen Ridge and the meander belt is narrow. To the west dolomite caps the ridge and the meander belt is wide.

the Jonesville district is 82 feet, and the maximum measured width is 130 feet; so Bates' figure for 100-foot streams should apply approximately.

From the mouth of Wallen Creek to the west edge of the district, the Powell River flows almost entirely in the area of peneplaned limestone. The meander-belt ratio for this stretch is 43 to 1. Near Hickory Flats the river skirts the peneplaned area. The average meander-belt ratio is 38 to 1. The ratio is highest for the stretch of river intrenched in the upland between Cheek Spring and Wallen Creek, where the meander belt is 51 times as wide as the river and individual meanders as much as 73 times as wide as the river. Where the river is confined in the narrow lowland east of Cheek Spring the meander-belt ratio is only 24 to 1.

Hence in most of the Jonesville district the width of the meander belt of the Powell River approximates the average for intrenched meandering streams of its size, but meanders partly or completely intrenched in the dolomite upland are oversized probably because they are remnants of meanders derived from the Schooley peneplain. Close to the foot of the sandstone-crested Wallen Ridge, meander growth has been inhibited and the meander belt is undersized.

There are few Powell River meanders that show clear evidence of downstream migration, but two appear on the aerial photograph (fig. 23), which shows wide river terraces bordering the upstream sides of the two easternmost meanders. Behind the terraces are high crescentic cliffs that intersect at a low angle the cliffs now being cut back by the river. The more conspicuous terrace and cliff adjoin the smaller meander. The white field is on the terrace, and the cliff is just behind the field. The river formerly flowed on the terrace at the foot of the cliff but has since withdrawn and moved more than 500 feet downstream.

CUT-OFF MEANDERS OF POWELL RIVER

Within the Jonesville district six abandoned meander channels of the Powell River are preserved. Three are of single meanders, and the other three form a continuous series. They are drawn in heavy dashed lines on the drainage map (pl. 6). In the topography they show as loops of low ground adjacent to the river, usually flat-floored, and from 30 to 100 feet above river level. The flat, alluviated floors of the channels are in crops or in pasture, but brush and timber still stand on many of the old cut-back cliffs. This contrast in vegetative cover causes most of the meanders to be conspicuous on aerial photographs.

BEECH GROVE CUT-OFF

The most recently cut-off and best preserved of the abandoned meanders is at Beech Grove School near the west edge of the Jones-

FIGURE 24.—Aerial photograph of the cut-off meander at Beech Grove School. The roughly triangular area of woodland in the center of the picture is on part of the old intermeander spur. The cut-off took place at the apex of this triangle.

ville district. In figure 24, another aerial photograph, the meander is shown as a loop of light-colored fields almost completely surrounded by dark woods. Steep slopes bound the meander, and the cut-back cliff at the south end is 160 feet high. The floor is from 250 to 400 feet wide, generally flat, and defined on both sides by a sharp break in slope. It stands 33 feet above river level in the undissected north-

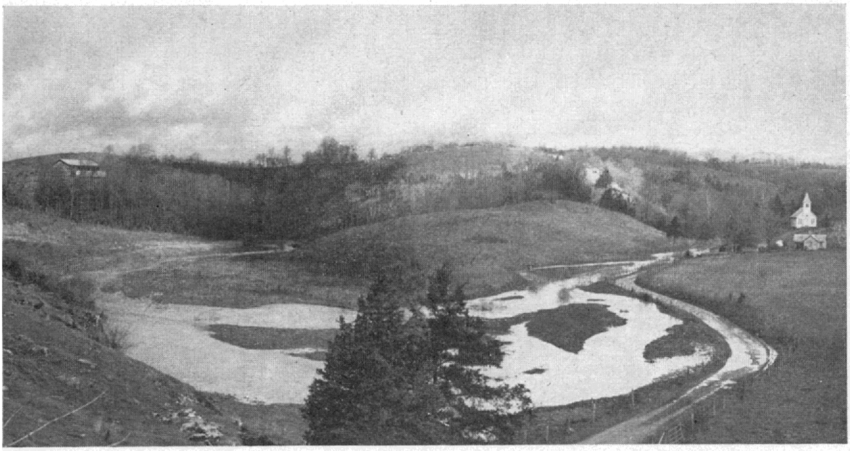

FIGURE 25.—Panorama of the long bend in Dry Creek in flood. The hills behind are of dolomite. At the church, Dry Creek emerges from its incised transverse valley and at the left disappears into its incised valley along the strike.

east end of the loop. No rock crops out within the channel. The surface is covered with yellow sand, some blocky chert gravel, and rare rounded cobbles of Clinch sandstone. A sinkhole in the east limb exposes the underlying residual clay of the local limestone. Sandy terraces occur from 20 to 40 feet above the channel floor on the slip-off slopes on the south and west ends of the intermeander spur, and a narrow talus-covered bench stands about 40 feet above the foot of the cut-back cliff at the end of the meander. Two streams flow into the meander from the foot of Wallen Ridge. One enters the east side and sinks below the floor. A larger stream flows the length of the west side of the meander and is intrenched in the river alluvium.

The intermeander spur ends in a cliff 80 feet high and 400 feet wide at the river's edge. On the north side of the river the continuation of the spur pinches out to a point about 500 feet north of the present channel. Before the cut-off the river impinged against the spur at this point on the downstream side of the meander, and the cut-off was affected by intercision of the spur. Since then the river has migrated both downstream and laterally about 500 feet from the point of cut-off and has left behind it a low terrace at the foot of the old cut-back cliff.

The old course of the river as it left the meander is plain on the aerial photograph. The wooded strip pointing into the meander from the upper side of the photograph is on part of the old intermeander spur and has cut-back cliffs on both sides. The light-colored fields to the left of the woods are on alluvium, and the river formerly flowed along the line between these fields and the woods.

WOODWAY CUT-OFF

Directly across the Powell River from Woodway is a second clearly defined abandoned meander. In the aerial photograph on figure 27 it appears as a sharply recurved loop that is marked by arrows because there is little contrast in the vegetation of the flat-floored channel, the undercut slopes, and the intermeander spur. Sparsely wooded slopes bound the loop on the north and east. The present river channel almost intersects the spur that separates it from the abandoned meander at the point marked by the sharply curved arrow on figure 27. Here the spur is only 150 feet wide and only 17 feet higher than the bottom of the old meander. Another intercision cut-off was imminent at this point, but the intercision farther downstream occurred first.

The meander floor is no longer quite flat. A stream has trenched a course 4–6 feet below the floor of the northwest limb. Shallow sinkholes make the rest of the meander floor undulatory but do not expose bedrock. River alluvium containing rounded sandstone cobbles ranging from 1 to 3 inches in size is at the surface over the flattest parts of the meander channel. Elsewhere local soil and cobbles from slopes

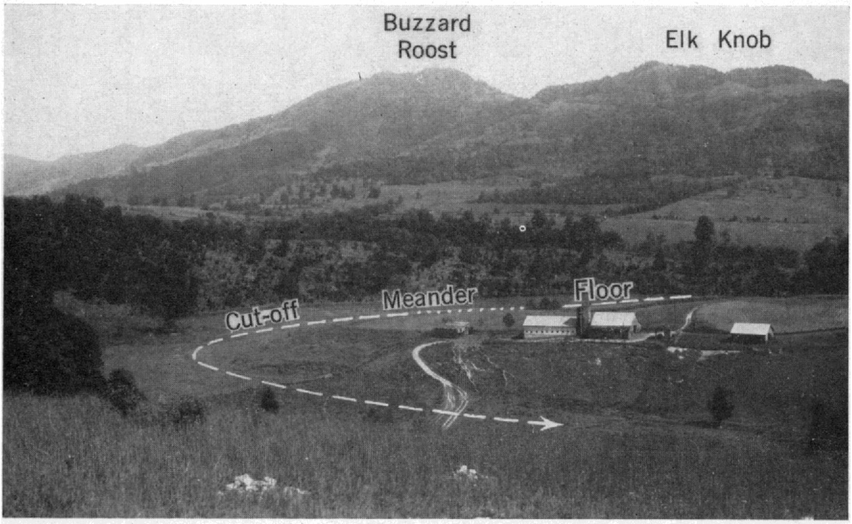

FIGURE 26.—View toward the southeast across the cut-off meander at Woodway. The dashed line shows the former course of the Powell River.

on both sides have crept over the alluvium, and the stream that enters the meander on the northwest has built a fan across it. This fan consists of white-weathering, poorly rounded, unsorted chert cobbles, and it rises gently to about 20 feet above the meander floor. The ground photo (fig. 26) was taken looking southeastward across the end of

FIGURE 27. Aerial view of the cut-off meander at Woodway. Black arrows show the former direction of flow of the river around the abandoned meander.

the meander. In the foreground the channel is hidden by the brow of the hill, but on the left it emerges and curves away between the wooded cut-back cliff and the intermeander spur on which the farm buildings stand. The double-track road in front of these buildings crosses the channel on the chert cobble fan.

At the point of cut-off the meander floor is perched 10 feet above a low terrace that now lies across the neck of the old intermeander spur; and the low terrace is about 25 feet above present river level. Another low terrace across the river from the cut-off meander is bounded by a wooded cliff 120 feet high. Before the cut-off the river swung against this cliff after leaving the meander, but after the cut-off it has migrated laterally away from the cliff.

STATION CREEK CUT-OFF

The third single abandoned meander is poorly preserved and is best outlined on the topographic map. Station Creek enters the Powell River along the southwest limb of this meander, and U. S. No. 58 runs along the north limb just east of Poteet Ferry bridge. A small stream flows southward into Station Creek along the east limb. Station Creek and its tributary have eroded most of the meander course, and Powell River gravel is preserved along the abandoned channel only at its highest point, which is on U. S. No. 58 at an elevation about 60 feet above present river level. However, the high cut-back cliff along the southwest limb remains, and on the opposite bank of the river the curve of the main cliff downstream is continuous with that of the abandoned channel. The latter cliff is separated from the river by a bench 60 feet above river level on which the river formerly flowed from the meander.

FLANARY BRIDGE CUT-OFFS

About 1½ miles southeast of Flanary Bridge is a series of three consecutive abandoned meanders. The easternmost and westernmost of these three lie on the south side of the river. As is shown on the aerial photograph and accompanying sketch in figure 28, both topography and the pattern of the alluvium outline each of these as a complete meander. The central meander, which connects the outer pair, swings to the north side of the river. The present river cuts across this meander, so evidence of the old channel is not continuous.

Eastern meander.—The eastern meander is the largest and the best preserved. Abundant sinkholes caused by solution of the underlying limestone have destroyed the flatness of the old channel bottom, and the bedrock limestones crop out where the sinkholes have exposed the bases of former cut-back cliffs. Alluvium of fine yellow sand and yellow and brown sandstone gravel still covers the meander and remains on the sinkhole floors. Cliffs and steep slopes bound the

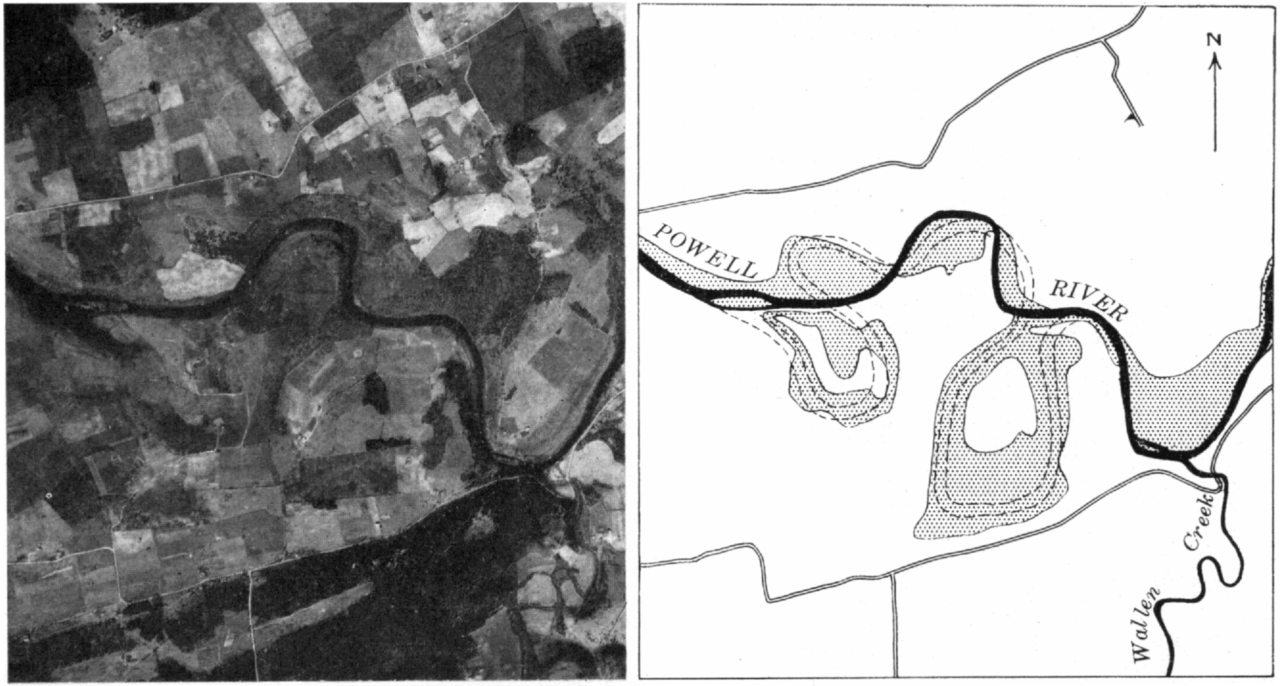

FIGURE 28.—Aerial photograph and sketch map of three abandoned Powell River meanders just east of Flanary Bridge. On the map Powell River and Wallen Creek are shown by solid lines, the probable former channel of Powell River by dashed lines, and undifferentiated alluvium and terraces of Powell River by stippling.

meander on the east and west, but the south end of the meander lies on a line of deep sinkholes, and any cliffs once there have been degraded to gentle slopes.

On the slip-off slopes of the meander are two levels of Powell River terraces, covered, like the channel floor, with sand and sandstone gravel. The lowest of these are from 80 to 90 feet above present river level. The high divides between sinkholes in the channel floor stand more than 70 feet above river level. Therefore, the meander floor was no less than 70 feet and no more than 90 feet above present river level when the meander was abandoned. Across the river from the downstream end of this abandoned meander is an alluviated terrace, bounded on the east by a concave cliff against which the river formerly swung as it left the meander. Since the cut-off the river bend here has been in the opposite direction and the river has withdrawn from the base of the cliff.

Western meander.—Very little remains of the original floor of the western of the three meanders. A stream flowing from a spring in the cliff at the back of the meander has destroyed the floor of the western limb and now flows on its own alluvium. Sinkholes have destroyed part of the floor of the eastern limb, but have left two high divides, both traversed by farm roads. Of these two divides, the southern has cherty clay soil and is mapped as part of the bedrock area. It is about 100 feet above river level. The divide nearer the river is broad, flat, and covered with yellow sand. A small remnant of gravel-covered terrace is at the same level as the divide. This level, about 110 feet above the present river, is taken to be the level of the meander floor. Gravel-covered surfaces 20–40 feet higher than this are found at the top of the intermeander spur.

Central meander.—On the north side of Powell River, opposite the upstream end of the western meander, is a semicircular re-entrant in the cliff. On the aerial photograph of figure 28 only the wooded east end of the re-entrant cliff stands out clearly, but the regularly shaped white field roughly outlines the gently sloping ground at the base of the cliff. The east end of the re-entrant cliff is sharply intersected by another cliff that is now being undercut by a small meander of the Powell River. The west end of the re-entrant cliff is less abruptly truncated by a low straight cliff that extends downstream from the abandoned meanders.

The floor of the re-entrant slopes toward the river across a series of terraces, the highest of which is 70–100 feet above river level. This highest terrace is preserved only on the west side of the re-entrant, but all the way around the arc the base of the re-entrant cliff is about 90–100 feet above river level. At this level the river must still have flowed at the base of the cliff.

The river cut off the eastern and western of the three meanders by intercision approximately where its present course intersects them. The western meander was cut off when the river was about 110 feet above its present level, and the eastern meander when the river was from 70 to 90 feet above its present level. At the latter stage the river also stopped cutting against the cliff of the re-entrant curve. The meander in the re-entrant may have been cut off by intercision at that time, but more likely the changes in course just above and just below the meander caused the river to withdraw gradually from the curve. In either case the area within the curve must already have been reduced to a low level, for if the meander was cut off by intercision some of the intermeander spur should remain, and if the river withdrew gradually from the curve it could have done so only across an already low and flat surface.

POWELL RIVER TERRACES

During the present erosion cycle the Powell River has cut a series of terraces on its banks. Except for the lowest and youngest, the terraces are found only on the slip-off slopes of the river. Lateral cutting in successive stages at successively lower levels of the river has removed part of each proceeding terrace, but, because in each stage the river channel has been farther out on the slip-off slope, remnants of earlier terraces are preserved at the heads of the slopes.

On the slip-off slopes the successive terraces descend steplike to the river. Where steps are numerous and closely spaced they approximate a smooth slope. Where less closely spaced they may still approximate a smooth slope, because creep and slope wash have made the rises more gentle and the flats less level. Only the widest remnants are clearly distinguishable as terraces, and the limits of most of these remnant levels are poorly defined. In mapping all but the youngest terraces, gross limits have been used. In some places long slopes have been mapped as terraces because each includes several fairly flat areas not separated by any mappable break in slope. The slope between two mappable terraces has been included with the upper terrace.

The geologic map (pl. 1) shows three groups of terraces, classified as high, middle, and low, according to their elevation above the Powell River. The low terraces are easily identified in the field. They are consistently about 25 feet above the river and have flat, well-defined surfaces. The bar graph (fig. 29) shows the correlation of the low terraces by elevation above the Powell River. The top of each solid black bar represents the elevation of the terrace top measured by hand level, and the length of each bar has been arbitrarily set at 8 feet, which represents about the maximum relief of the terrace surfaces. Individual elevations of the low terraces vary by only 7 feet from their mean, so the group is distinct and compact.

The high and middle terrace groups were defined after the completion of the mapping, and the terraces were assigned to them then. Neither group is homogeneous, and the boundary between the groups is not consistent. The middle terraces are shown on the graph in figure 29 by diagonally ruled bars, the high terraces by unpatterned bars. Elevations for almost all of these terraces were taken from the contours of the topographic map after the terraces were mapped. Because each terrace as mapped includes slopes as well as level areas, and because, as will be described in the next paragraph, some terraces on the geologic map include two mappable terraces, one terrace may cover a range in elevation of as much as 80 feet. The upper and lower ends of each bar are the highest and lowest elevations of the terrace represented.

Terraces were mapped in the field at more levels than are shown on the geologic map. At many places three terraces were distinguishable above the low terrace. When elevations of all terraces were plotted on a bar graph similar to that of figure 29, it was found that a dividing line between high and middle terraces could be drawn near the tops of most of the second of the three terraces. A few of the second terraces fell into the high terrace group. The rest were classified as middle terraces. On the geologic map, therefore, many of the areas shown as a single terrace include two mappable terraces and the slopes below both of them as well. On the graph in figure 29 the line that separates most high from most middle terraces is 90 feet above Powell River level, but there is overlap in elevation of the two groups between 70 and 90 feet above the river. Three terraces whose limits are within the zone of overlap have been classed as middle terraces because the top elevation of each is within 10 feet of the elevation of a middle terrace on the same spur.

The overlap of about 20 feet between high and middle terrace elevations may be due in part to the fact that elevations were determined by interpolation between contours drawn at 20-foot intervals. The distinction between high and middle terraces seems approximately valid, but accordance of levels within these groups is poor. Both the middle and high groups of terraces are found through an elevation range of more than 50 feet. Neither group can be described as the product of terracing by the Powell River at a single level.

Low terraces, however, do represent a single stage of lateral cutting. They are found along the entire length of the Powell River in the Jonesville district. In the broad limestone lowland they rim every slip-off slope. Where the river flows on dolomite they are less numerous and smaller but may be found in almost every meander. In the Jonesville district 57 hand-level measurements of the terrace elevations were made. The elevations ranged from 21 to 34 feet above the

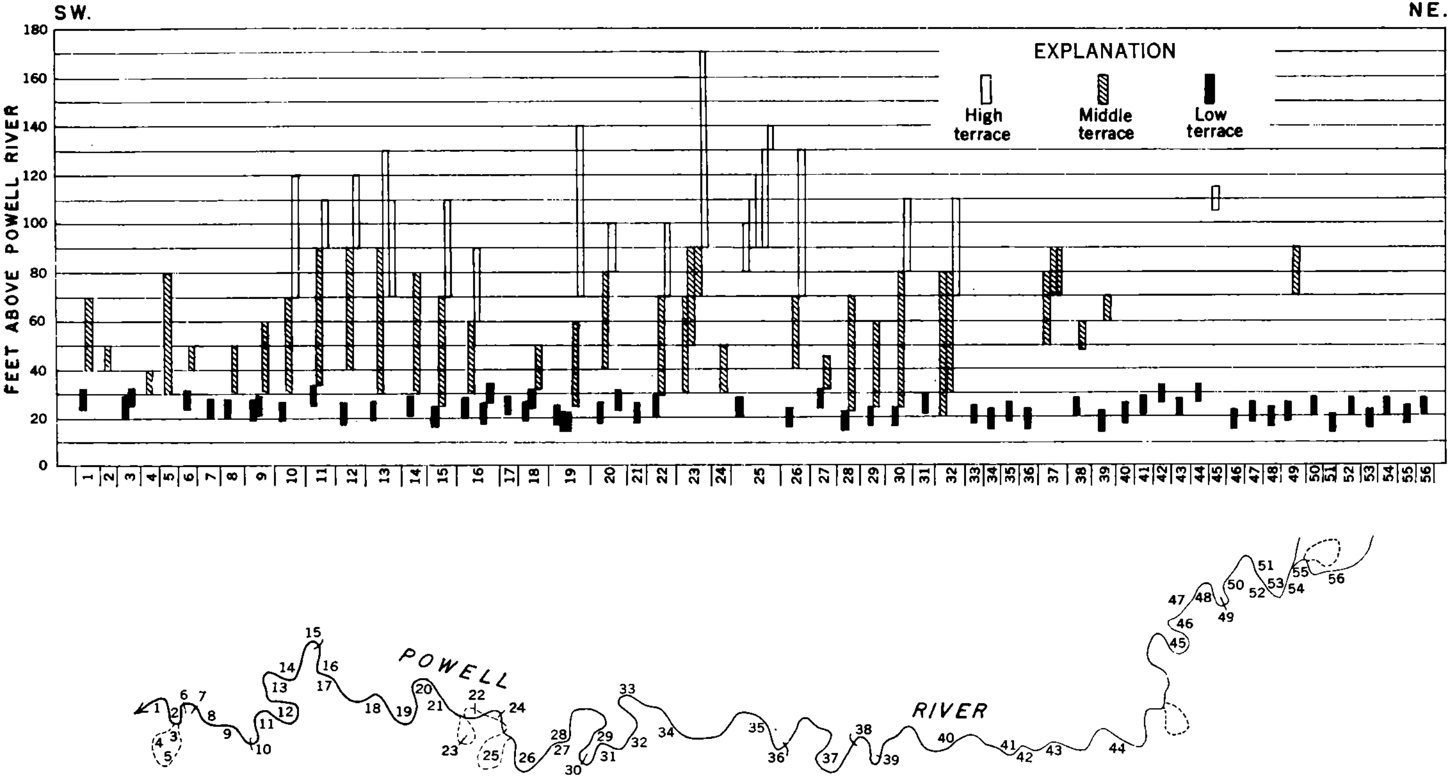

FIGURE 29.—Graph showing elevation of mapped terraces above the Powell River. Length of bar represents range of elevation included in area mapped as terrace. Elevations of top surfaces of low terraces are by hand level. Mapped low terraces for which no hand-level elevations are available have been omitted. All other elevations are from contour maps. Index map of the Powell River shows the locations of terraces by numbers corresponding to those on the graph, and also shows locations of cut-off meanders.

river. Half of the measurements were from 24 to 28 feet above the river, and the average of all the measurements was 27 feet.

At most places the present river bank is cut into the low terraces, but some low terraces are separated from the river by a strip of alluvium at mean water and low water stages of the river. The banks bordering the terraces are steep, and in some places expose bedrock near their bases. The terrace surfaces, however, are covered with gray and brown fine sand and silt and a little gravel. This material also covers most of the cut banks in the terraces. In the second meander west of Flanary bridge, however, a small stream has cut a deep gully through the terrace almost to river level. The walls of this gully show the sand and silt cover to be only a few feet thick and to be underlain by slick yellow residual clay probably derived from the bedrock limestone.

Low terraces are generally from 100 to 250 feet wide. They are found at the edges of slip-off slopes, and they also form narrow alluviated rock benches at the bases of the low cliffs between the slip-off slopes and the point of inflection of the meanders. Many of the wider low terraces are planted in corn, and on aerial photos they appear as white borders along the river.

Within the Jonesville district Wallen Creek has cut three terraces at about the same level as the low terraces of the Powell River. They are from 20 to 30 feet above Wallen Creek, and the one nearest to Powell River stands about 27 feet above river level, the average height of the low terraces of Powell River. The three terraces of Wallen Creek were formed at the same stage of lateral cutting as the low terraces of Powell River. They are broader than most of the low terraces of Powell River, however, and are separated from the creek by alluviated flats about 10 feet above creek level. Only at one place is the creek now cutting into a terrace of Wallen Creek.

The slope from the low terraces up to the middle terraces is usually gentle, but in places a steep bank forms a definite lower margin of the middle terrace. On the air photo in figure 28 such a bank may be seen on the slip-off slope of the meander that Wallen Creek enters. The top of the bank is on a middle terrace that extends to the north end of the small dark field in the southwest part of the meander.

The middle terraces are usually broad and undulatory. Their surfaces and those of the adjoining slopes have a thin cover of yellow and brown sand, well-rounded gravel, and some cobbles. Sinkholes are common but rarely expose the bedrock. However, where the middle terrace is the highest terrace on the slope, residual soil, angular chert chips, and even small slabs of local limestone may creep or wash out over the alluvium. Terrace levels included in the middle terrace group range from 40 to 90 feet or more in elevation above the Powell River.

The high terraces are the least numerous. All but one are in or close to the broad limestone lowland of the western half of the district, where most of them are on the summits of the intermeander spurs. They are from 60 to 170 feet above the river, but most are within a narrower range of elevation. Sixty percent of the areas mapped as high terrace are between 80 and 110 feet above the river, and over 80 percent are between 70 and 120 feet above the river. Sandy soil and rounded pebbles, cobbles, and some boulders of sandstone mark the terraces as river-cut surfaces. The alluvium is a thin cover, and where the high terrace is not at the crest of the intermeander spur the alluvium itself may be covered by a few inches of local soil washed over it from the higher slopes.

On the crest of the intermeander spur opposite the mouth of Wallen Creek, scattered gravel is found about 240 feet above the Powell River. This gravel is 70 feet higher than any of the high terraces and is even higher than the Harrisburg peneplain on nearby limestones. It has been mapped, therefore, as Quaternary gravel rather than as part of the high terrace group.

POSSIBLE CAPTURE OF UPPER DRY CREEK

Dry Creek has an almost continuously transverse course across the Clinch sandstone of Poor Valley Ridge and across the dolomites of the Chestnut Ridge upland. It has trenched deeply into both these resistant rocks. Where the creek emerges from the Chestnut Ridge upland only a belt of peneplaned limestones separates it from the Powell River. If its straight-line course continued across these limestones the creek would have to flow only two more miles to reach the river. Instead it turns back on itself in a sharp bend, re-enters the dolomites, flows 3 miles along the strike, and then enters Hardy Creek three-quarters of a mile from the river. The sharp change in direction of Dry Creek where it emerges from the upland may be seen in plate 1 and figures 25 and 30. The panoramic photograph in figure 25 was taken from a point on the highway that lies at the top of a 40-foot-high undercut bluff.

The course of Dry Creek along the strike below the bend is not in the limestone lowland but in the uppermost dolomites. The creek is intrenched about 200 feet into the lower slopes of Chestnut Ridge and is separated from the limestone lowland by a ridge that stands 100 feet above the lowland. The northeast side of this ridge is a steep undercut slope bordering Dry Creek, but the southeast slope of the ridge is a continuation of the slope of the Chestnut Ridge spurs that are truncated by the creek. The creek must have established its course here on a surface above the present summit of the low ridge, which is 100 feet higher than the level of the Harrisburg peneplain in this region.

FIGURE 30.—Aerial photograph of The Cedars. Timber covers the outcrop of Hurricane Bridge limestone along the synclinal axis. The intrenched valleys to the north and the southeast are in the foothills of the dolomite upland.

The ridge is capped by limestones; so the lower course of Dry Creek was originally on limestone, and the creek has subsequently deepened its valley into the underlying dolomite.

The possible capture of upper Dry Creek by lower Dry Creek is suggested by the sharp change in course strongly resembling an elbow of capture. The most plausible explanation for the advantage enjoyed by the pirate stream is that it maintained a continuously degrading channel at the surface along its subsequent course, whereas the waters of the former Dry Creek were dissipated underground through solution openings in the Ordovician limestones such as exist now in great abundance in The Cedars lowland.

SUBSURFACE DRAINAGE

SINKHOLES

Sinkholes occur in all the carbonate rocks of the Jonesville district. On the drainage map some, but by no means all of them, are outlined by dotted lines. It can be seen that they form the chief drainage features of the broad limestone lowlands and of the interstream areas of the dolomite uplands.

Within the limestone areas sinkholes are not uniformly distributed, but in any given area they tend to be concentrated along the strike of one or two belts of rocks. The younger limestones of the Ordovician, namely the Trenton, Eggleston, Hardy Creek, and Ben Hur limestones, have very few sinkholes in the Jonesville district, although in the Rose Hill district many sinkholes were found in the Trenton limestone near the base of Poor Valley Ridge (Miller and Fuller, in press). The absence of sinkholes in these rocks is due in part to their higher content of insoluble argillaceous material and in part to their position above the lowland on the lower slopes of Poor Valley and Wallen Ridges.

In the Sugar Run lowland most sinkholes are found within the area of outcrop of the Hurricane Bridge limestone. In the Powell River lowland, sinkholes are rare in the narrow part of the lowland from near Wallen Creek to Station Creek because here even the lower limestones are on fairly steep slopes. Where the Powell River lowland is broad, however, sinkholes are abundant, and most of the drainage is by subsurface channels. Sinkholes are found in all the limestone formations that crop out in the area of low dips along the Sandy Ridge anticline and The Cedars syncline near the west edge of the district. They are most numerous, however, in the Hurricane Bridge and Poteet limestones. In the embayment at The Cedars the wooded area is surrounded by a conspicuous zone of sinkholes near the contact between the Hurricane Bridge and the Martin Creek limestones. In figure 30 the edge of the woods follows closely the zone of sinkholes, as does

U. S. No. 58, which runs along the north border of The Cedars. This same zone in the rocks is marked in the narrow part of the Powell River lowland by an almost continuous series of little valleys that cut across the intermeander spurs of the Powell River. However, these valleys in the narrow lowland are without sinkholes. At Hickory Flats, sinkholes are again numerous, and most are in the Hurricane Bridge and Poteet limestones. None of the streams that flow from Wallen Ridge cross the flats, but all sink below the ground in the Hurricane Bridge limestone.

In all the broad limestone lowlands subsurface drainage has such dominance over surface drainage that only eight streams reach the Powell River above ground. In the dolomite uplands there are many perennial streams, both those that rise in the uplands and those that flow across them. Sinkholes are, however, about as numerous in the dolomites as in the limestones and are usually larger and deeper in the dolomites. They drain many of the broad interstream areas, and dry valleys formed by lines of sinkholes simulate perennial stream valleys. One such valley is followed by the road that crosses the Chestnut Ridge upland and joins U. S. No. 58 at Jonesville Camp Ground (pl. 1) near the east end of The Cedars.

Because most of the sinkholes of the dolomites are in the higher and flatter parts of the uplands, few large streams disappear into them. Rather, much of the upland subsurface drainage is tributary to the larger streams that cross the upland. Moreover, the surface streams are extending their drainage basins and tapping the higher areas that are now drained underground.

The deepest sinkhole of the district is in Hancock dolomite in the Sulphur Springs fenster. This sinkhole is about 130 feet deep and has a very steep wall on one side and a sheer cliff at the lower end. The stream that enters the sinkhole from the west flows into a cave at the base of the cliff, and probably emerges at the large spring in the south edge of the town of Sulphur Springs. This sinkhole is an oversized example of one of the two types of sinkholes found in the district, namely a rocky, steep-sided depression, opening into a rock-choked funnel into which the drainage into the sinkhole disappears.

Sinkholes of the other type are shallow and have gentle sides with few or no outcrops. Their bottoms are smooth and are covered with alluvium, through which their drainage soaks. On the air photo of The Cedars (fig. 30) the two upland streams east of Dry Creek empty into a long sinkhole of this type. These streams flood the sinkhole at times of heavy rains and have spread a nearly flat alluvial mantle over the floor of the sinkhole. The long, light-colored field just north of U. S. No. 58 is on the floor of this sinkhole.

UNDERGROUND STREAMS

It is very probable that numerous subsurface streams flow through the Jonesville district. Not only are there many small springs and many small streams that sink beneath the surface, but there are four big springs from which full-sized streams emerge and five large creeks that are swallowed up in sinkholes. Two other major streams disappear, only to reappear downstream in their same well-defined valleys. The Cane Creek tributary in the Sugar Run lowland is interrupted by a stretch of 1,000 feet of subsurface flow, and the Town Branch tributary that rises near Sulphur Springs is interrupted by a 2,000-foot stretch of subsurface flow. For each of these streams the probable underground course is along a nearly straight line from the sink to the spring.

Batie Creek disappears into a sinkhole where it leaves the dolomite upland west of Jonesville, and it flows by an underground channel almost to Natural Bridge. Here it comes to the surface in a spring at the south edge of The Cedars, flows under the Natural Bridge, and continues on the surface to join Town Branch about a quarter of a mile above the Powell River. Above the spring Batie Creek is exposed where two sinkholes have opened into the underground channel. Of these two sinkholes the one farther upstream is about a quarter of a mile from the spring. Cliffs about 30 feet high rim it on the north and west. (The State road makes a right-angle turn around the sinkhole at the top of these cliffs.) At the base of the north cliff the creek wells up. It flows southward about 150 feet on the sinkhole floor, gathering water from a small tributary spring on the way, and then turns west and descends into a small cave whose mouth is almost hidden by rock and timber debris from a small landslide. The creek reappears 1,000 feet downstream in a little sinkhole north of the road. It emerges on the east side from a low cave whose roof slopes inward to water level from a height of 2 feet at the mouth. Seventy-five feet west of this cave the creek disappears again beneath a ledge that lies exactly at water level.

The main spring is in a breached sinkhole only 300 feet southwest of this second sinkhole. There the creek comes out of a low opening at the base of a 25-foot cliff. It is joined by the flow from a smaller spring just to the west and then turns south and escapes under Natural Bridge into the open valley beyond.

All three sinkholes in which Batie Creek is exposed above Natural Bridge lie in the lowland zone of sinkholes at the top of the Martin Creek limestone. They represent progressive stages in the solution and collapse of the roof of the underground channel. The smallest is barely 100 feet long. The largest has been opened at the north end into a long valley and at the south end into the open tunnel spanned by Natural Bridge.

NATURAL BRIDGE OF LEE COUNTY

Lee County's Natural Bridge is diminutive compared with the colossal arch in Rockbridge County that is known to every native of Virginia and to most of the tourists. Lee County's unpublicized bridge is nonetheless a very pretty and interesting feature. It is an uncollapsed remnant of the roof of a former underground channel of Batie Creek. On the north side, where Batie Creek enters, the archway is 11 feet high and 49 feet wide. The creek here is about 30 feet wide and at most 1 foot deep, because fallen boulders from the rim of the bridge clog the channel and form a rapids at the tunnel entrance.

The tunnel under the arch is 92 feet long. It is most constricted at its middle, where the roof is 6 feet above water level and spans about 25 feet. From the south end of the tunnel the creek emerges into a roofless chamber whose solid south wall rises 4 feet above water level. The creek makes a right-angle bend at the base of this wall, flows east along it, and leaves the chamber through an archway cut in the east wall. Within the bend of the creek the rock wall of the room is honeycombed with solution passages 2 feet or more above water level. Above the archway the arch at the downstream end of the chamber rises like a flying buttress against the abutment of the main bridge. About 90 feet from the bend in the room, the creek turns south again into the open valley. A county road that follows The Cedars lowland crosses Batie Creek via the Natural Bridge. Road level is 33 feet above the creek. Here, as at the more famous Natural Bridge, one may drive across the arch without being aware of it, but the screen that blocks the view is nature-made rather than man-made.

SPRINGS

Springs are found in the Jonesville district not only in the areas of soluble carbonate rocks but also on the ridges of shale and sandstone. Most springs on Wallen and Poor Valley Ridges rise not from channels within the bedrock but from stream beds filled with loose talus. Water drains down both front and back slopes of these ridges beneath a cover of soil and boulders of the Clinch sandstone. At the heads of most streams the subsurface water seeps gradually up into the open stream bed over a distance of 100 feet or more, but in some, enough water enters at one point to form a small spring. These springs are few, and many are not perennial.

Almost every spring in the carbonate rocks is produced by the emergence of a subsurface stream from solution passages within the rocks. The water may rise at the bottom of a closed sinkhole and be lost again within the same depression, or it may emerge at the base of cliffs or steep slopes and form the headwaters of a surface stream in the valley below. Because so large a part of the areas of limestone and dolomite has subsurface drainage, springs are numerous and are generally perennial. Many residents of the district draw their household water from these springs rather than from wells.

Four important springs occur within the area of carbonate rocks of the Jonesville district. Crockett Spring and Sulphur Spring are within the Chestnut Ridge upland. Sulphur Spring rises near the head of the small valley just south of Ben Hur. It is down the dip of the Hancock dolomite from the deepest sinkhole of the district and is reported to draw its water from the stream that descends into that sinkhole. Crockett Spring rises from Mascot dolomite in the narrow valley of the Town Branch just inside the Jonesville town limits. It is the most valuable of all the springs, for it supplies the public water system of that town. The water is treated and then pumped to tanks on the high hill north of Jonesville.

Cheek Spring, the largest and also the prettiest spring of the district, is on the north bank of Powell River about 2 miles southeast of Jonesville. It rises from Longview dolomite about 100 yards east of the transverse fault across the Sandy Ridge anticline. The spring itself is at the bottom of a pool of blue water about 50 feet long, 20 feet wide, and said to be 35 feet deep. The pool is walled by rock cliffs and by a concrete dam over which the water spills. The overflow forms a stream about 6 inches deep and 5½ feet wide. Only the neighboring farmers draw water from this spring.

The fourth large spring of the district is unnamed. It emerges from a cave at the foot of a low cliff about 500 feet north of the Powell River and about half a mile northeast of the cut-off meander at Beech Grove School. The cave is 12 feet high and about 25 feet wide. The floor is flat and the walls vertical. Almost flat lying beds of uppermost Martin Creek limestone form the roof. A swift stream 3 to 12 inches deep and 12 feet wide flows along the west wall and out across a low terrace to the river. At the back of the cave the stream is crowded against the wall by a mass of brown and green earthy dripstone 10 feet high and 15 feet wide built out in concentric layers from the floor and the east wall. The source of the spring water is not certain, but less than 1 mile north of the spring, a creek flowing out of Long Hollow in Chestnut Ridge disappears into a sinkhole near White Shoals Church. The sinkhole and the spring are at about the same stratigraphic horizon, and the spring may be at the emergence of the creek from its underground course.

A fifth important spring lies in Poor Valley just outside the mapped area of the Jonesville district. It rises at Hubbard Springs in the valley of Dry Creek. Only one spring is shown on the map, and this was not visited; but, according to report, Hubbard Springs was once a resort to which people came by railroad to drink the water of four springs.

RECENT DEPOSITS

FLOOD PLAINS

Flood-plain deposits of silt, sand, and gravel are mapped as Quaternary alluvium along most of the larger streams of the district. In general, flood plains approaching or exceeding 100 feet in width have been mapped, but narrower flood plains have been disregarded. Mapped flood plains are widest and most continuous in the limestone lowlands, where they occur not only along the main streams but along some of their tributaries as well. In the dolomite upland the valleys of the largest streams also contain flood-plain deposits. The valleys of Town Branch and Hardy Creek are widely alluviated for short stretches. Dry Creek is unique in the district in that it has cut and alluviated a flood plain through the dolomite upland from the Sugar Run lowland to the Powell River lowland. All flood plains of the major tributaries of the Powell River are more than 50 feet below the Harrisburg peneplain level. Most of the flood plains are only a few feet above mean water level of the streams, but near the mouth of Wallen Creek the surface of the flood plain is about 10 feet above the creek. It is flooded, however, not by flood waters coming down the valley of Wallen Creek but by flood waters of the Powell River which back up into the lower part of Wallen Creek valley.

Flood-plain deposits of the Powell River are found below the low terraces on the inside of meanders where the river meanders are on the weak limestones. Besides the usual silt, sand, and gravel, some of these deposits contain coal cobbles as much as 10 inches long. The large cobbles of light coal are probably the hydraulic equivalents of the smaller pebbles of heavier rock moved by the river. Concentrations of coal have been seen at seven places along the river. The origin and nature of these deposits is discussed in the chapter on economic geology.

TALUS AND FANS

Steep slopes and cliffs are found almost continuously along the entrenched course of the Powell River and along the sandstone escarpments of Wallen Ridge and Poor Valley Ridge. As they weather, the rocks of these cliffs break down into fragments that move downhill. The rate of weathering of the cliffs is so rapid and the amount and size of the material broken down is so great that material is produced faster than running water can carry it away. At the bases of the Powell River cliffs, talus of limestone and dolomite accumulates in piles that slope down to water level. The river persistently eats away at the bases of these talus slopes.

The small streams flowing down the slopes of Wallen Ridge and Poor Valley Ridge are far less competent and have less capacity than the Powell River, so on the ridges much less of the talus is carried off.

The talus of the ridges consists mostly of Clinch sandstone. The Hagan shale member, the Reedsville shale, and the siltstones of the Sequatchie weather to fine particles that are carried off by slope wash. Although much of the Clinch sandstone is reduced to sand, gravel, and small cobbles, large angular boulders are the most conspicuous components of the talus. On the upper slopes of both ridges, only the cliffs and summits are generally free of talus cover. Sandstone boulders lie over most of the escarpment slopes down to the knobs of the Reedsville shale and they fill the stream beds at least to the front of these knobs. Although the back slopes of the ridges are less steep than the escarpments, a greater thickness of sandstone is present on them, and abundant talus from it almost everywhere hides the bedrock on and above the slight bench at the Clinch and Clinton contact.

Talus cover is more persistent on Wallen than on Poor Valley Ridge because the Clinch sandstone of Poor Valley Ridge has fewer and thinner massive beds. Near the east end of the district, talus on parts of Wallen Ridge is so abundant and so continuous that it is impossible to map the bedrock geology accurately. The talus there has been mapped instead. One such area is south of Poteet Ferry bridge, where the sheet of talus extends from the foot of the sandstone cliffs down to the Woodway limestone. Other mapped areas of talus are on the upper slopes in the region where Wallen Ridge rises to its maximum height at Buzzard Roost. Many other areas of broad but discontinuous talus cover were not mapped because the nature of the underlying bedrock could be determined from the residual soil or from outcrops exposed in the breaks in the surficial mantle of talus.

Some streams on Wallen Ridge were once powerful enough to carry the smaller fragments of sandstone down toward the limestone lowland. In the upper part of their ravines these streams had steep gradients and received an abundance of material derived as talus from the cliffs at the ridge crest. At the foot of the knobs of Reedsville shale, the streams emerged from their ravines onto gentler limestone slopes and lost most of their gradient and with it their carrying power. They deposited the heavier part of their load on these gentler slopes, filling the stream channels and forcing the streams to shift laterally to new courses. As successive channels were clogged by further deposits, the streams swung back and forth across their own alluvium, spreading sand and gravel in fans from the foot of the steep slopes. Eleven fans have been mapped along the escarpment slope of Wallen Ridge where Clinch sandstone forms the crest. The fan deposits consist mostly of unsorted yellow and brown sand and sandstone gravel and contain some rounded sandstone cobbles and boulders. The deposits are not confined within the present stream valleys but lap over the ends of the interstream spurs well above present stream level. The heads of the fans are within the valleys and are close to the top of the Trenton limestone. One fan is now being built over a low terrace of the Powell River, but most of them end about at the level of the Harrisburg peneplain.

Some streams on Wallen Ridge are now building small unmapped fans, but the large mapped fans have stopped growing and are being cut away. Most of the streams that built the fans still continue in courses across them, but three have been diverted around them and are attacking the margins of the fans.

Three classes of fans have been mapped. Those that are isolated or that merge indistinguishably with their neighbors have been classed as undifferentiated. In some areas fans have been distinguished at two separate levels, and these have been classed as high and low. These distinctions are only relative and are confined to local areas. No correlation in elevation or in age within the high and low groups is implied.

In addition to the fans on Wallen Ridge two others have been mapped in the Jonesville district. One, deposited by the stream flowing into the cut-off meander at Woodway, has been described in the section on the Powell River. The other is a small fan deposited below Poor Valley Ridge in the headwater region of Martin Creek. This fan, the one in the meander at Woodway, and the one overlying the low terrace at the foot of Wallen Ridge are the only fans in the district whose deposition during the present erosion cycle is certain. All of the other 10 fans lie above the Harrisburg peneplain level, and the fact that 7 of the 10 end almost at that level suggests that they were deposited before the peneplain was uplifted and trenched.

STRUCTURE

GENERAL

The Pine Mountain overthrust fault is the dominating structural feature of the Jonesville district. All of the major folds and faults and many of the minor ones are directly related to the development of the Pine Mountain fault plane and the subsequent extensive movements of the Cumberland overthrust block along it. The structural framework of the Cumberland block and the location of the Jonesville district within it have been shown in plate 2 and were described in the introductory chapter. Within the Jonesville district, there are two major structural zones: the sheet of overthrust rocks above the Pine Mountain fault, which includes almost all of the rocks at the surface; and the stationary block beneath the fault. The stationary block is visible in three small fensters and one fair-sized fenster. Elsewhere it is buried beneath the overthrust rocks, and its probable constitution and the attitude of the beds must be interpreted by indirect evidence, supplemented by information from the few wells that have been drilled in the district. The overall structural pattern of the stationary block may be deduced with fair assurance, but the details are known only within the fensters. In the sections that follow, the structural features of the overthrust block are discussed first, then the Pine Mountain fault, and third the structural features of the stationary block.

THE OVERTHRUST BLOCK

FOLDS

POWELL VALLEY ANTICLINE

As used in the Jonesville district, the name Powell Valley anticline is restricted to the fold that enters the western part of the district about 2 miles south of the northwestern corner and dies out in a region of flat dips 1 mile east of the western edge of the Jonesville district. This anticline is the major fold of the Rose Hill district to the west and continues southwestward into Tennessee. The Chestnut Ridge anticline that extends eastward across the northern part of the Jonesville district is a continuation, not of the Powell Valley anticline, but of the Rose Hill flexure.

The Powell Valley anticline has a long southeast limb, along which the dips are flat at the axis and steepen to about 14° midway down. In the vicinity of the Powell River the southeast dips are very gentle because of the influence of The Cedars syncline and the Sandy Ridge anticline, which begin a short distance farther east. In Wallen Ridge the dips steepen to nearly 30° and maintain this attitude to the Wallen Valley fault. Northwest of the axis of the Powell Valley anticline the dips are to the northwest and are gentle until the line of the Rose Hill flexure is reached, along which the northwest dips steepen abruptly. The axis of the Powell Valley anticline is difficult to trace in the Jonesville district because the dips are very gentle and variable in direction near the axis. The stresses that caused it to be the main fold of the Rose Hill district were transmitted farther to the northwest in the Jonesville district and were largely relieved by buckling along the Rose Hill flexure. The anticline dies out as a recognizable feature in a region of poor exposures, where the reversal of dip along the axis ceases and beyond which point all dips south of the line of the Rose Hill flexure-Chestnut Ridge anticline are to the south or southeast.

ROSE HILL FLEXURE

The Rose Hill flexure begins a short distance west of the town of Rose Hill 3 miles west of the Jonesville district. It enters the Jonesville district a mile north of the axis of the Powell Valley anticline, and the two folds converge rapidly. The Powell Valley anticline dies out, however, before a junction of the two folds is effected. The flexure is a very sharply defined structural feature. Along it the north dip of the beds on the north flank of the Powell Valley anticline steepens in a distance of a few score feet from less than 20° to more than 60°. In some places, such as along Hardy Creek, the beds approach verticality just north of the axis of the flexure, and in the Rose Hill district the beds are in places overturned so that they dip steeply to the southeast. Despite the sharpness of this fold, there is nowhere in the Jonesville district any evidence of dislocation along the line of the flexure. The extremely steep dips persist for only a few hundred to a thousand feet north of the line of the flexure and then gradually become more gentle. Thus, although the Rose Hill flexure in a sense represents the upper part of a monoclinal fold, the lower part of the monocline has no well-defined line of flexing. The Copper Ridge and Chepultepec dolomites are the only formations involved in the Rose Hill flexure at the surface. The sharp bending along the axis is not well exposed anywhere in the Jonesville district but may be seen at the Town Spring in the south edge of Rose Hill.

CHESTNUT RIDGE ANTICLINE

Just east of the region where the Powell Valley anticline dies out, the Rose Hill flexure changes from a fold, along which dips are all in the same direction, to an anticlinal fold which is named the Chestnut Ridge anticline. This anticline is traceable from Hardy Creek, near the west edge of the district, eastward for 12 miles to the vicinity of Ben Hur. Beyond this point the anticline is broken by large faults and ceases to be a simple fold. The belt along the crest of the Chestnut Ridge anticline is structurally higher than any other part of the Jonesville district, and all of the fensters lie along or near the crest of the fold.

The Chestnut Ridge anticline is strongly asymmetric. The dips on the long south flank of the fold are relatively low, in few places exceeding 25° and averaging 10°–15°. On the north flank, however, the dips steepen rapidly just north of the axis of the fold to angles of more than 45°, and in places the beds are overturned and dip steeply to the southeast. The steepest dips are near the axis. Farther north, in the Sugar Run lowland and along Poor Valley Ridge, the dips are in most places less than 45°.

The abrupt changes in dip along the axis of the fold and the increase and then decrease of dip northward from the axis are the same phenomena that were observed along the Rose Hill flexure, and they show that the Chestnut Ridge anticline is genetically more closely related to the Rose Hill flexure than it is to the Powell Valley anticline.

The structural relief along the crest of the Chestnut Ridge anticline is nearly 1,800 feet. From a low point near where Dry Creek crosses the axis of the anticline, the crest rises gradually in a westward direction and more steeply in an eastward direction. To the east it culminates in an elongate dome, the highest part of which is in the vicinity of Big Fleenortown fenster.

The structure contours on plate 1 are shown by dashed lines inside the fensters, and the line representing the axis of the fold is interrupted by the fensters because the anticline is confined to the rocks of the overthrust block. Where these have been completely eroded there is no longer a Chestnut Ridge anticline, though there is a much gentler anticline directly beneath in the rocks of the stationary block. (See structure sections of pl. 1.) The northward swing of the axial line of the anticline near the Bethel fenster seems to have been caused by greater northward movement of the surface rocks at this point, because they were gliding on the Bethel fault, an overthrust plane that is here much nearer the surface than the Pine Mountain fault.

THE CEDARS SYNCLINE

The Cedars syncline extends almost the full length of the Jonesville district. It begins near the west edge of the district a short distance east of the mouth of Yellow Creek and dies out just inside the eastern end of the area. It is a gentle broad-bottomed syncline in the western half of the area, is more sharply compressed east of Jonesville, and flattens out again near the eastern end of the district. The highest point along the trough of the syncline is southeast of Ben Hur. From here the bottom of the syncline plunges continuously eastward to the place where the syncline dies out, and it also plunges westward into a shallow basin that is coextensive with the area of The Cedars on the geologic map (pl. 1). From the west edge of this basin to the place where the syncline dies out in a region of flat dips, the trough of the syncline is nearly flat.

The Cedars syncline is flanked on the north by the Chestnut Ridge anticline and on the south by the Sandy Ridge anticline. From the trough of the syncline the beds rise somewhat more steeply northward toward the Chestnut Ridge anticline than they do southward toward the Sandy Ridge anticline. In the eastern part of the district this asymmetry is most marked. For a considerable distance the slope of the south limb of the syncline is less than 200 feet per mile, i. e., less than about 2°. Where the Sandy Ridge anticline is more prominent, however, the beds rise from the trough of The Cedars syncline toward the anticline at angles as much as 20°. Along the north limb of the syncline the dip of the beds is in most places more than 10° and reaches a maximum slightly in excess of 25°.

Because the syncline is in most places quite flat bottomed, the axial plane of the fold is not sharply defined. Minor wrinkles on the bottom of the syncline cause reversals of the direction of dips, which have little significance on a regional scale. As a result, the axial line of the syncline, as shown on plate 1, is only approximately correct and is quite sinuous because it had to be drawn through some areas where the locus of the regional reversal of dip was obscured by local reversals that represent very minor warpings of the trough of the major fold.

The Cedars syncline is a negative or passive structural feature—that is, it does not represent down folding caused by stresses applied within the area of the syncline. Rather it owes its existence as a fold to the arching of the Sandy Ridge anticline on one side and the Chestnut Ridge anticline on the other.

SANDY RIDGE ANTICLINE

The Sandy Ridge anticline lies about a mile south of The Cedars syncline, and its over-all length is nearly the same as that of the syncline. The two folds begin in the same general region near the western edge of the district, but the syncline extends about 3 miles farther east than the anticline in the eastern part of the area. Another anticline, which is offset to the north from the Sandy Ridge anticline, and which is genetically closely related to the Sandy Ridge anticline, continues eastward from the point where the Sandy Ridge anticline dies out.

The structural high along the Sandy Ridge anticline is in the vicinity of Tanbark Ridge in the south-central part of the district. Tanbark Ridge is a westward continuation of Sandy Ridge, from which the anticline is named. From Tanbark Ridge the crest of the anticline plunges continuously, though not uniformly, in both directions along the axis. The closure along the fold is about 500 feet, from the highest point structurally along Tanbark Ridge to the highest point along the trough of The Cedars syncline directly to the north.

The Sandy Ridge anticline is strongly asymmetric. From the axis of the fold the rocks dip southward beneath the Powell River lowland and Wallen Ridge at angles up to 45°; the south limb is finally cut off about 1½ miles south of the axis by the Wallen Valley fault. The north limb of the fold, which has much more gentle dips away from the axis, is the same as the south limb of The Cedars syncline and has been previously described. The Sandy Ridge anticline is cut by the Cheek Spring fault along Tanbark Ridge. The outcrops are poor in this vicinity, but the field evidence, such as it is, seems to indicate that the axis of the fold is not offset by the fault. If this interpretation of the field evidence is correct, it indicates that the movement along the Cheek Spring fault preceded the folding of the Sandy Ridge anticline, because the major displacement along the fault is lateral.

FAULTS

REVERSE FAULTS IN NORTHERN PART OF DISTRICT

Reverse faults are common on the north flank of the Chestnut Ridge anticline and Rose Hill flexure. All of these faults dip more steeply northward than do the beds and are upthrown on the north side. This results in a duplication of beds at the surface. Several of these faults may be seen in the excellent exposures of the Hardy Creek, Eggleston, and Trenton limestones, the Reedsville shale, and the Clinch sandstone along the railroad spur at Hagan. Along the fault planes they have a displacement of a few feet to a few tens of feet.

A much larger fault, also dipping northward but at a lower angle, is exposed in Upper Devonian shale in the cut leading to the mouth of the tunnel at Hagan. A graphic section of this cut was included in the bulletin on the Rose Hill district (Miller and Fuller, in press) because it illustrated a type of fault that was expectable along Poor Valley in the Rose Hill area. It is reproduced here (fig. 21) because it depicts the best exposed and one of the most interesting faults in the Jonesville district. The gray and black shales above the fault are little deformed and lie parallel with the fault plane, which dips 36° to the north. Beneath the fault, gray and black shales are intricately folded and fractured, as shown in the section. The shale above the fault and the overlying black shale near the portal of the tunnel are probably the same units as the gray shale, also overlain by black shale, shown at the right edge of the section. These and other lithologic units on opposite sides of the fault do not match exactly, but this may be because beds that were originally many hundreds of feet apart laterally have been brought into proximity by the faulting.

The relative movement along the fault plane has been upward on the north and downward on the south. This is best explained as an underthrust, formed as the Cumberland overthrust block moved northward down the underlying north-dipping Pine Mountain fault plane. The block sheared along north-dipping faults such as the one illustrated, and the passive northern part of the block rode upward over the forward-moving southern part of the block.

There are probably many reverse faults upthrown on the north along the Sugar Run lowland, but the duplication of beds is too small to be apparent except in perfect exposures such as those at Hagan. Three larger faults of the same type have been mapped along Poor Valley Ridge in the vicinity of Hubbard Springs, one of which was traceable for 1½ miles. In the water gap southeast of Hubbard Springs the Poor Valley Ridge member of the Clinch sandstone is repeated at the surface twice by two of these reverse faults, and farther west along the ridge the Clinch sandstone is offset along the third reverse fault, which trends at a low angle to the strike of the beds.

Other underthrusts, such as the one at Hagan, may be present along Poor Valley, and other reverse faults are probably present in both Poor Valley and Cumberland Mountain-Stone Mountain. One such is known in Cumberland Mountain at Falling Water Gap just west of the Jonesville district. Here the very resistant conglomeratic beds at the base of the Lee formation of Pennsylvanian age have been duplicated at the surface by the faulting, and Cumberland Mountain as a result is dual-crested for a distance of 2¼ miles in this vicinity. The excessive thicknesses of the measured sections of the Clinton shale at Hagan, of the Sequatchie formation and Trenton limestone in the eastern of the two gaps at Hubbard Springs, and of the Trenton limestone along the railroad west of Ben Hur are believed to be due to duplication of beds by unobserved reverse faults.

WADDELL FAULT

The Waddell fault extends from the west edge of the Sulphur Springs fenster in a northeast direction to and beyond the north edge of the district. It is the most obscure major fault of the district, partly because there are very few outcrops of the formations of the Knox group near the fault trace, and partly because from sparse outcrops in a faulted region it is difficult to recognize where a particular small, isolated outcrop of dolomite belongs in the Knox group. Although the location of the Waddell fault as shown on plate 1 may not be everywhere reliable, the existence of the fault is not in doubt. The Copper Ridge dolomite lies along the south side of the fault throughout most of its length, and a continuous southward sequence from the Copper Ridge upward through the younger formations of the Knox Group is demonstrable. If no fault were present between the axis of the anticline and the Ben Hur fault, which lies to the north, there would have to be a similar sequence north of the fault from the Copper Ridge upward to the Mascot dolomite along the north flank of the Chestnut Ridge anticline.

That this sequence does not exist can be demonstrated in favorable places such as along the road that climbs southward into the hills just west of Pennington Gap, or along the next ravine to the east. In both places there is not sufficient room for the necessary thickness of beds to be present between known Mascot dolomite south of the Ben Hur fault and known Copper Ridge dolomite only a short distance up in the hills. Thus a fault is necessary to explain the anomalous space relations. The approximate location of the fault is established by abrupt changes of dip in a few areas with good outcrops and, in the other areas, by the juxtaposition of types of float and of soil which do not belong together. The location of the fault is believed to be most accurate along the central and eastern ends of its extent within the district, and may be quite inaccurate near the Sulphur Springs fenster.

Along the plane of the Waddell fault, the Copper Ridge dolomite and locally the Chepultepec dolomite have been thrust northward over the Mascot dolomite. Thus along most of the fault the Chepultepec, Longview, and Kingsport dolomites have been eliminated at the surface. The stratigraphic thickness of missing beds is thus more than 1,000 feet. The actual movement along the fault plane is probably several times that amount.

The Waddell fault is not known to be present west of the Sulphur Springs fenster, but there is a suggestion that the east-west trending probable fault on opposite sides of the Town Branch fenster is a continuation of the Waddell fault. No convincing evidence of faulting could be found in the region just west of the Sulphur Springs fenster, however, so the probable fault near the Town Branch fenster was not extended into that region. Though it may not be a direct continuation of the Waddell fault, it is nevertheless a fault of nearly identical type in a similar structural location.

The Waddell fault was traced to the northeast beyond the area mapped for this report into a complexly faulted region along the Powell River southeast of the town of Pennington Gap. From the opposite side of this complex, a major fault, named by R. L. Bates (1939, p. 84) the Big Hill fault, emerges and has been traced 12 miles to the northeast. Until the complex near Pennington Gap is worked out in great detail, it is not possible to say whether or not the Waddell fault is a continuation of or closely related to the Big Hill fault.

The plane of the Waddell fault has not been seen anywhere in the district, but indirect evidence indicates that it dips southeastward, as shown in structure sections EE′ and FF′. Integration of this fault into a coordinated picture with the Ben Hur and Pine Mountain faults, which are present in the same region, seems to require that the Waddell fault merge with the Ben Hur fault at depth. The Waddell fault appears to be a subsidiary fault formed when the resistance to forward movement of the overthrust sheet along the Ben Hur fault plane exceeded the resistance to new rupture of the sheet, with the result that a fault of imbricate type was formed. Along this new fault plane, the main mass of the forward-moving sheet moved upward and forward over its frontal part. The fault plane either continued upward to the surface or more probably flattened out along the bedding at a higher stratigraphic level well above the present land surface.

BEN HUR FAULT AND ASSOCIATED FEATURES

The Ben Hur fault crops out along both the north and south sides of the valley of lower Cane Creek. On the south side of this valley, the fault begins at the east end of the Sulphur Springs fenster and extends northeastward to the north edge of the district, but dies out only 1,000 feet beyond. Another fault, only a few hundred feet north of the Ben Hur fault, begins where the Ben Hur fault dies out in the south part of the town of Pennington Gap, and continues northeastward into the complex area mentioned in the description of the Waddell fault. Along the southern trace of the Ben Hur fault in the Jonesville district the fault plane is in places practically flat and elsewhere dips gently to the southeast.

On the north and west sides of the Cane Creek Valley, the northern trace of the Ben Hur fault begins at the north edge of the Sulphur Springs fenster, trends nearly northward directly under the alluvial flat on which the town of Ben Hur is built, and thence swings northeastward to the north edge of the district. The fault is dying out in this direction but was followed for 3,000 feet farther northeast, beyond which it seems to be absent. Along the northern trace of the fault, the dip of the fault plane is gently to the west where the fault trace trends north. Where the trace swings around to the northeast the dip of the fault plane is to the northwest and steepens from a few degrees at the Ben Hur railroad station to a maximum of about 45° near the north edge of the district. Although the northern and southern traces of the Ben Hur fault do not join, two lines of evidence indicate that they are not two independent faults but that they represent a single arched fault plane coming to the surface on opposite sides of the arch.

1. The peninsula-shaped area of Mascot dolomite just north of Sulphur Springs fenster, is in contact along a nearly flat fault plane with the Clinton shale beneath. This area of dolomite seems to have been continuous before erosion with the belt of Mascot dolomite 2,000 feet to the northwest across the valley. The latter belt of Mascot is in contact along a gently dipping fault with Upper Devonian black shale beneath, and the shale is in normal stratigraphic sequence with the Hancock dolomite and the previously mentioned Clinton shale. If the two areas of Mascot dolomite were formerly parts of the same belt, the two underlying faults by which they have been thrust over much younger rocks must be isolated parts of a fault plane that was continuous between the two areas before erosion.

2. Exposures along the northern trace of the Ben Hur fault show that the fault plane dips to the northwest. The belts of Upper Ordovician formations on opposite sides of the fault may be seen to be converging in a northeast direction, and mapping along the continuation of the fault outside the Jonesville district has shown that this convergence continues until the belt of the Sequatchie formation north of the fault is in contact with the belt of Reedsville shale south of the fault. A short distance northeast of this juncture the contact between the Sequatchie formation and the Reedsville shale appears to be normal, and all stratigraphic and structural evidence for the existence of a fault ceases. Hence, because the formation belts on op-

posite sides of the fault may be traced northeastward into an unfaulted region of homoclinal dips, the relative movement necessary to account for the duplication and divergence of the belts is to the northwest for the beds above the fault and to the southeast for the beds below the fault. Although the movement of the beds above the fault is to the northwest down a northwest-dipping fault plane along most of the fault trace, it is apparent that this represents an overthrust fault and not a gravity fault, because the fault plane is nearly flat in the region southwest of Ben Hur where the stratigraphic displacement is greatest. The existence on opposite sides of the valley of Cane Creek of overthrust faults that dip in opposite directions but along both of which the beds above the fault have moved relatively to the northwest, and the absence of any other significant faults in the area between, strongly support the view that the two fault occurrences are parts of the same arched fault plane. No other mechanism to account for the downward thrusting along the northwest trace of the fault appears feasible.

BEN HUR SLICE

The Pine Mountain fault that encloses the Sulphur Springs fenster may be seen to underlie the Ben Hur fault in the hills east of Sulphur Springs where both faults are nearly flat. The two must have merged a few hundred feet to the south, however, because the klippen of Copper Ridge dolomite inside the Sulphur Springs fenster belong to the sequence of dolomitic rocks overlying the Ben Hur fault and they rest directly on Clinton shale that passes beneath the Pine Mountain fault.

Northward from Sulphur Springs, the Ben Hur fault rises above the surface, whereas the Pine Mountain fault descends beneath the surface. Farther north, however, the Ben Hur fault plane plunges downward beneath the surface at a considerably steeper angle than the Pine Mountain fault is known to do in either the Jonesville or Rose Hill district. Hence it seems certain that the Ben Hur fault merges with the Pine Mountain fault beneath Stone Mountain, as shown in structure sections DD′ and EE′ of plate 1. The slice of rocks lying between the Ben Hur fault and the Pine Mountain fault is called the Ben Hur slice. It is enclosed by the faults at the top and bottom and on three sides but is open to the northeast, where the Ben Hur fault dies out just beyond the north edge of the district. The slice is shaped like a half cylinder tapering at one end. It is approximately 2½ miles long from southwest to northeast, about 1¼ miles wide, and is probably about 3,000 feet thick at its thickest point. It represents a large mass of rock, formerly a part of the overriding Cumberland block that has nearly, but not completely, broken loose from the block. All formations from the Mascot dolomite to the Upper Devonian shale are included in the slice.

As the Cumberland block continued to move forward after the formation of the Ben Hur fault plane, the slice was held back by friction along the Pine Mountain fault and was overridden by the Cumberland block. Because it remained attached at the northeast end, however, the relative displacement was pivotal, increasing to about a mile at the southwest end. Fault slices that have broken loose from the base of the Cumberland Block and been left behind are known elsewhere along Powell Valley, but the Ben Hur slice differs from all previously described ones in having remained partially attached to the overriding block.

BEN HUR FENSTER

The Ben Hur fault plane is locally buckled by folding subsequent to the movement along the fault. Just southwest of Pennington Gap and south of the main fault trace, the fault plane has been folded upward and the overlying rocks have been eroded along a steep-walled ravine coming down from the dolomite hills. The very minute fenster thus formed is named the Ben Hur fenster. Along the road that follows the ravine, the rocks of the Ben Hur slice crop out for a distance of 340 feet, and the Ben Hur fault is well exposed at both ends of this interval. At the south end, the fault plane dips 37° to the southeast. Along it, Mascot dolomite has been thrust upward over chert-bearing limestone of the upper part of the Poteet limestone. From this point, the fault continues up the hillside above the road, flattens out, and then cuts sharply downward to the road, where it is again exposed. In this northern exposure of the fault, shown in the photograph in figure 32, the fault dips 25° to the north. Mascot dolomite here has moved down the fault plane over Rob Camp limestone. Between the two exposures of the fault along the road, the dove-colored cryptocrystalline limestones of the Rob Camp are warped and folded, but in general dip gently to the north, and the Poteet limestone at the south tip of the fenster normally underlies the Rob Camp limestone. The Rob Camp limestone here contains a zone of chert nodules, as it does everywhere in the eastern part of the Jonesville district. Directly across the ravine from the road, Mascot dolomite above the fault has numerous outcrops, but the limestones that underlie the fault are concealed.

The relations in the vicinity of the Ben Hur fenster are shown in section GG′ of plate 1. Undoubtedly the belts of Poteet and Rob Camp limestones are continuous beneath the overthrust cover with the belts of the same formations 1,000 feet to the west.

BETHEL FAULT AND ASSOCIATED FEATURES

The Bethel fault is of the same general type as the Ben Hur fault. It is an arched overthrust fault at a higher level than the Pine Mountain fault. It is believed to merge downward with the Pine Mountain fault in all directions from the crest of the arch. The slice of rocks lying between the two faults and entirely enclosed by them is named the Bethel slice. Southeast of Hubbard Springs, the overthrust rocks above the Bethel fault have been eroded along the Sugar Run lowland, and the Bethel fault is at the surface. It encloses an irregularly oval area, inside which the rocks of the Bethel slice crop out.

Exposed rocks of the slice include all formations from the Hurricane Bridge limestone to the Clinch sandstone, and these are in contact along the Bethel fault with all formations from the Longview dolomite to the Hurricane Bridge limestone. Thus older beds have been thrust over younger beds. The fenster outlined by the trace of the Bethel fault is named the Bethel fenster.

The fault relations are clear everywhere around the rim of the Bethel fenster because of the great stratigraphic discrepancy on opposite sides of the fault. The fault is well exposed along and just north of the road and east of Trading Creek. Figure 31 is a sketch looking northward to the Bethel fault. The beds in the roadcut and in the fields just above the road are within the fenster and are dipping steeply and striking almost directly away from the observer. The heavy ledges in the middle distance are just above the Bethel fault and are dipping away from the observer and striking crosswise of the sketch. There is a structural discordance of almost 90° along the fault.

The sheet of overthrust rocks above the Bethel fault has for the most part been little deformed, although the formation belts bulge northward in the immediate vicinity of the fenster. In places, however, the overthrust rocks close above the fault are overturned and dip steeply to the southeast owing to drag along the fault plane. Inside the fenster the formation belts trend at about 45° to the belts outside the fenster. They are considerably folded and faulted. East of the alluviated valley of Trading Creek, an isolated area of Reedsville shale overlies Ben Hur limestone along a low-angle fault. Apparently this represents a thin slice of Reedsville that has broken loose from the base of the overriding block as it moved forward along the Bethel fault and has been left behind on top of the much larger and thicker Bethel slice. Other minor faults are present and have been mapped, and still others that were not seen are probably also present. At and near the surface the structure of the Bethel slice is probably approximately as shown in section BB′ of plate 1; but at depth there are almost certainly unknown folds and faults which cause the internal structure of the slice to be more complicated than appears in the section.

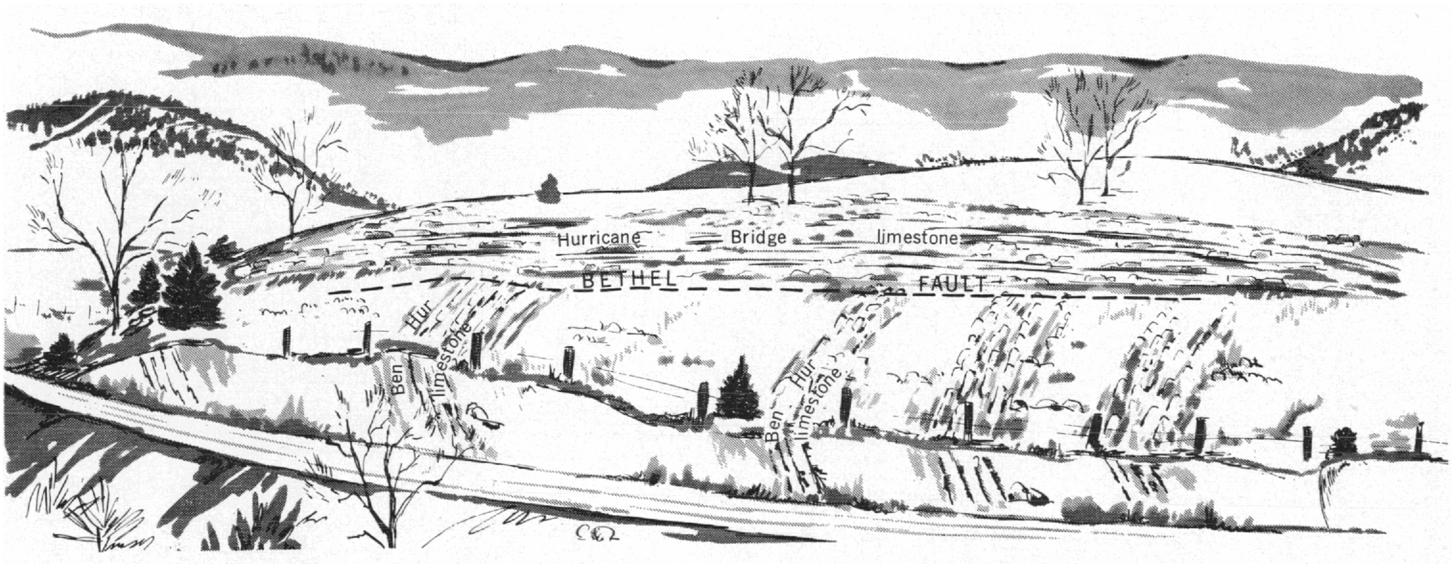

FIGURE 31.—Sketch looking northward to the Bethel fault just east of Trading Creek. Beds of Hurricane Bridge limestone above the fault in the middle distance overlie beds of Ben Hur limestone striking directly away from the observer in the roadcut and on the lower slopes of the field.

The junction of the Bethel fault with the Pine Mountain fault is nowhere exposed. The location of this junction shown in the structure section BB′ is only a reasoned guess. Thus the overall dimensions of the Bethel slice are also unknown, but the slice is unquestionably considerably larger than the part of it exposed in the Bethel fenster. Question may be raised as to whether the fault rimming the Bethel fenster might be the Pine Mountain overthrust and therefore the beds exposed within the fenster might belong to the stationary block. This question can be answered in the negative with considerable assurance for two reasons: 1. The displacement along the Pine Mountain fault in the Sulphur Springs and Fleenortown fensters east of the Bethel fenster is at least 2 miles, and at the Anthony Ely well west of the Bethel fenster it is at least 1½ miles. In both places it is probably several times this minimum amount. Along the Bethel fault, however, the displacement is less than a quarter of a mile at the east end of the Bethel fenster and less than a mile at the west end. These figures cannot be reconciled with an assumption that the fault rimming the Bethel fenster is the same fault as the one at the other localities, because the belts of overthrust formations would have to bulge southward in the vicinity of the Bethel fenster to account for the lesser displacement there; whereas, actually, they bulge northward. 2. The Pine Mountain fault has been seen in many fensters in the Jonesville

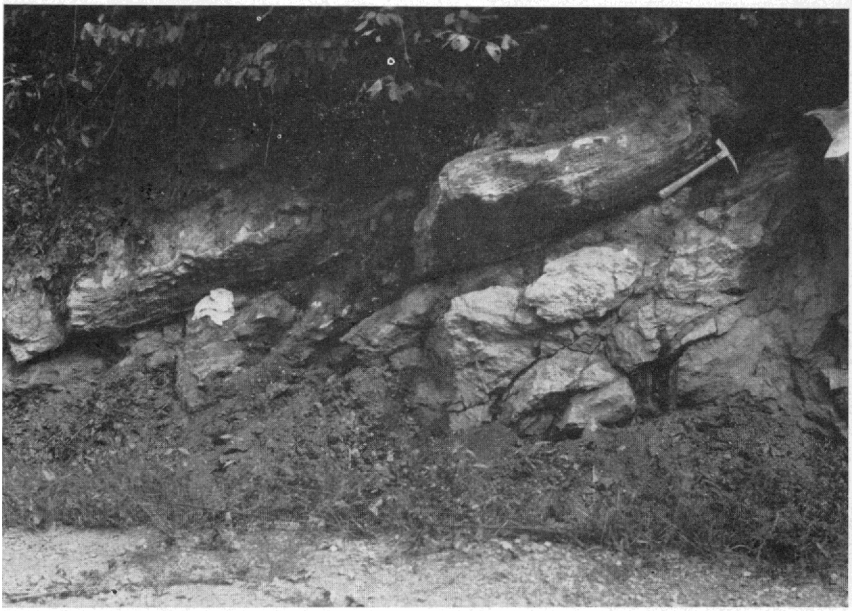

FIGURE 32. Ben Hur fault along road at north end of Ben Hur fenster. Fault is marked by hammer and handkerchief. Mascot dolomite above has moved from right to left (south to north) over Rob Camp limestone beneath the fault.

and Rose Hill districts and has been penetrated by quite a few wells. Nowhere has it been found to cut downward in a northward direction from younger to older beds of the stationary block. Wherever it rises to the top of the Clinton shale or the Hancock dolomite of the stationary block, it levels off there and stays at or near that horizon beneath the crest and north flanks of the Chestnut Ridge and Powell Valley anticlines. The fault plane is known to be at or above the top of the Clinton in the Fleenortown and other fensters of the Jonesville district and also in the Anthony Ely well, which lie along the crest of the Chestnut Ridge anticline. One of the most characteristic features of the Pine Mountain fault in the Jonesville and Rose Hill districts is its consistent behavior over broad areas. There is thus strong reason to believe that it has not cut downward into the stationary block to the Hurricane Bridge limestone beneath the north flank of the Chestnut Ridge anticline, as would be required if the fault rimming the Bethel fenster were the Pine Mountain fault. Any structural hypothesis devised to make it so would require an unusual and erratic location and attitude of the Pine Mountain fault at variance with all previous experience with that fault.

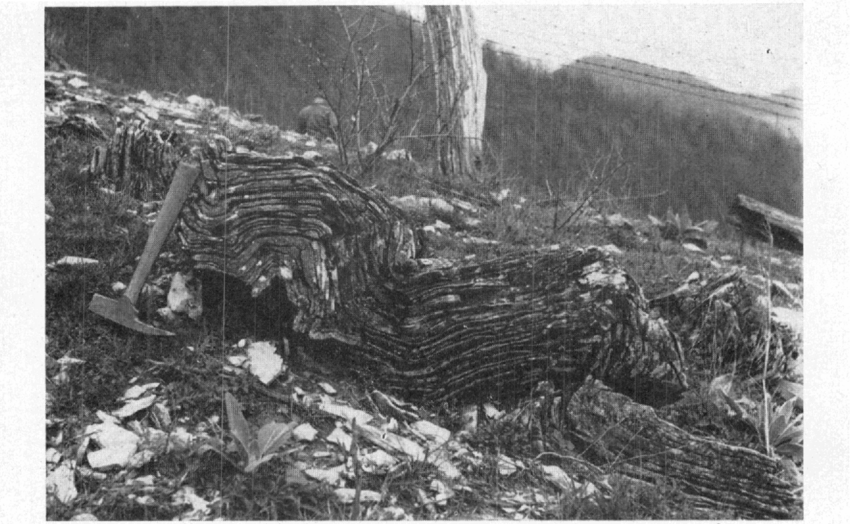

FIGURE 33.- Crumpled limestone in the Hancock dolomite directly below the Wallen Valley fault on a spur of Powell Mountain 800 feet east of the east edge of the Jonesville district.

CHEEK SPRING FAULT

The Cheek Spring fault is unique in the Jonesville district. It is the only large fault whose trend is transverse to the regional structure. The fault was traced for about 1½ miles in a northwest direction from the middle slopes of Wallen Ridge almost to U. S. No. 58. On the south side of the Powell River the fault is clear because of the offset of the relatively thin and very distinctive Middle Ordovician formations along the fault line. The offset is about 700 feet to the northwest for the rocks on the southwest side of the fault. In a southeast direction, the fault disappears beneath a large alluvial fan. No displacement of the rock belts was observed southeast of the fan, but the bend in the crest of Wallen Ridge directly in line with the mapped fault is due to warping of the belt of Clinch sandstone by the same stresses that produced the faulting. Just west of Cheek Spring the fault crosses the Powell River in a northwest direction and enters the area of thick dolomitic formations of the Knox group. In this region the fault is extremely difficult to recognize and locate because of the scarcity of outcrops and the absence of key horizons in the formations of the Knox group. It is believed to be present as far as the north slopes of Tanbark Ridge and it may continue farther.

Despite moderately good exposures along the fault south of the Powell River, the nature of the fault movements is obscure. In the steep bluff overlooking the Powell River, the fault plane appears to dip to the south at an angle that may be as low as 45°. In the fields at the top of the bluff, however, contortion of beds near the fault suggests more strongly a tear fault along a steeply inclined fault plane. In the area north of the Powell River no evidence on the attitude of the fault plane or direction of movement along it was obtained. All available evidence seems to indicate that the Cheek Spring fault dips to the south at high angles and that the dominant direction of movement was in the horizontal direction to the northwest for beds on the southwest side of the fault but that there was also an upward component along the inclined fault plane whereby the beds southwest of the fault overrode those northeast of the fault.

The Cheek Spring fault appears to be genetically allied to the Wallen Valley fault. The stresses producing the movement seem to have been transmitted downward from the moving fault block above the Wallen Valley fault. This block rode forward farther and with more ease in the area west of the Cheek Spring fault, where the resistant barrier of the Clinch sandstone is absent, than in the area south and east of the fault where it is present. In pushing forward on the southwest more than on the northeast, it appears to have transmitted this same shearing strain into the block that lies beneath the fault and which consequently broke along the transverse Cheek Spring fault.

WALLEN VALLEY FAULT AND ASSOCIATED SLICES AND KLIPPEN

The Wallen Valley fault borders the Jonesville district on the southeast and extends the full length of the district. It is one of the major faults of the southern Appalachians, extending from a point a few miles east of the Jonesville district for 100 miles southwestward, where it joins the Hunter Valley fault, the next major overthrust to the southeast of it. The trace of the Wallen Valley fault is remarkably rectilinear throughout most of the Jonesville district, but just east of the district it swings around in a great loop and reappears beneath the Butt of Powell Mountain at the northeast corner of the district. Thence it passes northward off the map; but just beyond, it turns east again and follows along the north slope of Powell Mountain. Campbell (1894) shows the Wallen Valley fault dying out completely 3 miles east of the Butt of Powell Mountain, but Butts (1933) and R. L. Bates (1939, pl. 6) continue the fault for nearly 9 miles more, along Lovelady Valley into Wise County, Va. The writers favor Campbell's mapping of this region because the formations are apparently in stratigraphic order along Lovelady Valley. Butts' and Bates' mapping shows the elimination of a few hundred feet of beds in several places along the valley, but R. L. Bates (personal communication) states that the exposures along the valley are so few that the evidence for the fault is inconclusive. If any fault exists along Lovelady Valley it is probably a minor and local one rather than the Wallen Valley fault, because the displacement, if any, is relatively small along Lovelady Valley and because there the fault as mapped has younger beds on the southeast against older beds on the northwest, whereas the reverse situation exists along the entire 100 miles of the Wallen Valley fault. Thus the unusual complexities along the Wallen Valley fault at the east end of the Jonesville district are believed to be associated with the dying out of the fault.

These complexities are due to a marked flattening of the dip of the fault plane. Beneath the Butt of Powell Mountain the fault is practically flat, and a secondary thrust plane, also nearly flat, has developed about 200 feet below the Wallen Valley fault. These two fault planes join on the west side of the Butt of Powell Mountain and probably join also east of the edge of the district. Between the two is a folded sheet of Hancock dolomite, which lies on flat, relatively undeformed Hancock dolomite below and is overlain by arched and gently folded layers of the Sequatchie formation and Clinch sandstone. Folded beds of laminated limestone in the Hancock dolomite just below the upper or main branch of the Wallen Valley fault are shown in figure 33. The photograph was taken on a spur of Powell Mountain at a point 2,000 feet east of the high knob of Powell Mountain and 800 feet east of the east edge of the Jonesville district.

On Sheepshank Knob half a mile west of the Butt of Powell Mountain, klippen of the two branches of the Wallen Valley fault have been isolated from the main fault sheets by erosion. Along the lower branch, folded Hancock dolomite lies on relatively undeformed Hancock dolomite as it does in Powell Mountain, but along the upper or main branch of the Wallen Valley fault Clinton shale lies on the Hancock. Thus in the interval between Powell Mountain and Sheepshank Knob, the Sequatchie formation and Clinch sandstone have dipped westward and died out downward against the Wallen Valley fault, and the next-younger Clinton shale is at the base of the main overthrust sheet.

Along the Wallen Valley fault where it forms the southeast border of the Jonesville district, the relations are in most places clear and simple. Formations of Cambrian age on the southeast side of the fault and dipping to the southeast have been thrust upward along a southeast-dipping fault plane over formations of Late Ordovician or Silurian age. The beds directly overlying the fault are either in the Maynardville limestone or in the lower part of the Copper Ridge dolomite and are approximately parallel with the fault plane. The beds below the fault are Clinton shale in the eastern and extreme western parts of the district. For the distance of 9 miles between the two places of truncation of the Silurian formations, the Cambrian beds above the fault have been thrust upon the Sequatchie formation of Late Ordovician age or the next-older Reedsville shale.

In the south-central part of the Jonesville district the Wallen Valley fault splits into two branches, which diverge gradually in a westward direction. The northern of the two branches dies out 6 miles west of the point of junction. Between the two faults is a narrow wedge that is composed, throughout most of its length, of formations older than the rocks to the north and younger than the rocks to the south. The oldest formation in the fault wedge is the Dot limestone, and the youngest is the Sequatchie formation. Where the wedge is narrowest the formation belts trend almost parallel with the regional structure and dip consistently to the southeast; but in the wider part of the belt the beds are complexly folded and in places faulted. The fault wedge represents a sliver that has broken loose from the block north of the fault and has slid upward along the northern branch of the fault. It is obvious from an examination of the geologic map (pl. 1) that the upward movement of the fault wedge has been pivotal, increasing to several thousand feet at the east.

Several relatively small fault slices occur along the Wallen Valley fault. Of these, the thickest one is well exposed where U. S. No. 58 crosses the fault. It consists of an area of platy and massive limestone belonging in the lower part of the Middle Ordovician and probably in the Hurricane Bridge limestone, and it lies in fault contact with the Clinton shale above and the Copper Ridge dolomite below. A few ledges of the limestone crop out in the roadcut along the highway at this point, but they may be seen better in the steep slope below the highway and in the small quarry west of the highway. A much thinner slice of Rob Camp and Martin Creek limestones lies along the Wallen Valley fault south of Slagle Gap; and two minute slices of Hurricane Bridge limestone lie along the fault, one just east of Wallen Creek and the other 1½ miles farther west. All four of these slices have been torn loose at depth from the block north of the fault and have been dragged upward along the fault plane to their present positions. A fault slice of the Low Hollow limestone member of the Maynardville limestone, and a faulted area of Reedsville shale along the Wallen Valley fault west of Wallen Creek are minor complications associated with the main thrusting.

FIGURE 34.—Copper Ridge dolomite thrust upon Woodway limestone along the Wallen Valley fault, marked by the hammer head and handkerchief. Taken on the east side of a deep ravine south of Hurricane Chapel.

The rocks adjacent to the Wallen Valley fault have few exposures along the lower south slopes of the high parts of Wallen Ridge, and the fault was mapped largely on the evidence from float. In the interval where the talus-making Silurian beds are absent and the fault lies north of the low irregular crest of Wallen Ridge, exposures are better and two places were found where the fault could be seen. One of these localities is south of Hurricane Bridge, where Copper Ridge dolomite is thrust over Woodway limestone lying in the sliver between the two branches of the fault, as shown in the photograph in figure 34.

The hammer head and handkerchief lie along the fault. In this vicinity the fault plane dips about 35° to the southeast. The second exposure of the fault is along the road just north of Fitts Gap, where Copper Ridge dolomite overlies limestone in the Reedsville shale along the fault plane, which here dips 41° to the southeast. Although no other places were found in the Jonesville district where the inclination of the fault plane could be measured accurately, in many other places it could be approximated. In all places, the dip to the southeast appeared to be 30° plus or minus 10°.

PINE MOUNTAIN OVERTHRUST

The Pine Mountain overthrust is the largest fault in or near the Jonesville district, in length, in breadth of belt affected, in displacement, and in total effect on the regional pattern of the geology. The regional relations of the fault have been described in the introductory chapter. In the Jonesville district the fault is believed to be everywhere present beneath the surface except in the four fensters that lie along the axis of the Chestnut Ridge anticline. In these the fault comes to the surface, its trace forms the rims of the fensters, and rocks beneath the overthrust are exposed inside the fensters.

The exact location and geologic relations of the Pine Mountain overthrust in the Jonesville district are known only in the fensters and in two oil wells that penetrated the fault at depth. The fensters and wells provided data which, though scanty, are adequate to show that the Pine Mountain fault has the same general characteristics in the Jonesville district as in the adjacent Rose Hill district, where fensters and wells that supply information on the fault are more abundant.

The details of the geology in the fensters of the Jonesville district are described in the ensuing sections, and the details of the geology in the wells that penetrated the overthrust are shown in plate 7 and described briefly in the sections on the wells. The generalizations about the Pine Mountain fault that follow are based on information from the fensters and wells, combined with a considerable amount of interpretation.

The Maynardville limestone and overlying dolomitic formations of the Knox group are massive-bedded and competent. Before faulting, the Maynardville limestone overlay the slick, fissile, very incompetent Conasauga shale. The Pine Mountain overthrust, as well as the Wallen Valley fault and other major thrust faults, has tended to develop at or very near the contact between this thick competent unit of dolomite and limestone and the underlying thick incompetent shale unit. After formation of the fault plane, slices and slivers of the competent beds have in places been torn from the base of the overriding competent block as it slid forward. Where there has been little or no slivering, the Low Hollow limestone member of the Maynardville now directly overlies the fault. Elsewhere the Low Hollow member has broken loose and been left behind, and the Chances Branch dolomite member of the Maynardville lies directly above the fault. In still other places all of the Maynardville limestone has been slivered off and Copper Ridge dolomite overlies the fault. Because the Pine Mountain overthrust has been seen to behave consistently in this manner in many places in the Jonesville and Rose Hill districts, it seems probable that it does so beneath all of the Jonesville district south of the axis of the Chestnut Ridge anticline, that is, beneath about four-fifths of the total area of the Jonesville district. The structure sections of plate 1 have been drawn on this hypothesis. If the hypothesis is correct, the approximate depth to the Pine Mountain fault can be determined by calculating the stratigraphic thickness between the beds outcropping at the surface and those at a horizon about 100 feet above the base of the Maynardville limestone—thus allowing for some slivering off of the lowest part of the Maynardville—and multiplying this figure by a factor determined by the average dip of the beds at the surface. This method has been successfully applied in predicting the depth to the fault at oil-well sites in advance of drilling, and in most places the error has proved to be less than 100 feet. On the basis of this method, the Pine Mountain fault is believed to be nearest the surface beneath the Chestnut Ridge and Sandy Ridge anticlines, to lie at greater depth beneath The Cedars syncline, which is intermediate, and to plunge steeply to great depths beneath the southern part of the Jonesville district.

Along the axis of the Chestnut Ridge anticline, the Pine Mountain fault cuts stratigraphically upward from its position near the base of the Maynardville limestone of the overthrust block. This transgression probably continues beneath the north flank of the anticline until the fault has reached the very incompetent Devonian shale, which it is believed to follow beneath Cumberland Mountain and the Middlesboro syncline north of the Jonesville district. Because the angle of crosscutting is not predictable and because the place where the fault plane reaches the Devonian shale and again parallels the bedding is not known, the depth to the fault beneath the north flank of the Chestnut Ridge anticline is also not known. The locations of the fault that are shown in the structure sections of plate 1 were determined by connecting the known or probable position of the fault beneath the Chestnut Ridge anticline with its probable position in the flat-lying Devonian shale along the south edge of the flat-bottomed Middlesboro syncline north of the Jonesville district. It is likely that in predicting the depth to the fault plane north of the axis of the Chestnut Ridge anticline by this method the error is much greater than it is in predicting its depth south of the axis, where the stratigraphic horizon at which the fault lies has been inferred.

In all four of the fensters that reveal the top of the stationary block and in the Phipps and Anthony Ely wells, which have penetrated it, the rocks at the top of the block are uppermost Clinton shale, Hancock dolomite, or basal Upper Devonian shale. The stratigraphic interval from the oldest to the youngest beds in this sequence is about 200 feet. All of the fensters and both wells are at or near the crest of the Chestnut Ridge anticline. Apparently in this region the fault plane developed at or very near the contact between the competent Hancock dolomite and the very incompetent Devonian shale, but it has in places cut a little lower and elsewhere a little higher. Beneath the flank north of the axis of the anticline, it is most unlikely that the top of the stationary block is appreciably higher or lower stratigraphically, because elsewhere wherever the Pine Mountain fault reaches a very incompetent unit such as the Devonian shale it follows the incompetent unit for great distances. Hence it probably behaves in the same manner here. The only important crosscutting of the stationary block north of the Chestnut Ridge anticline is believed to be beneath Pine Mountain 15 miles to the northwest, where the fault plane turns upward from the Devonian shale and breaks through to the surface (pl. 2).

Somewhere to the south of the axis of the Chestnut Ridge anticline, the fault plane must cut downward to the base of the Maynardville limestone, crosscutting all formations between the Upper Devonian shale and the Maynardville. There is no direct evidence as to where this crosscutting occurs, because no wells that reached the top of the stationary block south of the Chestnut Ridge anticline have yet been drilled in the Jonesville district. However, where the overthrust block rides stratigraphically upward across the edges of competent and incompetent formations of the stationary block it is more likely to arch and buckle, and where the overthrust block glides parallel with the beddings of the stationary block it probably is little deformed. The only significant buckling of the overthrust block south of the Chestnut Ridge anticline is along the sharp-crested Sandy Ridge anticline. Hence this seems the logical place beneath which the crosscutting of the stationary block occurs.

Using another line of approach, the approximate position at which a given formation in the stationary block abuts against the Pine Mountain overthrust can be calculated if the position at which the same formation in the overthrust block meets the fault is known and if the displacement along the fault is also known. The junction of the Middle and Upper Ordovician and Silurian formations with the fault plane beneath Sugar Run lowland, Poor Valley Ridge, and Poor

Valley as shown in the structure sections of plate 1 is believed to be relatively accurate. The displacement along the fault cannot be measured in the Jonesville district, but reasons are adduced in a later section (p. 199) for believing that it is between 5 and 5½ miles. Using 5.3 miles as the approximate displacement along the overthrust fault in the middle of the Jonesville district and projecting this distance backward along the fault from the point where the base of the Clinton shale comes down to the overthrust in section BB′ of plate 1, one finds that the base of the Clinton in the stationary block should abut against the fault at a point 0.7 mile north of the axis of the Sandy Ridge anticline and that formations underlying the Clinton should be encountered in order of increasing age from this point in a southward direction at the top of the stationary block.

It seems significant that both lines of evidence discussed above point to the conclusion that the crosscutting of the formations of the stationary block by the Pine Mountain fault takes place beneath the Sandy Ridge anticline. Hence the Clinton shale probably lies at or very near the top of the stationary block beneath the south flank of the Chestnut Ridge anticline and beneath most of The Cedars syncline. The available data are too scanty and have been extrapolated too far, however, to venture any prediction as to what formation would be found at the top of the stationary block at any given point along the Sandy Ridge anticline.

Subsidiary overthrust faults close to and associated with the Pine Mountain fault, such as the Ben Hur fault and the Bethel fault, have been described in the Jonesville district. Others have been described from the Rose Hill district. These subsidiary overthrusts, together with the Pine Mountain fault, enclose slices of exotic rocks that may be several miles in longest dimension and may be hundreds of feet thick. In addition, numerous other much smaller slices or slivers have been seen or have been encountered in drilling. Some of the known slices or slivers are composed of rocks cut loose from the base of the overriding block and left behind along the fault, and the others are composed of rocks cut loose from the top of the stationary block and dragged forward along the fault. Because so many slices and slivers have been found in the relatively small areas where the Pine Mountain fault reaches the surface or has been drilled, it is to be expected that there should be many more subsidiary faults with accompanying slices and slivers in the areas where the Pine Mountain fault is concealed and has not been penetrated by drilling. In the Jonesville district, slices and slivers can be composed of any formation or formations from the Maynardville limestone to the Upper Devonian shale, because all these formations are in contact with the fault at some point within the district.

The writers present the above interpretations of the Pine Mountain fault as the working hypothesis that appears most logical in the light of present scanty knowledge of the subsurface of the Jonesville district. Should any of the basic assumptions be proved erroneous, the geology described above and shown in the structure sections of plate 1 would have to be revised accordingly. In order to refine or revise these interpretations, the accumulation of accurate information about the subsurface based on drilling in strategic locations becomes a matter of economic importance, inasmuch as intelligent exploration for oil and gas in the Jonesville district is largely dependent upon a knowledge of the depth to the stationary block, of the constitution of the block, and of the attitude of the beds in it.

EXPOSED PART OF STATIONARY BLOCK

LITTLE FLEENORTOWN FENSTER

The Little Fleenortown fenster is the smallest of the fensters formed by outcropping of the Pine Mountain fault in the Jonesville district. It lies along the axis of the Chestnut Ridge anticline in the bottom of a tributary valley of Fleenortown Creek. The limits and even the existence of a fenster at this location are obscure because dolomite of the Chances Branch dolomite member of the Maynardville limestone above the fault is in contact with Hancock dolomite of nearly identical appearance below the fault. The identification of the Hancock dolomite in the bottom of this valley is based on its darker color and its petroliferous odor and also on the finding of a *Leperditia*-like ostracode. Just south of the fenster, the lowest exposed beds of the Chances Branch dolomite member are strongly brecciated, and beds higher in the Chances Branch dip gently away from the fenster both to the north and to the south.

The fault is not exposed around the rim of the fenster, and outcrops are not numerous enough to locate it exactly. The fenster cannot be much larger than shown on plate 1, but it could be considerably smaller

BIG FLEENORTOWN FENSTER

The Big Fleenortown fenster lies a quarter of a mile east of the Little Fleenortown fenster. It is an irregular-shaped area a mile long from east to west and a half a mile wide at its widest place. The western part includes the deep valley of Fleenortown Creek, but the eastern part is at a higher elevation and is drained by sinkholes.

The Clinton shale crops out in the center of the western part of the fenster, dipping gently in opposite directions away from an east-west trending anticlinal axis which almost bisects the Clinton area. Overlying the Clinton and directly underlying the fault around most of the fenster rim are massive beds of Hancock dolomite, which are well exposed in numerous places. These beds dip more steeply away from the anticlinal axis than does the underlying Clinton shale. Along the northwest rim of the fenster a thin belt of Upper Devonian black shale overlies the Hancock and directly underlies the Pine Mountain fault. Wherever it can be seen as bedrock, the shale is folded or contorted owing to the stresses transmitted from the overthrust block directly above. Maynardville limestone directly overlies the Pine Mountain fault around most of Big Fleenortown fenster and is well exposed near the fault in places on the south and west sides of the fenster. The Maynardville dips gently southward south of the axis of the Chestnut Ridge anticline, which apparently lies a few hundred feet north of the axis of the anticline that affects the rocks of the stationary block inside the fenster. North of the Chestnut Ridge anticlinal axis the beds of the overthrust block dip steeply northward, but the fault plane continues nearly flat. Hence the belt of Maynardville limestone is truncated by the fault, and the overlying Copper Ridge dolomite comes in contact with the Hancock dolomite or Upper Devonian shale along the fault.

The eastern half of the fenster is less clearly defined than the western half. Outcrops are much fewer and the position of the fault is less accurately known. In this region Hancock dolomite is the only formation exposed inside the fenster except for one small sliver of Upper Devonian shale along the fault northeast of Fleenortown. The Maynardville limestone is believed to overlie the fault, but there are very few exposures of it.

The plane of the Pine Mountain fault is exposed in only one place around the rim of Big Fleenortown fenster. This is in a sharply trenched gully tributary to Fleenortown Creek where the creek crosses the fault and the belt of Upper Devonian shale in the northwest part of the fenster. Here dolomite at the top of the Hancock is normally overlain by 4½ feet of Upper Devonian shale which is directly overlain above the fault by brecciated dolomite probably belonging in the Copper Ridge dolomite but which might be in the upper part of the Maynardville limestone. The fault plane and the beds below the fault dip 18° to the north, but the bedding of the overlying brecciated dolomite cannot be ascertained. A medium-sized spring enters the gully exactly along the fault line.

TOWN BRANCH FENSTER

The Town Branch fenster is almost coextensive with a triangular-shaped flat area on the headwaters of Town Branch north of Jonesville. The triangle is roughly equilateral and each side is about 1,000 feet. State Route 70, which is the most travelled road in Lee County, traverses the fenster from end to end. Good outcrops of the stationary block inside the fenster are, however, a short distance off the highway, and the only highway cut inside the fenster is so deeply weathered and so slumped that digging is necessary to demonstrate that the bedrock in the cut differs from the rock that crops out in cuts along the highway outside the fenster. Hence it is not surprising that the fenster was not discovered until the area was mapped in detail, even though many geologists have driven along the highway.

The top of the stationary block in Town Branch fenster is composed of Upper Devonian shale which varies from a few feet to a few tens of feet thick. The best exposures of the Upper Devonian shale are along the east side and at the northeast corner of the fenster, but a little of the deeply weathered shale and of the basal sandstone of the Upper Devonian shale can be dug out in the roadcut along the highway. The Hancock dolomite forms the bedrock in the central part of the fenster because the overlying shale has been removed by erosion, but only the top 10–20 feet of the Hancock is exposed. The Hancock dolomite crops out on the east edge of the flood plain of Town Branch and also along a lane in the northwest corner of the fenster. It is here as elsewhere difficult to distinguish the Hancock from the Maynardville limestone that overlies the Pine Mountain fault around the south end of the fenster, but the intervention of the unmistakable Upper Devonian black shale between the two and the finding of the basal sandstone of the Devonian shale make the identification of the Hancock in the central part of this fenster certain.

The Pine Mountain fault plane is nowhere exposed, but its location is quite accurately known because of fairly abundant outcrops near the fault around part of the fenster and contrasts in soil and float on opposite sides of the fault around the rest of the fenster. The fault plane is very gently arched along an east-west line that bisects the east side of the fenster. South of this the fault plane dips gently southward and passes beneath the surface in a downstream direction. North of the axis of folding, the fault dips gently northward but probably steepens considerably at or just beyond the north edge of the fenster.

The beds of the overriding block are exposed along the highway and creek both south and north of the fenster but do not crop out near the fault on the east or northwest sides of the fenster. To the south the beds directly above the fault are largely dolomites of the Chances Branch dolomite member of the Maynardville limestone, although some limestone of the Low Hollow member of the Maynardville is irregularly present in places. This irregular and apparently anomalous space relation of the outcrops of the Low Hollow and Chances Branch members is probably due to small reverse faults upthrown on the south side that duplicate parts of the Maynardville close to the fenster. Small faults of this type are common in the beds directly above the Pine Mountain fault in the Rose Hill district. They probably are present near the fensters in the Jonesville district, but outcrops are not adequate to locate them accurately. In the outcrops of the Maynardville south of the fenster the beds dip southward at angles from 16° to 35°, but this dip is due more to tilting of blocks of Maynardville to the southeast by the probable reverse faults just mentioned than to regional dip away from the fenster. The Maynardville limestone must die out against the Pine Mountain fault approximately as mapped because the beds that crop out along the highway just north of the fenster are of Copper Ridge dolomite and dip steeply to the north. Here as at Big Fleenortown fenster, the Pine Mountain fault cuts upward across the fenster in a northward direction from its position in the Maynardville limestone to higher horizons of the overthrust block. The very steeply dipping beds of Copper Ridge dolomite and younger formations north of the fenster are cut off at depth by the Pine Mountain fault, which dips northward from the fenster at a lower angle.

A probable thrust fault which displaces the beds of the overriding block on opposite sides of the fenster has been mapped. This fault has not been seen, but it must exist because space is not adequate for all of the Copper Ridge dolomite to be present between the Maynardville limestone and the Chepultepec dolomite. The fault probably developed along the sharp flexure where the dip of the beds changes from nearly flat to very steeply northward. The fault is very similar in character to the Waddell fault, and, as previously noted (p. 175), it may possibly continue eastward to the rim of the Sulphur Springs fenster and may be an extension of the Waddell fault.

SULPHUR SPRINGS FENSTER

The largest of the fensters in the Jonesville district is the Sulphur Springs fenster. It is roughly rectangular in shape, approximately 1½ miles in longest dimension and nearly a mile wide at its widest part. The fenster lies just south of Ben Hur and includes the small settlement of Sulphur Springs in its northern part. The geology of the fenster is more complex than that of the previously described fensters because two other large faults besides the Pine Mountain fault are present in the area, namely the Ben Hur and Waddell faults.

Unlike the other fensters associated with the Pine Mountain overthrust, the Sulphur Springs fenster does not lie in the bottom of a valley but is in a very hilly region and includes several of the highest hills in the vicinity. The rocks of the stationary block in the central part of the fenster have been so recently unroofed that there has been too little time for them to have been eroded to a lower level, even though they are somewhat less resistant than most of the surrounding rocks outside the fenster. Inside the fenster the exposed rocks of the stationary block consist of Clinton shale, Hancock dolomite, and Upper Devonian shale. These rocks are arched into an elongate dome, the axis of which trends northeast and nearly bisects the fenster lengthwise. Southeast of the axis the Clinton shale alone is exposed dipping southeastward and it disappears beneath the overthrust block about half a mile southeast of the axis. Northwest of the axis the Clinton shale passes beneath the Hancock dolomite, which forms a belt of variable width in the northwest part of the fenster and which loops around both ends of the fenster, enclosing the central area of the Clinton shale on three sides. The Hancock dolomite is in contact with and passes beneath the overthrust at the northeast and southwest ends of the fenster, but along most of the northwest side it is overlain by Upper Devonian shale, which is in contact with the fault. Folding and small-scale faulting in the eastern part of the fenster cause the pattern of the geologic contacts between these three formations to be somewhat irregular.

The rocks of the overriding block above the fault have not been completely eroded away inside the fenster. On each of the three high hills in the central part of the fenster, remnants of the overthrust sheet are preserved as klippen. Bedrock is not exposed in any of the three klippen, but abundant oolitic chert is present in the soil, which is unquestionably derived from either the Copper Ridge or Chepultepec dolomites and probably from the upper part of the Copper Ridge. Three similar but smaller klippen, probably of Copper Ridge dolomite, lie on the north and east slopes of the high hills. The relation of these klippen to the main overthrust sheet is shown in section DD′ of plate 1.

Around most of the fenster the rocks overlying the Pine Mountain fault are dolomite formations of the Knox group; but in the vicinity of Sulphur Springs the Ben Hur slice, described on page 177, intervenes between the stationary block and the overriding block, and the Pine Mountain fault passes beneath rocks of the slice, which is here composed of Clinch sandstone, Clinton shale, Hancock dolomite, and Upper Devonian shale. The trend of the belts of these formations is almost at right angles to the trace of the Pine Mountain fault.

The Pine Mountain fault is not exposed anywhere around the rim of the Sulphur Springs fenster or around any of the klippen. Its location can be determined within a few tens of feet in many places, however. It comes nearest being exposed where it passes beneath the Clinton shale of the Ben Hur slice on the hillside just north of an extremely sharp U-turn in the road east of Sulphur Springs. At this point Upper Devonian shale underlies the fault.

CONCEALED PART OF STATIONARY BLOCK

In the northern half of the Jonesville district the structure of the stationary block reflects in a subdued manner the structure of the overriding block. A gentle anticline is present in the rocks of the stationary block, the axis of which follows approximately the axis of the Chestnut Ridge anticline in the overthrust block. Near the western edge of the district where the Chestnut Ridge anticline changes into the Rose Hill flexure, the anticlinal axis in the stationary block probably turns southwestward approximately along the axis of the Powell Valley anticline of the overthrust block.

The crest of the anticline in the stationary block is highest in the fenster area of the Jonesville district and culminates in a pronounced dome in the Sulphur Springs fenster. A much lower dome is present farther west along the axis, and its high point is approximately in the position of the Fleenortown fensters. This smaller dome is revealed by the fact that in the Big Fleenortown fenster the top of the Clinton shale is about 150 feet higher than it is beneath the Town Branch fenster to the east, and it must be more than 200 feet higher and is probably more than 1,000 feet higher than it is 3 miles to the west where Dry Creek crosses the axis of the Chestnut Ridge anticline without exposing the top of the stationary block. In the region west of the Fleenortown fensters, the crest of the anticline in the stationary block is believed to be approximately determinable by subtracting from the topographic elevation the stratigraphic thickness between the exposed beds along the Chestnut Ridge anticline and the middle of the Maynardville limestone. The top beds of the stationary block will probably be either shale and sandstone near the top of the Clinton shale or dolomite and limestone of the overlying Hancock dolomite.

The beds of the stationary block on the north flank of the anticline dip northward less steeply than do the beds on the north flank of the very asymmetrical Chestnut Ridge anticline above the Pine Mountain fault. They are believed to parallel the Pine Mountain fault, to descend with it uniformly beneath Sugar Run lowland and Stone Mountain-Cumberland Mountain, and to flatten out beneath the Middlesboro syncline. No evidence suggesting any major faulting or any major folding of the rocks of the stationary block in the region north of the crest of the anticline has been found, though fault slivers and slices have probably broken loose from the top of the stationary block in places. Hence the top formation of the stationary block at any given point might be Upper Devonian shale, Hancock dolomite, or Clinton shale, depending on whether some of the top beds of the block had been sliced off during the overthrusting; but it is unlikely that any formations younger than the Upper Devonian shale or older than the Clinton shale lie at the top of the stationary block beneath the northernmost part of the Jonesville district.

South of the Chestnut Ridge anticline, the beds of the stationary block probably continue to parallel the Pine Mountain fault plane. They dip southward from the axis of the anticline and pass into a syncline similar to The Cedars syncline in the overthrust block. Somewhere in this region, however, the Pine Mountain fault begins cutting downward across the stationary block, as previously described in the section on the Pine Mountain fault; and as a result, successively older formations become the top of the stationary block and are in turn cut off by the Pine Mountain fault. Because no wells for which records were kept have reached the Pine Mountain fault in the central or southern part of the Jonesville district, it is at present impossible to predict with any assurance just where the crosscutting begins or what formation would lie at the top of the stationary block at any given point south of the axial line of The Cedars syncline. For this reason the general structure of the stationary block in this region has been suggested in the structure sections on plate 1 but has not been shown in detail.

SMALL THRUST FAULTS

In a region that has been deformed by major overthrusts as has the Jonesville district, it might be expected that small thrust faults would be common or abundant. Near the major overthrusts, high-angle reverse faults of small displacement are numerous and a few lower-angle thrust faults, also of small displacement, have been seen. Elsewhere, however, the overthrust block is broken by very few

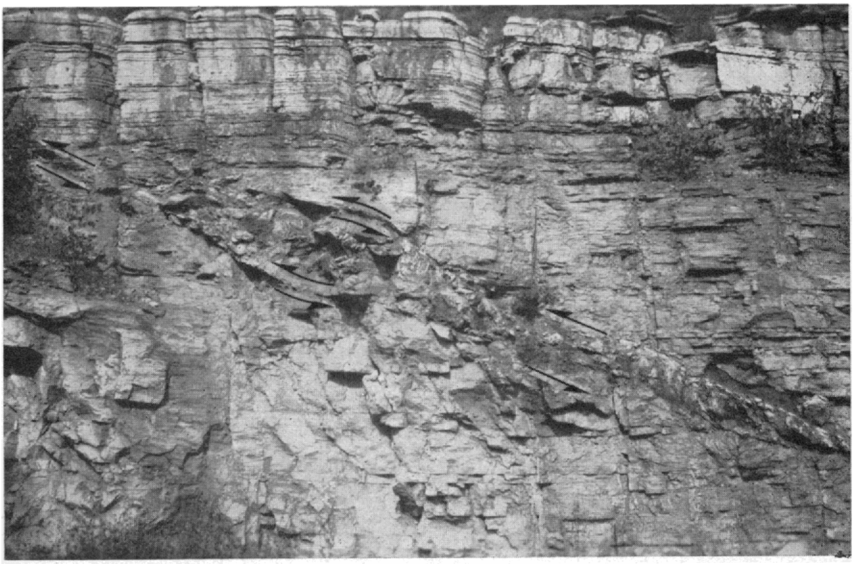

FIGURE 35.—Fault slice along a small thrust fault in a quarry in Hardy Creek limestone north of U. S. No. 58 and south of Elk Knob.

faults of any type. One of the exceptions is a small thrust fault that is perfectly exposed in a quarry just north of U. S. No. 58 and south of Elk Knob. The quarry is in nearly flat-lying Hardy Creek limestone. Displacement along the fault, which dips 18° to the southeast, is 43 feet. The fault slice, about 5 feet thick, lies along the fault plane in the middle of the quarry wall (fig. 35). It is identical in origin with the previously described Bethel slice along the Pine Mountain overthrust and with slices along the Wallen Valley fault, but it is on a much smaller scale. Thus it serves as a sort of laboratory model for a very common and characteristic feature of the overthrust faults of Lee County. The overthrust was traced northeastward into a very complex area of Eggleston limestone, where the folds and faults were too small to be shown on the scale at which the mapping was done.

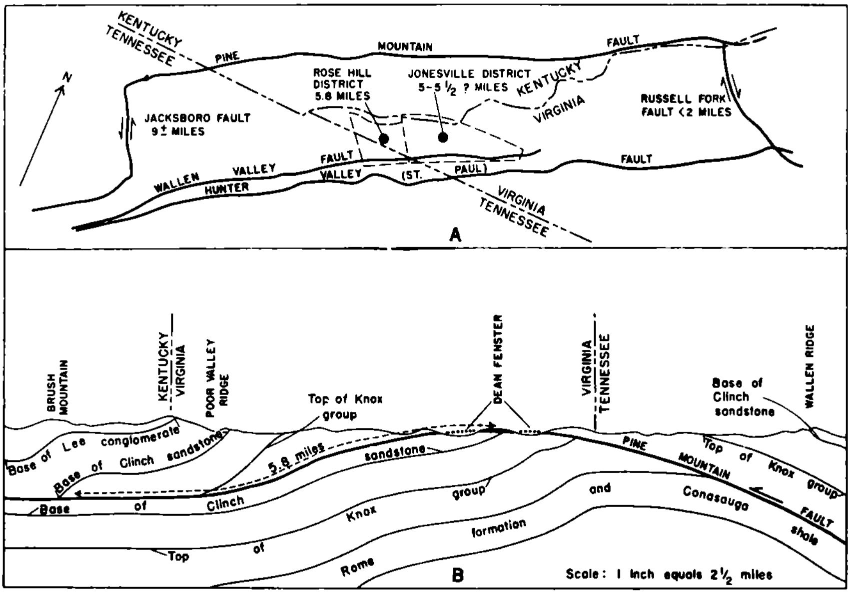

FIGURE 36.—*A*, Estimated displacement on Pine Mountain fault in Jonesville district based on known displacements elsewhere in the Cumberland block. *B*, Measurement of displacement on Pine Mountain fault in Rose Hill district 5 miles west of Jonesville district.

INTERPRETATION OF MAJOR STRUCTURAL FEATURES OF THE JONESVILLE DISTRICT

DISPLACEMENT ALONG THE PINE MOUNTAIN FAULT IN THE JONESVILLE DISTRICT

The forward movement of the Cumberland block along the Pine Mountain fault cannot be measured in the Jonesville district. In the Rose Hill district, however, it can be measured because the abrupt truncation by the Pine Mountain fault of several pre-Clinton formations at the top of the overridden block can be seen in the Fourmile and Dean fensters. A structure section was drawn through this region and was extended northwestward to show the truncation by the fault of these same formations at the base of the overthrust block, which takes place northwest of Poor Valley Ridge (fig. 36*B*). Measuring along the fault from the truncated ends of the formations above and below the fault shows that the actual displacement is about 5.8 miles.

On opposite sides of the Jacksboro tear fault at the southwest end of the Cumberland block, the forward movement of the block is approximately 9 miles; and on opposite sides of the Russell Fork tear fault at the northeast end of the block, the forward movement was estimated by Wentworth (1921a, p. 65) to be less than 2 miles (fig. 36*A*). The movement was thus pivotal, decreasing from southwest to northeast. In areas where no other major faults have cut upward from the Pine Mountain fault to the surface and thus dissipated the stresses that produced the overthrusting along subsidiary fault planes, it seems likely that the displacement along the Pine Mountain fault decreases continuously, though not necessarily uniformly, in a northeast direction. Hence one would expect the forward movement of the block in the Jonesville district to be less than in the Rose Hill district, but not greatly less because the two districts are close together. By interpolation from the displacement figures given above the displacement along the fault in the Jonesville district is estimated to be between 5 and 5½ miles. If wells that penetrate to the Pine Mountain fault are drilled in the central and southern parts of the Jonesville district, data will then be available to determine the location where the Pine Mountain fault truncates the formations of the stationary block and hence to calculate with considerably greater accuracy the displacement along the fault in the Jonesville district.

RELATION TO MAJOR STRUCTURAL FEATURES IN THE ROSE HILL DISTRICT

In many respects the structure of the Jonesville district resembles that of the Rose Hill district directly to the west, but there are some striking differences. The most important of these are:

1. There are two major anticlines in the overthrust block in the Jonesville district but only one centrally located anticline in the Rose Hill district.
2. The fensters of the Jonesville district lie structurally farther to the northwest than do those of the Rose Hill district. They are at or near the place where the Pine Mountain fault truncates the formations of the overthrust block. For several miles southeast of the fensters in the Jonesville district there is believed to be approximate parallelism between the bedding of the overthrust block, the Pine Mountain fault, and the bedding of the stationary block. But in the Rose Hill district the southeastern fensters are in the region where

the Pine Mountain fault truncates the formations of the stationary block, and the northwestern fensters are in the region of parallelism of the fault with the overlying beds. None of the Rose Hill fensters are far enough to the northwest to show truncation of the beds of the overthrust block by the fault.

3. In the Jonesville district there is one major fault of imbricate type, the Waddell fault, which either broke through to the surface or else died out as a bedding plane fault at a level above the present surface. In contrast with this, all major faults of the Rose Hill district that branch from the Pine Mountain fault rejoin it, thus representing merely secondary planes of movement of the Pine Mountain fault.

4. The Wallen Valley fault flattens at the east end of the Jonesville district, where it is dying out. The trace of the fault swings around in a great loop, and a klippe of the overthrust beds is preserved. Elsewhere in the Jonesville district and in all of the Rose Hill district, the Wallen Valley fault dips to the southeast at an angle of about 30°, and the trace of the fault is remarkably rectilinear.

RELATION TO MAJOR STRUCTURAL FEATURES OF NORTHEASTERN LEE COUNTY

R. L. Bates (1939, pp. 31–94) has described the geology of the northeastern part of Lee County which adjoins the northern border of the Jonesville district. Bates' map, published without topographic base on the approximate scale of 1 to 70,000, shows numerous faults but does not show their relation to the Pine Mountain fault. Bates and Miller together have examined some of these faults in the field in an attempt to determine the relations between the mapped faults of northeastern Lee County and the more recently mapped faults of the Rose Hill and Jonesville districts. Insufficient time was available to resolve all of the numerous problems of interpretation, but Miller reached the following conclusions, and Bates concurs in some of them.

There are few major faults that have an important bearing on the structural interpretation of northeastern Lee County. In the southwestern half of the area mapped by Bates, only the Big Hill fault and the Ely fault appear to have large displacement. The Big Hill fault lies southeast of the Ely fault, dips to the southeast, and is upthrown on the southeast side. The Ely fault dips to the northwest and is not upthrust on the southeast side as Bates has shown it. This suggests that the Ely and Big Hill faults are two parts of only one fault and that the relationship is similar to that described for the arched Ben Hur fault in the Jonesville district. The Ely and Big Hill faults join in the town of Pennington Gap and also north of Dryden, but the complex geology at these points of juncture is not yet well understood. The area of younger rocks enclosed by the "two" faults may prove to be a fenster. If the Big Hill and Ely faults are two parts of the same fault plane, it may possibly be the Pine Mountain fault, but more likely it is a higher overthrust that merges, both to the southeast and to the northwest, with the concealed Pine Mountain overthrust.

In northeastern Lee County, mapped faults believed by Miller to be of small displacement or non-existent are: the Poor Valley Ridge fault, the fault directly south of the Ely syncline, the fault that passes through the town of Dryden and continues due east, the Camp Creek fault from the south edge of the map to the junction with the Big Hill fault south of Stocker Knob, the Wallen Valley fault from Jasper northeastward, and the River Ridge fault from Olinger northwestward. The key to the interpretation of the geology of northeastern Lee County lies in extremely detailed mapping of the complex area in the vicinity of Pennington Gap and of the area in the vicinity of Dryden and Stocker Knob. The reconnaissance nature of Bates' mapping and the small scale of his published map did not permit the accumulation and presentation of much structural data that must be available before the geology of northeastern Lee County can be correctly visualized in relation to the larger framework of the geology of the whole Cumberland block.

INTERPRETATION OF THE DEFORMATION OF THE JONESVILLE DISTRICT

At the close of Paleozoic sedimentation in the Appalachian geosyncline, mountain-building stresses accumulated. These were directed from southeast to northwest across the geosyncline. As a result, the Pre-Cambrian crystalline rocks and the Lower Cambrian clastic sedimentary rocks of the Blue Ridge and Great Smoky Mountains overrode the younger Paleozoic rocks along a series of great overthrust faults such as the Iron Mountain fault and the Great Smoky overthrust. Farther to the northwest the basement rocks have nowhere been brought to the surface but older Paleozoic rocks have been sheared up and over younger Paleozoic rocks along faults such as the Pulaski overthrust and Saltville fault. The Pine Mountain fault is the northwesternmost of this series of large overthrust faults, and the Cumberland block is the northwesternmost of the overthrust sheets.

The rocks of the Cumberland overthrust block range from the Rome formation of Early and Middle Cambrian age, which has been penetrated in a well in the western part of the Rose Hill district, to the coal-bearing beds of Pennsylvanian age in the Middlesboro syncline northwest of the Jonesville district. They have a total thickness of about 15,000 feet. Lower Cambrian sedimentary rocks older than the

Rome are probably also present above the crystalline basement, and these older rocks are at least 1,000 feet thick. Sediments of late Carboniferous age and possibly also of Permian age have been completely eroded from the region. They may have been many thousand feet thick. Thus the total sedimentary cover of Paleozoic rocks at the time of Appalachian folding and faulting was probably more than 20,000 feet thick.

In this sequence there are two extremely incompetent units of considerable thickness. The older of these is the Conasauga shale, composed predominantly of fissile micaceous shale and overlain by a great thickness of competent dolomites and limestones of the Maynardville limestone and dolomites of the Knox group. The younger incompetent unit consists of the black and gray shales that comprise the Chattanooga shale of early workers. Besides these two weak rock units, there also appears to be a zone of incompetent shale in the lower part of the Rome formation of Early Cambrian age. This incompetent zone is believed to have overlain a thick, massive-bedded, competent carbonate unit equivalent to the Shady dolomite of the eastern part of the Valley of Virginia. The competent and incompetent units are shown to scale in section *A* of plate 7.

When the Pine Mountain fault plane was formed as the result of strong compressional stresses directed from southeast to northwest, it broke through from the crystalline basement rocks into the overlying mantle of relatively unfolded and undeformed sedimentary rocks at some unknown point southeast of the Jonesville district. Because the compressive forces were acting largely in the horizontal plane, with only a small vertical component, it was easier for the developing fault to form along one of the incompetent units described above than to break to the surface across the massive competent beds. The lowest incompetent unit that the fault plane followed was the weak shales in the lower part of the Rome formation. Although the fault may have formed along this incompetent unit southeast of the Jonesville district, it has developed along the next-higher incompetent unit, the Conasauga shale, beneath the southern and central parts of the Jonesville district. At about the present location of the Chestnut Ridge anticline, the fault plane was deflected upward, probably by a pre-existing warp or gentle fold of the beds, to the highest of the major incompetent units, the Chattanooga shale. It followed this unit nearly to the present location of Pine Mountain. There it was again deflected upward across the remainder of the sedimentary mantle and broke through to the surface. This course of the fault plane before large scale movement along the fault had begun is shown in section *B* of plate 7.

After formation of the fault plane, the horizontally directed forces thrust the overlying rock sheet forward. The part of the sheet under-going most intense stress was sheared loose from the less compressed adjacent rocks along two steeply inclined transcurrent faults, the Jacksboro tear fault on the southwest and the Russell Fork tear fault on the northeast. As Wentworth (1921a, pp. 63–67), Butts (1927, pp. 8–9), and Rich (1934, pp. 1584–1596) have pointed out, the earliest movement along the Pine Mountain fault and the greatest forward displacement of the overthrust sheet were on the southwest, and the Jacksboro fault was the first of the tear faults to form. The wave of forward movement gradually progressed northeastward, and in a late stage of the overthrusting the Russell Fork tear fault was formed at the opposite end of the Cumberland block.

During the movement along the fault plane, the overthrust sheet underwent relatively little folding or minor faulting. In section *C* of plate 7, the structure of the Jonesville district is shown approximately as it is believed to have been in the late stages of overthrusting. Section *C* has been constructed from section *B* by merely moving the overthrust block forward along the fault plane for a scaled distance representing 4 miles of displacement. In the final stages of overthrusting the stationary block began to buckle gently along an axis that coincides with the axis of the Chestnut Ridge anticline, thus arching upward the fault plane and the still-moving overthrust block. As forward movement of the overthrust block continued down the steepening slope of the fault plane north of the Chestnut Ridge anticline, steep reverse faults and lower-angle thrust faults, both inclined to the northwest, were formed owing to the tendency of the beds on the slope to underthrust the flat-lying beds beyond (pl. 7, section *D*). These are the faults that are characteristic of and confined to the belt between the Chestnut Ridge anticline and the edge of the flat-bottomed Middlesboro syncline. In this final stage of overthrusting, the overthrust block buckled sharply along the axis of the Rose Hill flexure and Chestnut Ridge anticline, owing principally to the resistance of the flat Middlesboro syncline part of the sheet to being underthrust in the manner described. Before rupture of the overthrust block along the Chestnut Ridge anticline and Rose Hill flexure could take place, however, the stresses that were beginning to deform severely the overthrust block were relieved by rupture of the block farther to the southeast, forming the Wallen Valley fault (pl. 7, section *E*). In section *E* and subsequent ones, the Wallen Valley fault is shown as a single plane of movement for purposes of simplicity, rather than as a dual fault as in plate 2. After the formation of the Wallen Valley fault plane there was no further movement along the Pine Mountain fault plane beneath the Jonesville district, but the rocks lying to the southeast of the district were overthrust along the new fault. Still later the Hunter Valley (St. Paul) fault is believed to have developed in a similar manner, relieving the stresses that were producing the displacement along the Wallen Valley fault and transferring the plane of relief farther to the southeast to the still newer fault (pl. 7, section *F*).

How far this sequence of events continued southeastward, where still other large overthrusts such as the Clinchport fault (pl. 7, section *F*) parallel the Wallen Valley and Hunter Valley faults, is not known, because the location of the roots of the original Pine Mountain fault is not known. The failure of any of the thrust faults between Lee County and the Blue Ridge-Great Smoky Mountain chain to bring crystalline rocks to the surface, despite displacements that are measurable in thousands of feet along all of them and measurable in miles along some of them, tempts one to postulate a continuous, relatively flat fault plane above the crystalline basement beneath the entire 60-mile width of the Appalachian Valley. According to this theory, the thrust and overthrust faults that come to the surface between the outcrop of the Pine Mountain fault and the Blue Ridge would merge at depth but above the crystalline basement with a flat overthrust that represents a Pine Mountain fault extended to the southeast. This theory presents mechanical difficulties, however, whether one assumes that the entire sheet above the flat overthrust first moved as a unit and later ruptured along imbricate faults that developed in successive order from northwest to southeast, or that the southeasternmost of the major faults was formed first and the flat fault plane was extended to the northwest as other major faults developed in order from southeast to northwest.

When detailed mapping of the faulted belt and more complete information on the character of the faults in southwest Virginia and northeast Tennessee become available, it may be possible to build an integrated picture of the faulting across the entire belt. At present neither the theory of a continuous fault plane beneath the entire valley belt nor the earlier theory that each fault is separately rooted in the crystallines seems entirely tenable. Probably the most nearly true theory is a combination of the two, by which the major overthrusts, such as the Pine Mountain, Saltville, and Pulaski faults, are represented as having separate roots in the crystallines, and the other faults are imbricate faults merging with them at depth.

AGE OF THE DEFORMATION

Evidence for accurate dating of the folding and faulting of the rocks is not available within the Jonesville district because of the long hiatus in the record from Late Devonian to Quaternary time. In nearby areas, however, Pennsylvanian rocks have been subjected to the same deformation that affected the rocks of the Jonesville district, and elsewhere in the Appalachians early Permian rocks are in structural accordance with the underlying Pennsylvanian rocks. Thus the major folding and faulting did not begin until Permian time. In eastern Virginia and in other areas along the Piedmont belt, late Triassic rocks have been deformed in a totally different manner. Hence the Appalachian type of faults and folds that characterize the Jonesville district must have been formed between early Permian and late Triassic time. The deformation which then occurred has been named the Appalachian revolution and is considered to mark the end of the Paleozoic era.

ECONOMIC GEOLOGY

The mineral resources of the Jonesville district that have been exploited in the past are principally iron and crushed stone. In addition four wells have been drilled for oil, none of which was successful. At present the only mineral industry of the district is the quarrying of crushed stone, and this is on a small scale for local use on the roads. In view of the discovery of oil in the nearby Rose Hill district and the similarity in stratigraphy and structure of the Rose Hill and Jonesville districts, the possibility of finding oil in commercial quantities in the Jonesville district seems good. The geologic factors involved in the search for oil in the Jonesville district, a brief history of the defunct iron-mining industry, and, briefly, other minor mineral resources are discussed in the following sections.

OIL

WELLS IN JONESVILLE DISTRICT

D. C. McCLURE WELL

The first well drilled in the Jonesville district, and also the first in Lee County, was on the farm of D. C. McClure, 4 miles west of Jonesville. It was started in 1910 and drilled intermittently until 1915, when it was finally abandoned. No cuttings and no log of the well were kept by the drillers, and the reported depth of the hole varies from 3,250 to 3,400 feet.

The McClure well was drilled before Wentworth (1921, pp. 351–369) recognized the Cumberland overthrust block and before Butts (1933) discovered the fensters of the Rose Hill region. There was thus no comprehension of the regional structure, and apparently there was little understanding of the local structures in the vicinity of the site chosen for drilling.

The well lies on the south flank of the Chestnut Ridge anticline and on the north edge of The Cedars syncline, which is flat-bottomed. It was located in a region of almost flat dips. North of the well the beds dip southward off the crest of the Chestnut Ridge anticline, but they are undulatory and in general flat-lying for nearly half a mile south of the well.

The well started at an altitude of 1,353 feet, about 210 feet above the base of the Hurricane Bridge limestone. It thus started stratigraphically lower in the overthrust block than any formations in which pays or shows of oil and gas have more recently been found in the stationary block.

The well is believed to have reached the Pine Mountain overthrust near the bottom of the hole and to have penetrated a few feet into the stationary block beneath. This interpretation is based on the only evidence about the well that could be uncovered, which consisted of the statements of the driller who was on the job for the last 800 feet of drilling. According to this driller, the rocks penetrated from the top of the hole to the bottom were entirely limestone and dolomite. He further stated that a gas pocket was very near the bottom of the hole; also very near the bottom of the hole drilling troubles were encountered and the hole was shot in order to straighten it. The driller said that, after the shot, pieces of chert with abundant fossils "like snails" came up in the bailer. So far as the driller knew, none of these fossils was saved, and a search by the senior author for pieces of this fossiliferous chert around the well site was fruitless.

All these statements by the driller suggest the presence of a fault near the bottom of the hole. If the section had been normal the base of the Maynardville limestone should have been reached at about 3,150 feet and Conasauga shale should have been present from that depth to the bottom. The driller's statement that only limestone and dolomite were encountered would indicate that the Conasauga had not been found where it was to be expected. Gas has not been reported from wells in the Rose Hill district that have drilled the Maynardville and Conasauga. The presence of the gas pocket in the McClure well in this general part of the section suggests entrapment of gas along a fault with gas-bearing formations other than the Maynardville present beneath the fault. The drilling troubles near the bottom of the hole may have been due to fractured and (or) folded rock, thus accounting for the absence of the Conasauga and the presence of the gas pocket in the hole at this place and also suggesting faulting at this depth. Furthermore the fossils "like snails" that are said to have come out of the well when the hole was shot to straighten it do not sound like any fossils that could have come from either the Maynardville or Conasauga formations. The abundant "snail-like" fossils probably were gastropods, which are present in many of the Ordovician formations but are most abundant in the upper part of the Trenton limestone. If the fossiliferous beds penetrated near the bottom of the McClure well really are from the upper part of the

Trenton, the formation probably is present there as a fault slice along the Pine Mountain fault, inasmuch as the McClure well is in a region where the available structural evidence indicates that Clinton shale rather than Trenton limestone should lie at the top of the stationary block directly beneath the Pine Mountain fault (see p. 190).

Although the interpretation of the presence of the Pine Mountain fault near the bottom of the McClure well is based on evidence consisting of the 30-year-old recollections of one of the drillers, somewhat more weight is attached by the writers to the interpretation than might otherwise seem justified, because of the fact that four different recollections about the well by the driller, namely, the absence of shale, the gas pocket, the drilling troubles, and the "snail-like" fossils, all suggest the probable presence of a fault near the bottom of the hole.

The McClure well is known to have had 6-inch casing to 1,800 feet, but there may also have been additional casing. The well is now partly plugged with concrete and filled with stones. The McClure well is shown diagrammatically in plate 8, but no data were available on which to base any interpretations of the rocks penetrated between the surface and the Pine Mountain overthrust.

CHARLES PHIPPS WELL

The Phipps well, which was drilled in 1944, 1946, and 1947 by Clarence Ellison, lies 7 miles west of Jonesville. It is in the middle of the Chestnut Ridge upland about 700 feet southwest of U. S. No. 58, where the highway cuts from the Sugar Run lowland through Chestnut Ridge to the Powell River lowland. It started at an elevation of 1,590 feet in rocks of the overthrust block about 1,700 feet south of the axis of the Chestnut Ridge anticline. The surface rock around the well is Chepultepec dolomite. Sinkholes are abundant in the region, and the dolomite is so deeply weathered that a mantle of 70 feet of clay and sand was penetrated before bedrock was reached.

A graphic log of the Phipps well is shown in plate 8. The top of the Copper Ridge dolomite was reached at 190 feet. In the upper part of the hole the drillers had trouble with their equipment and with heavy flows of fresh water into the hole. After very slow progress over a period of several months, the well was closed down at a depth of 712 feet. In the winter of 1946 it was deepened to 855 feet and again abandoned while still in the Copper Ridge dolomite. In the spring of 1947 drilling was resumed, and it continued in the Copper Ridge dolomite to a depth of 1,032 feet, at which point a fault was encountered. Below this fault 224 feet of Chepultepec dolomite was penetrated. Then, at a depth of 1,256 feet, the drill reached the Pine Mountain fault and entered the Clinton shale at the top of the stationary block. From this point the section was normal. The well penetrated a nearly full section of Clinton, and a full section of the Poor Valley Ridge member of the Clinch sandstone; and it was 17 feet into the Hagan shale member of the Clinch when the well at a depth of 1,902½ feet was abandoned for the third time.

The only unusual and unpredictable feature in the section penetrated by the Phipps well is the zone of Chepultepec dolomite lying between the Copper Ridge dolomite and the Pine Mountain fault. It seems to be a fault slice broken from the base of the overriding block and left behind in its present position as the overriding block continued to move forward.

Drilling was stopped before the Phipps well reached any of the producing horizons of the Rose Hill oil field. The top and base of the Trenton limestone, the principal producing formation of the Rose Hill oil field, should lie at about 2,600 and 3,200 feet, respectively. The Phipps well is not far from the crest of the Chestnut Ridge anticline, beneath which is a more gentle anticline in the rocks of the stationary block. Possibilities for oil in the stationary block are better along the structurally high areas than elsewhere. Hence the Phipps well, though not near the structurally highest part of the Chestnut Ridge anticline, is still in a reasonably good location. It is unfortunate that the well has not been carried down to test the potentially productive formations.

M. H. SNODGRASS WELL

The M. H. Snodgrass well was drilled by C. E. Deaton in the spring of 1947. It is on the south bank of the Powell River 5 miles southwest of Jonesville and half a mile northwest of the mouth of Wallen Creek. In this region the Sandy Ridge anticline is the dominant structural feature but is much lower structurally than it is farther to the east. The well is about 1,000 feet south of the axis of the anticline, and all beds near the well dip gently southward.

The well was begun in Mascot dolomite at a horizon calculated to be 125 feet below the top of the formation. A normal section was drilled from the Mascot dolomite to the bottom of the hole at 1,706 feet, at which depth the well was in about the middle of the Copper Ridge dolomite. The contacts of the formations of the Knox group are extremely difficult to pick accurately in well cuttings, but the top of the Chepultepec dolomite in the well appears to be at a depth of about 600 feet and the top of the Copper Ridge dolomite at about 1,320 feet. A show of oil was reported at 945–950 feet, in about the middle of the Chepultepec dolomite. Little significance is attached to this oil show because similar shows have been reported in the dolomitic formations of the overthrust block in the Rose Hill district, but a large show has never been found above the Pine Mountain fault.

The Snodgrass well did not reach the base of the overthrust block, which is probably 500 to 700 feet below the bottom of the hole. What formation forms the top of the underlying stationary block at this location is unknown, because this is almost surely in the region where the Pine Mountain fault is crosscutting the stationary block in a southward direction from the Clinton shale to the Maynardville limestone. Hence it is also unknown whether the Trenton limestone is present beneath the Pine Mountain fault at the Snodgrass well site, or whether formations older than the Trenton limestone here form the top of the stationary block.

CANDY CAWOOD WELL

The Candy Cawood well was started in 1947 by Herbert Gardiner at a site in the extreme western part of the Jonesville district just south of the axis of the Powell Valley anticline. At a depth of only about 150 feet the well was abandoned owing mainly to financial difficulties. No cuttings were saved, but the well is known to have spudded in very near the base of the Chepultepec dolomite and was probably in the upper part of the Copper Ridge dolomite when it was abandoned.

At this site the Pine Mountain overthrust is probably at a depth of about 1,000 feet, and the top of the underlying stationary block is probably either Hancock dolomite or Clinton shale. The top of the Trenton is probably at a depth of about 2,200 feet, or at about the same elevation above sea level as the top of the Trenton in the Anthony Ely well.

ANTHONY ELY WELL

At present the Anthony Ely well is the only well drilled in the Jonesville district to have penetrated the formations of the stationary block that are productive in the Rose Hill oil field. It was a dry hole but had a large show of gas. The well was drilled by R. R. Murray in the spring and early summer of 1947. It is on the flood plain of a tributary of Hardy Creek just south of U. S. No. 58 and 2 miles southeast of Hagan. The casing and casing head have been pulled, and when last visited the open hole was covered with a few boards.

The beds near the well dip about 80° N. on the steep north flank of the Chestnut Ridge anticline, the axis of which is about 800 feet south of the well. A graphic log of the well is shown in plate 8. The well started in the Chepultepec dolomite at an elevation of about 1,330 feet. The top of the Copper Ridge dolomite was at a depth of 270 feet and the Pine Mountain overthrust at 643 feet. All of the beds above the fault probably dip very steeply, so that the actual stratigraphic thickness penetrated in the Chepultepec and Copper Ridge dolomite is considerably less than the distance drilled in them. Directly below the fault were 13 feet of limestone and dolomite with a sandy zone at the base. These are believed to be the basal beds of the Hancock dolomite. Below the Hancock, the section was perfectly normal. The tops of the formations and members were found at the following depths: Clinton shale at 656 feet, Clinch sandstone at 976 feet, Hagan shale member of the Clinch at 1,075, Sequatchie formation at 1,144, Reedsville shale at 1,403, Trenton limestone at 1,815, Eggleston limestone at 2,324, and Hardy Creek limestone at 2,450. The well was abandoned at 2,532 feet in the lower part of the Hardy Creek limestone. Below the overthrust the drilled thicknesses of all formations except the Reedsville shale correspond closely to their stratigraphic thicknesses; hence the formations of the stationary block are here flat or only gently dipping.

Several shows of oil and gas are said to have been encountered in the stationary block, but the writers have been unable to obtain a driller's log showing the depths to them. A gas show reported to be in the Reedsville shale was apparently the only one of appreciable size. The flow of gas was very roughly estimated by the driller to be about 100,000 cubic feet a day. After the well was abandoned and all casing pulled in the summer of 1947, the gas bubbled up vigorously through the water that filled the hole to the rim, and one year later it was still bubbling up at a rate apparently little diminished.

The Anthony Ely well is close to the axis of the Chestnut Ridge anticline and that of the broader, gentler anticline in the underlying stationary block. It is, however, at a structurally low point along the crest of the Chestnut Ridge anticline. The occurrence in the well of several oil shows and an appreciable flow of gas offers encouragement that oil and gas may be found elsewhere along the Chestnut Ridge anticline.

RECENT WELLS NEAR JONESVILLE DISTRICT

MILL DAVIS WELL

Since preparation of the report on the Rose Hill district, (Miller and Fuller, in press) several wells have been drilled in the eastern part of that district that supply important information on the subsurface geology of the adjacent Jonesville district. For this reason and because they have not been previously described, they are included in this report. The Mill Davis well is the deepest of these and is also closest to the Jonesville district. It was drilled in 1947 by Robert Vorhees. It lies near the center of the Chestnut Ridge upland a quarter of a mile south of Silver Leaf Church and exactly 2 miles S. 68° W. from Horton School, which is in the west-central part of the Jonesville district. The well is 0.9 mile south of the axis of the Powell Valley anticline. Bedrock is not exposed near the well, but from outcrops some distance removed on opposite sides of the well it appears that the bedrock dips to the southeast, probably at an angle between 5° and 10°. A graphic log of the well is given in plate 8.

The well started near the base of the Chepultepec dolomite, but the first cuttings that were saved came from a depth of 170 feet and are in Copper Ridge dolomite. For the next 555 feet the drill was continuously in Copper Ridge dolomite, but at 725 feet the Pine Mountain fault was reached. All of the Maynardville limestone and the lowest part of the overlying Copper Ridge dolomite have slivered off the base of the overthrust block and have been left behind along the fault plane as the block moved forward. Hence, the fault is here nearly 400 feet higher than would have been predicted in advance of drilling. Beneath the overthrust, the Clinton shale lies at the top of the stationary block. From this point to the bottom of the hole, which is 4,406 feet deep, the drill passed through a normal section of beds, presumably dipping gently to the southeast. The well bottomed in the lower part of the Mascot dolomite, the deepest horizon in the stationary block yet reached by any well drilled in Lee County.

The tops of formations are shown in the following table, in which the stratigraphic names used in this report appear in the center column and the corresponding names previously used in the Rose Hill district appear in the right-hand column.

TABLE 2.—*Tops of formations in Mill Davis No. 1 well*

Depth below surface, in feet	Formation names used in Jonesville district	Formation names used in Rose Hill district
0	Chepultepec dolomite	Chepultepec dolomite.
(0–170, no cuttings)		
170–725	Copper Ridge dolomite	Copper Ridge dolomite.
725	Pine Mountain overthrust	Pine Mountain overthrust.
725–1,057	Clinton shale	Clinton shale.
1,057–1,182	Poor Valley Ridge member of Clinch sandstone	Poor Valley Ridge member of Clinch sandstone.
1,182–1,238	Hagan shale member of Clinch sandstone	Hagan shale member of Clinch sandstone.
1,238–1,538	Sequatchie formation	Sequatchie formation.
1,538–2,007	Reedsville shale	Reedsville shale.
2,007–2,537	Trenton limestone	Trenton limestone.
2,537–2,696	Eggleston limestone	Eggleston limestone.
2,696–2,845	Hardy Creek limestone	Hardy Creek member of Moccasin limestone.
2,845–2,957	Ben Hur limestone	Lower member of Moccasin limestone.
2,957–3,200?	Woodway limestone	Platy member of Lowville limestone.
3,200?–3,522?	Hurricane Bridge limestone	Redbed member of Lowville limestone.
3,522?–3,594	Martin Creek limestone	Lenoir limestone.
3,594–3,731	Rob Camp limestone	Mosheim limestone.
3,731–3,828	Poteet limestone	Chert member of Murfreesboro limestone.
3,828–4,020	Dot limestone	Limestone and dolomite members of Murfreesboro limestone.
4,020–4,406	Mascot dolomite	Mascot dolomite.

The Davis well had three shows of oil in the Trenton limestone, only one of which was of appreciable size. This was 2,535 feet below the surface and 2 feet above the base of the Trenton. Apparently a few bailers of oil were obtained from this show. The horizon was not acidized. Below this no significant shows of oil or gas were reported. A zone of sandy dolomite in the Mascot dolomite between 4,254 and 4,270 feet was without oil or gas.

O. CAVINS WELL

This well was drilled in 1947 by K. R. Wilson. It is in the southeastern part of the Rose Hill district, a quarter of a mile southeast of Mt. Davis School (Mt. Davidson School) and 3 miles due west of Beech Grove School, which is shown on plate 1 in the southwest part of the Jonesville district. Except for the McClure well, the Cavins well is farther down the southeast flank than any well yet drilled on the Powell Valley anticline. It is 2½ miles southeast of the axis of the Powell Valley anticline and only about 100 yards northwest of the Mascot dolomite and Dot limestone contact near the southeast edge of the Chestnut Ridge upland.

The well starts near the top of the Mascot dolomite, which dips 12°–13° SE. in the vicinity of the well. At a depth of 307 feet, where the first cuttings were saved, the drill was in Kingsport dolomite. The top of the Longview dolomite was reached at 441 feet, the top of the Chepultepec dolomite at 578 feet, and the top of the Copper Ridge dolomite at 1,283 feet. At 1,847 feet, 564 feet below the top of the Copper Ridge dolomite, the drill passed abruptly from typical lower "stinkstone" of the Copper Ridge dolomite into light-colored sandy dolomite believed to be Chepultepec dolomite, and it continued in this to the bottom of the hole at 2,001 feet. The contact at 1,847 feet is believed to be a fault, though the cuttings from this depth were so finely pulverized that no slickensides were seen. The fault is probably the Pine Mountain overthrust. This is not certain, however, because only about 150 feet of beds below the fault were drilled, and these beds could be in a thick fault slice above the principal plane of movement of the Pine Mountain fault.

Assuming that the fault at 1,847 feet is the Pine Mountain fault, as shown in the graphic section of the Cavins well (pl. 8), the top of the stationary block at this place is composed of Chepultepec dolomite. Much younger formations underlie the Pine Mountain fault in the fensters of the Rose Hill district and in all other wells outside the fensters, but these are nearer the axis of the Powell Valley anticline than is the Cavins well. Southeast of the axis of the Powell Valley anticline in both the Rose Hill and Jonesville districts, the Pine Mountain fault cuts downward across the formations of the stationary block to the Maynardville limestone. The beginning of this truncation can be seen in the Fourmile and Dean fensters. In a geologic section (Miller and Fuller, in press) drawn before the well was drilled, the data from the Fourmile and Dean fensters were extrapolated to the southeast, and the formation that was estimated to be at the top of the stationary block near the Cavins well was the lower part of the Chepultepec dolomite or the uppermost part of the Copper Ridge dolomite. The evidence from the Cavins well thus appears to verify the predictions. In the section, however, the Pine Mountain fault was predicted to be about 2,400 feet below the surface, on the assumption that the fault would lie at or near the base of the Maynardville limestone. The Cavins well has shown, however, that all of the Maynardville limestone and the lowest 300 feet of the Copper Ridge dolomite are absent from the overriding block, whether the fault at 1,847 feet is the Pine Mountain fault, which seems more probable, or is a higher overthrust that connects with the Pine Mountain fault in all directions, thus enclosing a fault slice of Chepultepec dolomite.

The Cavins well was a dry hole, without any significant shows of oil or gas. There is very little possibility that any oil- or gas-bearing zones would have been found had the well been carried deeper.

GRANT SMITH WELL

The Grant Smith well is in the northeast part of the Rose Hill district, about half a mile north of Pleasant View Chapel and 1½ miles west-southwest of the Candy Cawood well which appears on plate 1 of this report. It is about 0.3 mile north of the axis of the Powell Valley anticline and 0.4 mile east of the Possum Hollow fenster, the easternmost of the fensters in the Rose Hill district. The rocks near the well dip very gently to the northwest. The well was drilled by the H. and R. (Hindman and Rose) Oil Co. in the fall and winter of 1947–48.

The Grant Smith well penetrated a normal and approximately predictable section from top to bottom except for 47 feet of sheared and mixed-up dolomite directly above the Pine Mountain fault. The well started in the lower part of the Copper Ridge dolomite, and it encountered a small fault at 280 feet and the Pine Mountain fault at 327 feet. Between the two faults is a zone consisting of brecciated and sheared dolomite, most of which is "stinkstone" of the Copper Ridge dolomite but some of which is light-colored fine-grained dolomite of the Chances Branch dolomite member of the Maynardville limestone.

Directly below the Pine Mountain fault is the Clinton shale; and from the fault down to the bottom of the hole at 2,188 feet, the formations penetrated are in their proper order and have approximately their true stratigraphic thickness. This indicates nearly flat dips and no minor folding or faulting. The well bottomed 4 feet below the top of the Hardy Creek limestone, having passed through all of the

Trenton limestone, which yields almost all of the production in the Rose Hill oil field. Only one small show of oil was reported approximately in the middle of the Trenton limestone.

The failure of the Grant Smith well, near the axis of the Powell Valley anticline, and of all eight wells in the Possum Hollow fenster along the axis of the anticline makes it seem unlikely that any production will be found in the stationary block beneath the Powell Valley anticline northeast of the Grant Smith well in the Rose Hill district or in the western part of the Jonesville district.

ROSENBAUM WELL

The Rosenbaum well was drilled in the summer of 1947 by the K. R. Wilson Co. It is just east of the town of Rose Hill, about 1,000 feet south of U. S. No. 58, about 300 feet west of Martin Creek, and about 2 miles west of the edge of the Jonesville district.

The beds at the surface dip almost vertically on the north flank of the Rose Hill flexure, the axis of which lies only 500 feet to the south. In beds as steeply dipping as these it is extremely difficult to recognize stratigraphic units in well cuttings, but the well started near the Kingsport and Mascot contact and appears to have passed into Longview dolomite at about 750 feet and into Chepultepec dolomite at about 1,190 feet. At 1,442 feet the well crossed a fault believed to be the Pine Mountain fault, and samples from 1,442 to 1,456 feet are largely composed of greenish-gray to grayish-white fine- and medium-grained sandstone believed to belong at or near the top of the Clinton shale. A great deal of drilling trouble was encountered in this well owing to the steeply dipping beds and to shattering of the rock near the Pine Mountain (?) fault. The well was abandoned at 1,456 feet after having penetrated only 14 feet into what is believed to be Clinton shale at the top of the stationary block.

The stationary block is not folded into a flexure, as is the overthrust block. The Clinton shale and underlying formations probably dip 10°–20° NW., as does the Pine Mountain fault; this approximate attitude of the beds is probably persistent for several miles both northwest and southeast of the well. Thus there is no known folding, warping, or faulting of the beds in the stationary block that would favor the accumulation of oil in the Trenton limestone at this place.

OIL IN THE ADJACENT ROSE HILL DISTRICT

The Rose Hill oil field has been described in numerous publications, the most comprehensive of which is the Virginia Geological Survey Bulletin 71 by Miller and Fuller (in press). Other contributions (Butts, 1927, pp. 1–12; Jillson, 1947; Miller, 1948, pp. 452–479; Miller and Fuller, 1947; Oil and Gas Journal, 1948, p. 341) deal specifically with the geology and development of the oil field. A more extensive bibliography is given in the Jillson paper.

The salient geologic factors of the oil occurrence in the Rose Hill field are summarized below so that the possibilities for similar occurrences in the Jonesville district can be evaluated.

Location of successful wells.—In June 1948 there were 21 successful oil wells in the Rose Hill field. These were located in or near three different fensters. More than half of the producing wells were drilled in the Fourmile fenster, the northwesternmost fenster in the Rose Hill district and the site of the discovery well. Two successful wells have been drilled along the north edge of the Hamblin Branch fenster, and two other wells in this fenster had initial production that failed to hold up. Four successful wells have been drilled in or near the Martin Creek fenster, and others were being drilled that had good prospects of success. In the 2-mile interval between the Fourmile and Hamblin Branch fensters, two dry holes have been completed. No wells have been started in the 1-mile interval between the productive Hamblin Branch fenster area and the productive Martin Creek fenster area. In general the two productive belts as now known are about half a mile wide from northwest to southeast. The one in the Fourmile fenster area is about a mile long from southwest to northeast, and the one in the Hamblin Branch-Martin Creek fenster area is a little more than a mile long in the same direction.

Numerous dry holes have been drilled on both sides of the Fourmile fenster productive belt, and other dry holes have been drilled north of the Martin Creek fenster belt. Still other dry holes have been drilled in the Possum Hollow fenster and in outlying areas south, southeast, and east of the fensters.

Production of the field.—From 1943, when the field was first put into production, until late 1945, production of oil from the Rose Hill field averaged from 10 to 12 barrels a day, coming from two wells. Since that time many new producing wells have been drilled. Some of these had initial production as low as 20 or 30 barrels a day and settled rapidly to less than 10 barrels a day. Others had initial productions of more than 100 barrels a day and a few more than 200 barrels a day; but they settled to about a third of the initial rate of production in a few days or weeks. Quite a few of the wells in the Fourmile fenster have gone dry, but some of them have subsequently been deepened and have found lower producing zones. The biggest and most consistent producers in 1948 were the wells in the Martin Creek fenster. From the middle of 1946 to the middle of 1948 the daily production of the field varied greatly, depending on whether one or more wells were contributing large initial production to the total.

At times the total was probably as low as 100 barrels a day and at other times it approached, if not reached, 600 barrels a day. It probably averaged between 200 and 300 barrels a day during this 2-year period.

Almost all of the wells produce from depths between 1,000 and 2,000 feet. All were drilled with cable tools. The cost of drilling such shallow wells is low, and so even the shorter-lived of the wells have returned most if not all of the original investment, and the longer-lived ones have paid for themselves several times over.

The oil is high-volatile paraffin-base oil with a gravity of 44.4° A. P. I. It is comparable to the best Pennsylvania-grade oil and brings top or near-top prices at the refinery.

Producing horizons and structure.—Almost all of the successful wells in the Rose Hill oil field obtain their production from the Trenton limestone; but in this field there are no consistent oil-bearing zones in the Trenton. Production has been found in the upper, middle, and lower parts of the formation, which is about 560 feet thick. In several places wells only a few hundred feet apart produce from widely separated horizons in the Trenton. In general, however, pays in the lower part of the formation have been longer-lived than those in the middle and upper parts.

One well has produced from the underlying Eggleston limestone, and at least two have found significant production in the top beds of the Hardy Creek limestone directly below the Eggleston. Shows of oil and gas have been reported from the Reedsville shale and the Woodway limestone, but none of these oil shows was larger than a barrel a day, and the gas pockets blew off in a few hours or days. Small amounts of oil have also been found in the Clinton shale in the wells in Possum Hollow; and a well in the western part of the Rose Hill district had a flow of about 225,000 cubic feet of gas from the basal sandstone of the Hancock (Cayuga) dolomite.

The two known productive belts of the Rose Hill field both lie north of the axis of the Powell Valley anticline. The producing zones are in the underlying stationary block where the beds are nearly flat or very gently dipping. Just northwest of the productive belts, the dips steepen and are consistently to the northwest for several miles until they flatten out beneath the Middlesboro syncline. Southwest of the Martin Creek-Hamblin Branch productive belt, the beds of the stationary block are nearly flat for approximately a mile and then dip gently to the southeast for approximately another mile before they are truncated by the Pine Mountain fault. Near the southern edge of the Fourmile productive belt, the beds change from a nearly flat attitude to northwest dips of 10° to 20°, and the formations in order of increasing age form the top of the stationary block and are truncated by the Pine Mountain fault. Thus the oil in both productive belts is coming from flat-lying or nearly flat-lying beds that are at the top of a long northwest-inclined slope of these beds. In the Fourmile belt, however, the flat-lying beds are part of a monoclinal fold with northwest-dipping beds on both sides of it, whereas in the Martin Creek-Hamblin Branch belt, the flat-lying beds are at the crest of an anticline, the southeast limb of which is much shorter and more gently dipping than the northwest limb.

Almost all of the productive wells inside the fensters start in Clinton shale and penetrate a normal section to the Trenton. The wells outside the fensters start in Copper Ridge dolomite or Maynardville limestone near the base of the overthrust block, penetrate the Pine Mountain fault at a shallow depth, and enter either Hancock (Cayuga) dolomite or Clinton shale. From the top of the stationary block down to the producing beds in the Trenton the section is normal.

The oil in the producing zones is believed to be in fractures in the limestone induced during the overthrusting and folding of the region. Solution by circulating ground water may have enlarged the fractures somewhat before the oil entered them. The source beds are believed to be the dark-colored limestones of the Trenton that are rich in organic remains, some of which have a slight oily smell immediately after the rock is fractured.

POSSIBILITIES FOR OIL IN THE JONESVILLE DISTRICT

Because the rocks of the Jonesville district are nearly identical with those in the Rose Hill oil field and because the major structural features are similar, the district is considered a potential oil-bearing region. The possibilities are almost untested, because only one of the five wells that have been started in the district has reached the Trenton limestone, the most favorable formation for oil. In the succeeding sections the possibilities for oil are discussed, and structural situations that are believed to merit test wells are described. Similar recommendations for drilling were included in a preliminary map of the Jonesville district published by the U. S. Geological Survey. (Miller and Brosge, 1950.)

Before the present bulletin appears in print some or all of the most favorable structural locations may have been tested and the possibilities for oil here discussed may have been realized or have vanished.

Possible producing horizons.—The Trenton limestone has the same lithologic character and almost the same thickness in the Jonesville district as in the Rose Hill district. Because this is by far the most productive formation in the Rose Hill field, it is also considered the most favorable for production in the Jonesville district.

If the Trenton does carry oil in the Jonesville district, the oil will probably be present in fractures in the limestone, as it appears to be in the Rose Hill field. Chances for fracturing of the Trenton are equally good in both areas, because the rocks of both regions have been subjected to similar deforming stresses and have yielded to these stresses in a similar manner. The obvious differences in structure between the two regions are much greater in the overthrust block and in the fault slices along the Pine Mountain fault than they are in the stationary block.

Because the Eggleston and Hardy Creek limestones are also nearly identical in both districts and have produced some oil in the Rose Hill district, they are considered to offer some possibilities for oil in the Jonesville district also. Certainly no well that tests the Trenton and finds it dry should be abandoned without drilling the additional 150 to 200 feet necessary to test all of the Eggleston and the top 20 or 30 feet of the Hardy Creek limestone. Oil occurring in the Eggleston or Hardy Creek would probably be present in fractures in brittle limestone beds. The mudstones that compose all of the lower member of the Eggleston and much of the upper member are too incompetent to yield by fracturing. Thus they would not be possible reservoir beds, but they may form impervious zones that would prevent the escape of oil that entered underlying fractured beds. The oil that has been found in the top beds of the Hardy Creek limestone has probably been trapped there because these beds are overlain by the impervious mudstones of the lower member of the Eggleston.

Porous sandstones in the Poor Valley Ridge member of the Clinch sandstone, in the lower part of the Clinton shale, and at the base of the Hancock dolomite are possible reservoir rocks. Early wells drilled in the Possum Hollow fenster of the Rose Hill district produced a few barrels of oil from both the Clinch and the Clinton, and, as previously noted, the basal sandstone of the Hancock is the gas-bearing zone in a well in the western part of the Rose Hill district. The first two of these three formations are not especially promising for oil production in the Jonesville district because the only obvious source beds stratigraphically near them are the black shales of Upper Devonian age that are in places present beneath the Pine Mountain fault, and there is no apparent route by which oil or gas could migrate from the black shales stratigraphically downward into the Clinton or Clinch. The Hancock dolomite is discontinuously present at the top of the stationary block and is also exposed in all four of the fensters along the axis of the Chestnut Ridge anticline. Its basal sandstones might, however, carry some gas in stretches along the anticline where there is adequate cover of overthrust rocks to prevent escape to the surface.

Limestones and sandstones older than the Hardy Creek limestone have not supplied any pays or good shows of oil or gas anywhere in Virginia. Chances that they might be productive in the Jonesville district are therefore small. Any of the platy, brittle limestones of early Middle Ordovician age could locally be fractured and could locally retain oil or gas if there were adequate source beds for oil and routes of migration from the source beds to the fractured beds. These possibilities seem poor. Zones of sandstones up to 6 feet thick are present in the Mascot dolomite, and thinner zones of sandstone are common in the lower half of the Chepultepec dolomite. At the surface these sandstones appear very porous owing to the leaching of the dolomitic cement, but they are certainly much less porous below the zone of weathering and may be too tight to serve as reservoir rocks. The sandy zones in both of the formations are lenticular. Even thick and prominent zones are not traceable for more than a few miles along the strike. Because the overthrust block is several miles out of place with respect to the stationary block, specific sandy zones found in the overthrust block at the surface would probably be absent in wells penetrating the same horizons of the stationary block in the same area; but other sandy zones would probably be found in the wells.

Possible source beds for oil and gas.—Source beds from which oil might be derived are not wanting in the Jonesville district. The Trenton limestone, which is believed to be the source of the oil in the Rose Hill oil field, including the small amount that has been found in the Eggleston and Hardy Creek limestone, is equally rich in organic remains and equally dark-colored in the Jonesville district. The black shales in the Upper Devonian and lower Mississippian are also excellent source beds for gas and possibly also for oil. Much of the gas in eastern Kentucky comes from similar beds.

The only other apparent source beds in the Jonesville district are the dark-colored, oily-smelling dolomites of the lower half of the Copper Ridge dolomite; the dark-colored, oily-smelling limestones of the lower parts of the Poteet limestone and Martin Creek limestone; and a few oily-smelling zones of limestone and dolomite in the Hancock dolomite. In all of these formations, however, the rock is so dense and impervious that the contained oil has probably not been driven out of them to accumulate in reservoir rocks, from which it could be produced.

Favorable structural locations for oil accumulation.—One or more oil shows have been found in almost every well that has penetrated the Trenton limestone in the Rose Hill and Jonesville districts. This is to be expected inasmuch as the Trenton limestone is believed to be the source of the oil as well as a reservoir rock for oil in the areas where it is fractured. Oil pays in the Rose Hill field have, however, been confined to structurally high parts of the stationary block and particularly to areas of gentle or flat dips at the top of the long slope that carries the beds of the stationary block northward below the Middlesboro syncline. Logically, therefore, the structurally high areas of the stationary block probably offer the best chances for production in the Jonesville district, especially where these structural highs are adjacent to the same long slope into the Middlesboro syncline.

The most pronounced structural high in the Jonesville district is the dome in the rocks of the stationary block that is revealed inside the Sulphur Springs fenster. The crest of the dome is in the vicinity of the three klippen of Copper Ridge dolomite that cap the highest hills in the fenster. Beneath these is Clinton shale. There is no evidence at the surface to indicate that the section is not normal from the Clinton on down, with the top of the Trenton limestone, also in a domal structure, at a depth of about 1,200 to 1,400 feet and the bottom of the Trenton at about 1,800 to 2,000 feet.

A first test well to be drilled at this site should probably be located at or near the crest of the dome. Such a well would test the productive possibilities of sandstones in the Clinton shale and Clinch sandstone on the way down; and if these and also the Trenton limestone were dry, the well should be carried downward into the Hardy Creek limestone to test the possibilities of the Eggleston and the top of the Hardy Creek.

The writers want to emphasize that the geology in the vicinity of Sulphur Springs that appears in the sections of plate 1 is subject to major errors if faults exist in the stationary block. Such faults could be present even though they are not revealed in the small part of the stationary block that can be seen in the fenster. The writers believe that major faults in the stationary block are rare or absent in the Jonesville district and that the subsurface geology is approximately as shown; but in a region as complexly faulted as the Sulphur Springs area is known to be, one cannot be certain that still other faults of significant size do not exist beneath the sheet of overthrust rocks.

Probably the second most favorable area for drilling along the Chestnut Ridge anticline is the structurally high area in the vicinity of the Fleenortown fensters. This is a lower and more elongate dome than that in the Sulphur Springs fenster. It plunges very gently eastward toward Town Branch fenster. The westward plunge of the dome cannot be observed at the surface because there are no exposures of the stationary block west of the Little Fleenortown fenster. The plunge probably begins only a short distance west of the Little Fleenortown fenster, however, because the top of the stationary block is definitely below the level of Dry Creek, which is 2 miles west of the Little Fleenortown fenster and topographically lower than the fenster. This elongate dome surmounting the anticline of the stationary block is a favorable site for oil accumulation for the same reasons that the Sulphur Springs dome is favorable. It is not as pronounced a structurally high area, which fact may render it less promising; but on the other hand the structure is not so complicated in this vicinity, and so faults are not so likely to be present in the stationary block. Along the crest of this dome, the Hancock dolomite is at the top of the stationary block; but along the valley of Fleenortown Creek, all of the Hancock has been eroded, exposing more than 100 feet of the underlying Clinton shale. A first well to test this dome could be located anywhere along the axis of the anticline in the vicinity of the Fleenortown fensters, but a location along Fleenortown Creek in the western part of the Big Fleenortown fenster offers the advantage of a lower topographic elevation and a lower stratigraphic horizon at the surface. The reversal of dip on opposite sides of the axis of the dome is also excellently displayed in the numerous outcrops of Clinton shale and sandstone along the creek.

The two domes just described are the only known domes surmounting the anticline of the stationary block that underlies the Chestnut Ridge anticline. The remainder of the anticline is considered much less favorable for oil because of the failure of the Anthony Ely well, which was located almost on the crest of the anticline in one of its low stretches. The region along the axis of the Powell Valley anticline in the western part of the Jonesville district is also not particularly promising in view of the failure of the Grant Smith well, which was located along this axis only a short distance west of the Jonesville district. The rocks of the stationary block underlying the Rose Hill flexure have not been tested, but enough evidence has accumulated to show that they are not involved in the flexure and that they probably dip consistently and quite uniformly to the northwest. Hence there is no reason to believe that oil or gas would have been retained in them beneath the flexure.

A third good location for a test well would be the Tanbark Ridge section of the Sandy Ridge anticline. The Sandy Ridge anticline is not quite as high structurally as the Chestnut Ridge anticline, but it is a long and prominent fold. The Pine Mountain fault plane is probably folded in the same manner as are the rocks of the overthrust block exposed at the surface. Beneath the fault, however, the stationary block is probably so truncated by the fault plane that the formations at the top of the stationary block are probably of increasing age from northwest to southeast. If the Trenton limestone comes to the top of the stationary block beneath the high part of the anticline, or if it is present beneath the anticline and rises to the top of the block farther to the southeast, the place where it abuts the fault might be an unusually favorable place for oil accumulation. Unfortunately there are too many unknown factors to predict what formations and what structure would be found in the stationary block by drilling a well that penetrated the overthrust beneath the Sandy Ridge anticline. Despite these intangible factors, the structurally high area along the Tanbark Ridge section of the Sandy Ridge anticline seems to be the third most favorable area for test drilling in the Jonesville district, because structural highs of the overthrust block seem to be reflected in part by corresponding highs in the stationary block, and at present these latter seem to be most favorable for oil in Lee County.

The most logical location for a first test well in the Sandy Ridge anticline would be along the structurally highest part of the fold, i. e., in the Tanbark Ridge region. A well located here would probably have to be drilled from 1,500 to 2,000 feet to reach the base of the Pine Mountain overthrust block. It should then be continued several hundred feet to be assured that the rocks directly beneath the overthrust block represent the top of the stationary block rather than a fault slice along the Pine Mountain fault and also to identify with assurance the formation or formations below the overthrust block. If these prove to be formations of pre-Trenton age, there is little point in continuing the well deeper unless the operator wishes to test the unknown, but probably slim, chances for oil in the sands of the Mascot or Chepultepec dolomite. However, if formations younger than the Trenton form the top of the stationary block beneath the anticline, the well should be continued downward to test the Trenton. If this is not productive, the Eggleston limestone and top of the Hardy Creek limestone that lies just below should also be tested.

If the Trenton limestone proves to be absent beneath the crest of the Sandy Ridge anticline, there might be some chance for production where the Trenton forms the top of the stationary block, presumably beneath the north flank of the anticline. This is based on the assumption that gouge along the Pine Mountain fault plane or in pervious beds above the fault has sealed off oil migrating upward through the beds of the Trenton.

There is no geologic reason for believing that oil has accumulated in the homoclinally dipping beds of the stationary block beneath either the Sugar Run lowland or the Powell River lowland. Nor does the stationary block beneath The Cedars syncline, which is flat bottomed, appear favorable for oil accumulation, although oil may have collected there in structurally low parts of the stationary block in the absence of water drive. Wells drilled in any of these three locations would have to penetrate a much greater thickness of overthrust rocks before reaching the Pine Mountain fault than they would along the anticlines.

In summary, the three most favorable locations for test drilling in the Jonesville district are thought to be the Sulphur Springs dome, the Fleenortown fensters dome, and the high part of the Sandy Ridge anticline in the region of Tanbark Ridge. Other parts of the district appear much less promising on the basis of present knowledge of the subsurface.

ACIDIZATION OF WELLS

Several early wells in the Rose Hill field were acidized without improving production, but relatively small amounts of acid were used. In April 1948, the J. R. Osborn well of the Rouge Oil Co. was treated with 5,000 gallons of acid. Before treatment the well was producing 1¼ barrels of oil per day from the Trenton. After acidization it produced 250 barrels of oil the first day, and nearly 2 months later it was reported to be producing 140 barrels a day. Subsequently another well was acidized, also with good results. It would appear from this that no well drilled in the Jonesville district that has good shows of oil in the limestones of the Trenton, Eggleston, or Hardy Creek should be abandoned as a dry hole until the shows have been acidized in a thorough manner.

LOGGING OF WELL CUTTINGS

Cable tools have been used in all wells drilled in Lee County, and this practice will probably continue. Logging of the cuttings from cable-tool wells presents no particular problems. Many of the formations of the Jonesville district are sufficiently distinctive that the contacts between them can be readily recognized. This is particularly true of formations from the Hardy Creek limestone to the top of the column. Formation contacts from the Hardy Creek limestone downward are much less easy to recognize. In the limestone formations underlying the Hardy Creek, the lithologic differences that distinguish the formations are accentuated by weathering at the surface and are much more obscure in the fresh rock. Furthermore, such features as thickness of bedding, presence of fossils such as *Stromatocerium*, and presence of scattered chert nodules may be undiscernible in cuttings. In the dolomitic formations of the Knox group, the approximate contacts between the Copper Ridge and Chepultepec dolomites and between the Chepultepec and Longview dolomites are normally recognizable with fair accuracy, but the contacts between the Longview and Kingsport dolomites and between the Kingsport and Mascot dolomites are likely to be obscure.

The major lithologic differences between contiguous formations have been described in the chapter on stratigraphy and are not repeated here. In the sections that follow, however, useful criteria for recognition in well cuttings of the formations and of certain horizon markers within formations are described briefly, with particular emphasis on those criteria that are not readily apparent from a reading of the descriptions of the formations in the stratigraphic chapter.

Hancock dolomite.—If present in wells, the Hancock dolomite is likely to be at the top of the stationary block, directly beneath the Pine Mountain fault and below the Maynardville limestone or the Copper Ridge dolomite that form the base of the overthrust block. In some determinations of cuttings from wells in the Rose Hill district, the Hancock has not been distinguished from dolomite of the Maynardville or Copper Ridge, and hence the Pine Mountain fault has erroneously been drawn at the contact between the Hancock dolomite and the Clinton shale. Consideration of the following points will be helpful in making a correct interpretation. If a full thickness of the Clinton shale is present in a well and if the overlying beds begin with a thin sandstone that is coarser than that of the Clinton, succeeded by 10 to 20 feet of limestone and then by light-colored fine-grained dolomite, these beds above the Clinton belong to the Hancock dolomite. The top of the Hancock dolomite is clear where Upper Devonian shale normally overlies the Hancock or where coarse-crystalline medium-brown dolomite ("stinkstone") of the lower part of the Copper Ridge overlies it above the Pine Mountain fault. Where dolomite of the Chances Branch dolomite member of the Maynardville limestone overlies the Hancock dolomite along the Pine Mountain fault, the contact between the two is determinable by evidence of faulting in the cuttings, such as slickensided and weathered chips, and by an abundance of white crystalline carbonate derived from veins.

Clinton shale.—The Clinton shale is easily recognized by its predominance of interbedded red and green shale and fine-grained quartz sandstone. A few chips of red hematite coming from an iron-ore bed may be present near the base of the formation. The base is normally a few feet below the lowest red shale and above the Clinch sandstone, which is consistently coarser than any except very rare beds of sandstone in the Clinton.

Clinch sandstone.—The Clinch sandstone consists of interbedded medium-grained sandstone and green and gray shale. The contact between the Poor Valley Ridge member and the Hagan shale member is drawn at the horizon above which cuttings consist largely of sandstone and below which they consist almost entirely of green and gray shale.

Sequatchie formation.—The Sequatchie formation consists of interbedded maroon and greenish-gray calcareous siltstone and mudstone. A few fossil fragments and a very little crystalline calcite are found in the cuttings.

Reedsville shale.—Gray slightly gritty shale interbedded with crystalline limestone makes up the Reedsville shale. A few samples contain more than 30 percent of limestone. Fossil fragments of bryozoans and brachiopods are common.

Trenton limestone.—The cuttings of the Trenton limestone are predominantly crystalline and contain numerous fossil fragments. The upper part of the formation is of limestone that is light brown in cuttings; the lower part is of limestone that is dominantly gray. There is much white calcite throughout. A bed of light-gray to grayish-white bentonite is persistent about 75 feet above the base of the formation. The base of the formation is determined by an abrupt change from the medium- to coarse-crystalline gray limestone of the Trenton to the fine-grained and some fine-crystalline tan limestone of the Eggleston.

Eggleston limestone.—The upper and lower big bentonite beds of the Eggleston limestone are always very conspicuous. The upper beds are about 9 to 15 feet below the top of the formation and the lower beds 50 to 60 feet below the top. Both bentonite beds slough off into the hole and contaminate samples for several tens of feet below the horizons of the bentonites. The top of the middle member is at the top of the lower big bentonite bed. The top of the lower member is at the change from tan dense limestone to greenish-gray calcareous mudstone.

Hardy Creek limestone.—The Hardy Creek limestone is tan and dense in cuttings. Chert that characterizes the formation at the surface is likely to be absent in the cuttings because the zones of chert nodules are few and the nodules are quite widely spaced; hence they are likely to be missed entirely by the drill.

Ben Hur limestone.—The Ben Hur limestone is difficult to distinguish from the overlying Hardy Creek limestone and the underlying Woodway limestone, but it is somewhat darker brown, and it appears less dense.

Woodway limestone.—Fragments of bryozoans in the fossiliferous zone at the top of the Woodway limestone help to determine the contact with the Ben Hur. The contact of the Woodway with the underlying Hurricane Bridge limestone is almost impossible to locate accurately because there is no abrupt lithologic change at the contact and because *Stromatocerium* is not recognizable in well cuttings even if the drill happens to penetrate a specimen. In practice, the approximate position of this contact has been calculated on the basis of stratigraphic thicknesses of the Woodway and Hurricane Bridge limestones.

Hurricane Bridge limestone.—Cuttings of the Hurricane Bridge limestone are predominantly of very pure, very dense, tan limestone, but have some chips of white crystalline calcite (birdseyes) and of less-pure, fine-grained limestone. None of the argillaceous zones that are yellow or red at the surface are conspicuous in the cuttings, but zones of somewhat darker brown limestone in several wells probably represent the argillaceous zones.

Martin Creek limestone.—The upper part of the Martin Creek limestone is of tan or light-brown limestone with an occasional chip of chert. The lower part is darker-brown limestone with fairly abundant chips of chert. The contact with the overlying Hurricane Bridge limestone is vague. The contact with the underlying Rob Camp limestone is normally recognizable by an abrupt change from brown limestone that may be coarse crystalline (fragmental) to tan limestone that is very dense and very pure.

Rob Camp limestone.—Cuttings from the Rob Camp limestone consist almost entirely of very dense, very pure, tan cryptocrystalline limestone with occasional chips of white crystalline calcite (birdseyes). One or two samples containing a few chips of chert may be included in the Rob Camp because the formation contains chert-bearing zones in the overthrust block in the central and the western parts of the Jonesville district and may also contain them in the stationary block. The contact with the underlying Poteet limestone is vague.

Poteet limestone.—The upper part of the Poteet limestone is tan dense cryptocrystalline or fine-grained limestone with an occasional chip of chert. The lower part is light- to medium-brown limestone with fairly common chips of chert, and it may contain a few feet to a few tens of feet of medium- to coarse-crystalline (fragmental) limestone at the base.

Dot limestone.—Tan dense cryptocrystalline or fine-grained limestone without chert composes the upper part of the Dot limestone. This is mixed with tan fine-crystalline dolomite in the middle part; and tan fine-crystalline dolomite predominates in the lower part. The base may be marked by a few chips of chert.

Mascot dolomite.—The Mascot dolomite is dominantly fine-crystalline white to tan dolomite in the upper part and is dominantly medium- to coarse-crystalline nearly white dolomite in the lower part. Chips of white non-oolitic chert are abundant in some samples. There are a few sand grains in some samples and abundant sand grains in a few samples. Numerous chips of green shale are very conspicuous in many samples. Green shale is present but not nearly so abundant in the underlying Kingsport dolomite, and it is rare in the overlying dolomite of the Dot limestone.

Kingsport dolomite.—Almost all of the Kingsport dolomite is white, medium- to coarse-crystalline dolomite. A few sand grains and a few chips of non-oolitic chert are present in some samples and a little green shale in a few samples.

Longview dolomite.—The Longview dolomite is mostly white medium-crystalline dolomite, but it contains some fine-crystalline dolomite. Chips of white non-oolitic chert are common, and there are also a few sand grains but almost no green shale.

Chepultepec dolomite.—The Chepultepec dolomite is characterized by tan or light-brown dolomite which appears to be less pure than the overlying Longview dolomite, but the Chepultepec contains some white dolomite like that of the Longview. It also contains occasional chips of white or light-gray chert, some of which are oolitic. Sand grains are numerous in many samples in the lower half of the formation and are present in a few places in the upper half. The top of the formation is placed at the top of the highest conspicuous sandy zone. If there is no conspicuous sandy zone, the top is placed above the brown dolomite of the Chepultepec and below the cherty white dolomite of the Longview. The base of the formation is placed at the base of the lowest conspicuous sandy zone. It is overlain by brown and white dolomite that is much more sandy and less cherty than the underlying white dolomite of the Copper Ridge.

Copper Ridge dolomite.—The upper part of the Copper Ridge is composed mostly of white dolomite which is fine- or medium-crystalline and which contains fairly abundant chert chips in some samples. Some of the chert is oolitic. The lower part is dominantly light- to medium-brown medium- and coarse-crystalline dolomite, with a little oolitic chert.

Maynardville limestone.—The Chances Branch dolomite member of the Maynardville limestone is readily distinguished from the lower part of the overlying Copper Ridge dolomite by its light-gray to white color and finer-grained texture. The Chances Branch dolomite member is difficult to distinguish from the Hancock dolomite, with which it may be in fault contact as previously described in the section on the Hancock dolomite. The Low Hollow limestone member of the Maynardville is light-gray to grayish-white fine-grained limestone. The Maynardville limestone apparently is much less commonly present at the base of the overthrust block in the Jonesville district than in the Rose Hill district.

Older (Pre-Maynardville) formations.—Pre-Maynardville formations are not likely to be present in the overthrust block anywhere in the Jonesville district. In the stationary block they are probably more than 6,000 feet beneath the surface everywhere in the district. Hence they are not likely to be drilled here. The general character of the pre-Maynardville formations is described on page 14.

IRON

HISTORY

Thin beds of hematitic iron ore in the Clinton shale were mined intermittently in the Jonesville district in the last century, possibly beginning as early as 1825. The ore was hauled to nearby forges or furnaces near Rose Hill and Pennington Gap. When the valley line of the Louisville and Nashville Railroad was built about 1890, many mines were opened along the outcrop of iron-ore beds of the Clinton on the north slope of Poor Valley Ridge. Mining was most active during the early years of the 20th century, but a few mines continued to operate almost up to the first World War. Holden (1907, pp. 465–467) describes six groups of mines that were operating in 1907 in the Jonesville district. Mining of the thin low-grade ores of the Clinton and operation of small local furnaces to treat the ore became uneconomic with the discovery and exploitation of the rich abundant iron ores of the Lake Superior region and the rise of the great iron- and steel-making centers of the East and Midwest. Of all the numerous mines formerly working iron ores of the Clinton in the Appalachian states, only those near Birmingham, Ala., have been able to continue operations up to the present time because of unusually thick ore beds, coal, and fluxing limestone nearby, and because of the fact that Birmingham offers a large market for the iron and steel. It is unlikely that it will again be profitable to work any of the ore beds of the Clinton in the Jonesville district in the foreseeable future.

DESCRIPTION OF IRON-ORE BEDS

All of the mined beds of ore in the Jonesville district are in the lower part of the Clinton shale and lie on the north slope of Poor Valley Ridge or of the unnamed curving ridge of Clinch sandstone and Clinton shale east of Ben Hur. Iron-ore beds of significant thickness are either absent or unexposed along almost all of Wallen Ridge, but some float from an iron-ore bed of Clinton was found in the extreme eastern part of the Jonesville district at the point marked Fe on plate 1.

Holden (1929, p. 37) states that there are three known seams of ore along Poor Valley Ridge, but identification and tracing of the different seams is now almost impossible because of caving of the old workings in the mines and because of a heavy cover of float of Clinch sandstone in the intervals between the groups of mines. In the completely exposed section of the lower part of the Clinton at Hagan and also in the moderately well exposed section of the lower part of the Clinton along the railroad northwest of Ben Hur, only one bed of ore was seen. At the former locality the ore bed is from 5 to 9 inches thick and lies 5 feet above the base of the Clinton. At the latter place the ore bed is 3 feet thick and lies 3 feet above the base of the Clinton. Because of this close accordance in stratigraphic location and because beds of iron ore at about this horizon have been mined at many places between Hagan and Ben Hur, there is believed to be one persistent bed of iron ore just above the base of the Clinton along Poor Valley Ridge from the west edge to the north border of the Jonesville district. Other lenticular beds may, however, be locally present higher above the base of the Clinton. The thickness of the ore bed or ore beds that were mined is in places less than 1 foot, as in the mines just above and to the west of the railroad cut at Hagan, and the thickest bed that has been seen is the 3-foot bed at Ben Hur.

The Clinton ore is of the type that has been called oolitic ore or flaxseed ore. It consists predominately of flattened pellets of hematite in a matrix of hematitic mud. Some of the ore contains numerous rounded grains of quartz sand, and even the nonsandy ore contains high percentages of silica. Fossils, principally *Coelospira* (*Anaplotheca*) *hemispherica* and ostracods, are common in some layers but absent in most of the ore. When fresh, the ore is cemented by calcium carbonate. This is dissolved away in the zone of weathering, causing the near-surface ore to be soft and crumbly and also proportionately enriched in iron.

Holden (1907) gives five analyses of ore that was being shipped from mines in the Jonesville district in 1907. The highest and lowest percentages of metallic iron are 43.20 percent and 34.01 percent. The average of the five analyses, which may be taken as a fair average of the ore that has been mined in the district, is as follows:

	Percent
Metallic iron	39.28
Silica	26.90
Phosphorus	.30

Beds of iron ore similar to those in the Clinton are also present in the Clinch sandstone along Poor Valley Ridge in the western part of the Jonesville district. One of these beds is 5 inches thick and lies 35 feet above the base of the Hagan shale member of the Clinch at Hagan, and another bed is 4 inches thick and lies 31 feet below the top of the Poor Valley Ridge member. Both appear to be of lower grade than the ore bed at the base of the Clinton, and neither of these two nor any other ore bed of the Clinch has been mined in the Jonesville district.

A little hematitic iron has also been found in the basal dolomitic beds of the Dot limestone along Dry Creek just below the mouth of Kinzer Hollow. The occurrence consists of pebbles of red hematite scattered over a small area. They seem to have been derived from the bedrock rather than to have been formed as nodules in residual soil. The iron-rich bed or lens that supplied the pebbles was not found. A small test pit was dug at the point of greatest concentration of pebbles on the surface but did not reach bedrock. The occurrence has no commercial significance.

IRON MINES

The iron mines are in groups along the back side of Poor Valley Ridge. The abandoned cuts are numerous from the west edge of the district to a point half a mile east of Hagan. No mines were found in the 9-mile stretch from this point to a point 1 mile east of Ocoonita, but mines are again abundant from here to the place where Poor Valley Ridge passes beyond the north edge of the district. Two sets of mines lie on the north and northwest slopes of the unnamed ridge of Clinch and Clinton rocks east of Hagan. The easternmost of these sets was named the Lavine mine, and the other appears to have been unnamed. Of the mines along Poor Valley Ridge, those on opposite sides of the Ben Hur gap seem collectively to have been named the Ben Hur mine, those 1½ miles east of Ocoonita were named the Truro mine, the one a mile east of Ocoonita was named the Noes Siding mine, those east of Hagan gap were collectively named the Grabill mine, and those west of Hagan gap were named the Boones Path mines. The Boones Path mines are said to have been the largest in the district and also to have produced the best grade of ore.

The abandoned mines now appear as cuts paralleling the ridge crest and are from a few score feet to several hundred feet long. The cuts are now less than 15 feet deep because the walls have slumped, but they were originally much deeper. At some mines the ore beds were mined underground by following them down dip. Holden (1907) states that the ore bed at the Ben Hur mine was followed 150 feet down dip and that the ore bed at the Noes Siding mine was followed 225 feet down dip. At most of the mines the dip of the ore beds is from 35° to 65°.

CRUSHED STONE

In numerous places in the Jonesville district limestone and dolomite have been quarried for crushed stone to be used on the highways. The largest of these quarries are as follows: two in Woodway, both of which are in the Hurricane Bridge limestone; two northeast of Dot, one of which is in Ben Hur limestone and the other in Hardy Creek limestone; one west of Ben Hur in the Woodway limestone; one along Fleenortown Creek west of Jonesville, in the Poteet and Martin Creek limestones; one at the mouth of Caney Hollow in dolomite and limestone of the uppermost Mascot dolomite and lowermost Dot limestone; one at Hurricane Bridge in the same beds; one west of Bethel in the Woodway limestone; and one just above the mouth of Hardy Creek in the Poteet and Hardy Creek limestones. Of these, the only quarries that were active in the summer and fall of

1947 were the northeastern of the two at Woodway and the one at Hurricane Bridge. Both supplied crushed stone of varying sizes for local use on the roads. There is a great abundance of limestone and dolomite in the district suitable for highway use or as aggregate in concrete, but local demand is small and the expense of shipping such a bulky, low-value product prohibits long-distance haulage.

SAND

Deposits of commercial sand and gravel, probably the commonest and most useful of construction materials, are almost nonexistent in the Jonesville district. Only two deposits have been worked, both on a very small scale. One of these is a deeply-weathered zone of very friable dolomitic sandstone in the middle of the Mascot dolomite. At the quarry, half a mile southwest of Ben Hur, the zone is 6 feet 3 inches wide and dips 52° to the northwest. It has been followed into the hillside along a cut that is 20 feet long and, at the back face, 12 feet high. A wooden tramcar, which ran on wooden rails from the back of the cut out onto a short trestle, was used to load the sandstone into trucks. The pit does not appear to have been worked for several years.

The other quarry is on the southwest side of U. S. No. 58 at the crest of Wallen Ridge. Here a zone of very massive-bedded sandstone 9 feet thick is in the lower part of the Poor Valley Ridge member of the Clinch sandstone. The beds dip 37° to the southeast. They have been quarried in an open cut that is only a few feet deep, and the stone has been crushed for sand. The quarry was not operated in 1947, but it apparently is not totally abandoned and probably is still worked from time to time.

Undoubtedly there are other places where thick zones of sandstone in the Mascot dolomite and Clinch sandstone could be worked, but quarrying bedrock sandstone for sand, even though the sandstone is considerably weathered, is much more expensive than working alluvial sand deposits. No commercial deposits of alluvial sand or gravel are known along the Powell River. The alluvium of the low terraces seems at the surface to be more silty than sandy, but layers of sand and gravel may be interbedded with the silt. If such exist, they could easily be found by testing the deposits of the low terraces with an auger. Possibly also some of the sandy and pebbly alluvium of the middle terraces may be thick enough to be workable, and this could also be determined by auger holes. The high terrace deposits are thought to be too thin to offer much chance of workable sand or gravel deposits.

CEMENT

The Jonesville district contains abundant limestone that is sufficiently free of impurities, and abundant shale that is suitable to mix with the limestone to obtain the proper composition, for manufacture of Portland cement. Bassler (1909, pp. 246–257) discusses the cement resources of Lee County, and gives analyses of some of the Ordovician limestones that might be suitable for cement. Unfortunately one of the prerequisites of successful cement plants is that they be near large urban centers so that the cost of shipment of the finished product can be kept to a minimum. The Jonesville district does not fulfill this requirement, so it could hardly compete in the manufacture of cement with other regions that are equally favored geologically and more favored geographically.

CHEMICAL LIME

High-calcium limestone for industrial uses—such as for fluxing stone, for the manufacture of calcium carbide, for lime, and also for use as agricultural limestone—is probably present in the Jonesville district in quantities sufficient to have commercial significance. The greatest thickness of high-calcium limestone appears to be in the Rob Camp limestone. In the Hickory Flats-Woodway region the Rob Camp limestone is at the surface over broad areas. Almost all of it is a tan, very dense, massive-bedded, apparently very pure limestone. No analyses have been made of the Rob Camp limestone in this region, but two analyses of apparently almost identical limestone from the Rob Camp at Hagan and near Cumberland Gap showed 83 percent and 92 percent calcium carbonate, respectively. The larger figure is thought by the writers to be much nearer the probable average composition of the Rob Camp limestone than the smaller figure. Near Woodway the Rob Camp limestone is 91 feet thick, of which all except two thin chert-bearing zones appears to be high-calcium limestone. At Hagan, the Rob Camp limestone is about 72 feet thick; but here, as previously noted, an analysis of a supposedly representative sample of the formation showed it to be much lower in calcium carbonate and higher in silica than was to be expected.

Other formations besides the Rob Camp also contain thick zones of limestone of high purity. These zones are, in many places, several scores of feet thick. They are especially thick and apparently are especially high-grade in the upper part of the Dot limestone, in the Hurricane Bridge limestone, in the Woodway limestone, and in the Hardy Creek limestone. The middle and upper parts of the Trenton limestone have also been sampled, and analyses of the samples showed about 90 percent calcium carbonate. It is doubtful, however, that shale partings that separate the beds of limestone were included in the analyzed samples.

Samples of high-calcium limestone were collected in the Jonesville district by B. N. Cooper and R. S. Edmundson for the Virginia

Geological Survey and were analyzed by Froehling and Robertson, Inc., of Richmond. All samples were collected from localities near the Louisville and Nashville Railroad because an industrial plant utilizing the limestone would have to be located on or not far from railroad transportation. The table of analyzed samples follows:

TABLE 3.—*Analyses of limestone from localities in the Jonesville district*

	1	2	3	4	5	6	7
$CaCO_3$	82.58	93.38	94.09	88.39	88.31	91.80	88.72
$MgCO_3$	4.71	2.20	2.60	4.29	2.47	2.65	2.04
Fe_2O_3	.16	.24	.28	.44	.60	.28	.56
SiO_2	8.84	2.28	1.00	4.62	5.62	4.98	7.84
Al_2O_3	2.32	1.12	2.46	1.08	2.04	1.06	1.60

1. Rob Camp limestone at Hagan, 72 feet thick.
2. Massive birdseye limestone No. 5, in Hurricane Bridge limestone at Hagan. 36 feet of beds sampled.
3. Hurricane Bridge limestone along Louisville and Nashville Railroad at Ben Hur. 140 feet of beds sampled.
4. Ben Hur limestone along Louisville and Nashville Railroad west of Ben Hur.
5. Composite of Ben Hur, Hardy Creek, and Eggleston limestones along Louisville and Nashville Railroad west of Ben Hur.
6. Middle part of Trenton limestone along Louisville and Nashville Railroad west of Ben Hur. 262 feet of beds sampled, measuring downward from a point 144 feet below the top of the Trenton.
7. Upper part of Trenton limestone along Louisville and Nashville Railroad west of Ben Hur. 144 feet of beds sampled.

RIVER COAL

In several places along the Powell River, coal has been deposited on bars and flats during high-water stages of the river. The quantity of coal is small and has no commercial significance, but families living near the coal placers are able to collect a winter's supply with very little effort and with no expense.

The coal probably comes down the North Fork of the Powell River from the coal-mining regions of northeastern Lee County rather than down the main stem of the river from the more distant mining part of Wise County. The two branches of the river join south of Pennington Gap within the Jonesville district. No exhaustive search was made for coal placers, but those that were seen are all downstream from the junction. Assuming that the coal was derived from the nearer of the two possible source regions, it has been transported by the river at least 6 miles to the first deposit and at least 35 miles to the one farthest downstream.

When the Powell River is in flood it undoubtedly encroaches on culm heaps from some of the numerous coal mines near the river in the coal regions and washes the slate and coal into the river channel. The slate, being heavier, sinks to the bottom and moves slowly downstream along with the other rock the river is transporting. Coal, however, has a much lower specific gravity. Although it is heavier than water and hence cannot float, it is light enough to be lifted above the river bed by turbulent currents. Thus it moves downstream, at times moving along the river bed and at other times being caught by rising water currents and catapulted upward through the water. The coal accumulates where particularly strong flood currents have been deflected from the main river channel and have lost their velocity as they spread out over floodplains. When the water recedes, the coal is left high and dry on islands, bars, and flats. The largest alluvial deposits of coal cover as much as an acre of land. Of the seven coal placers shown on plate 1, most were only 5–10 feet above the low-water stage of the river during the summer and fall months when the mapping was done. The coal placer above Poteet footbridge, however, is about 20 feet above the river and only slightly below the average level of the low terrace at this point.

The cobbles of coal on the floodplains, bars, and islands are smooth and well-rounded, and most are oval and flattened. Cobbles as much as 10 inches in longest dimension have been seen. The abraded outer surfaces have a dull luster and show crescent-shaped concussion marks. Inside, however, the coal is bright and shiny. All of the coal seen on the bars was of good quality. Slaty coal, being heavier, has not been lifted out of the main stream of the river. Hence the river has acted in the same manner as the hydraulic separators in modern coal breakers that float the good coal across a cone containing an agitated mixture of sand and water but which permit the heavier slaty coal to sink through the mixture. The coal placers along the river are replenished with each high-water stage of the river.

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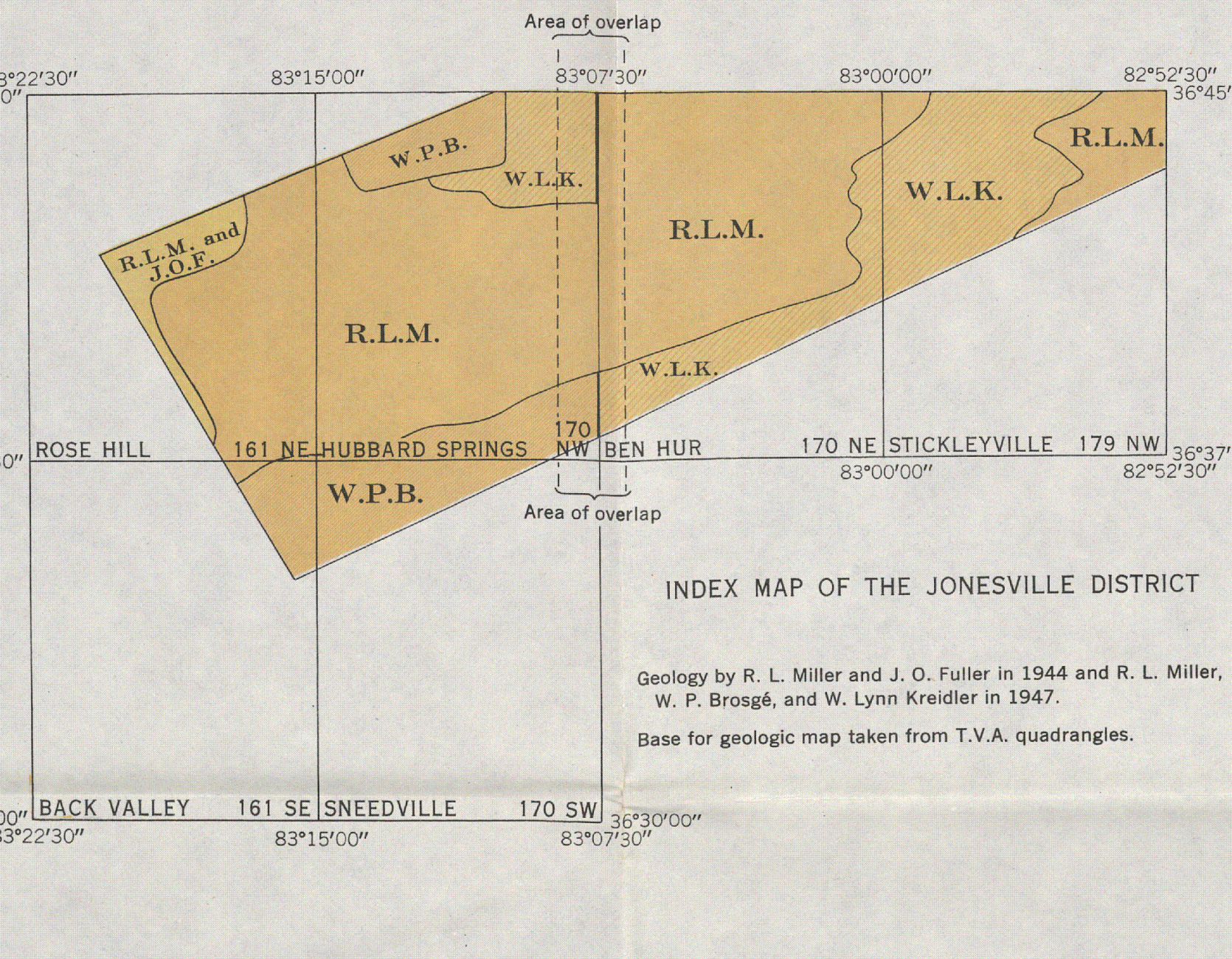

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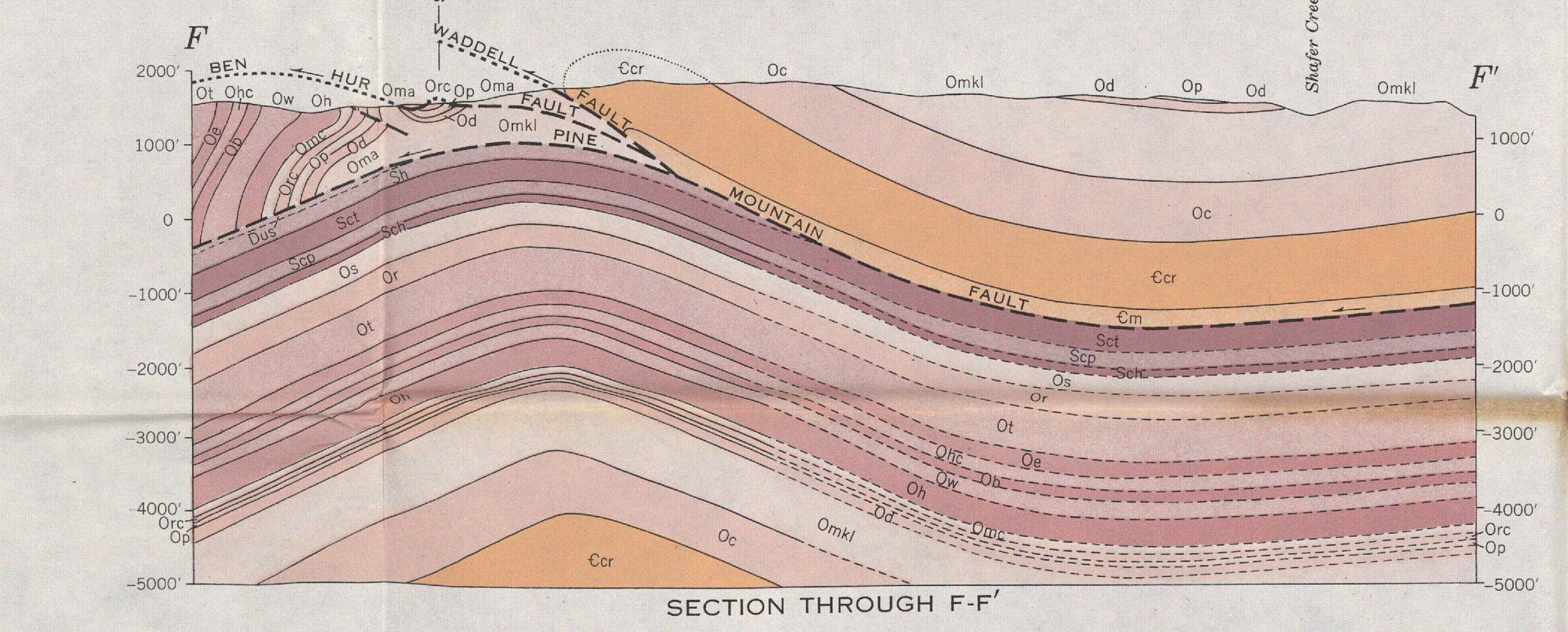

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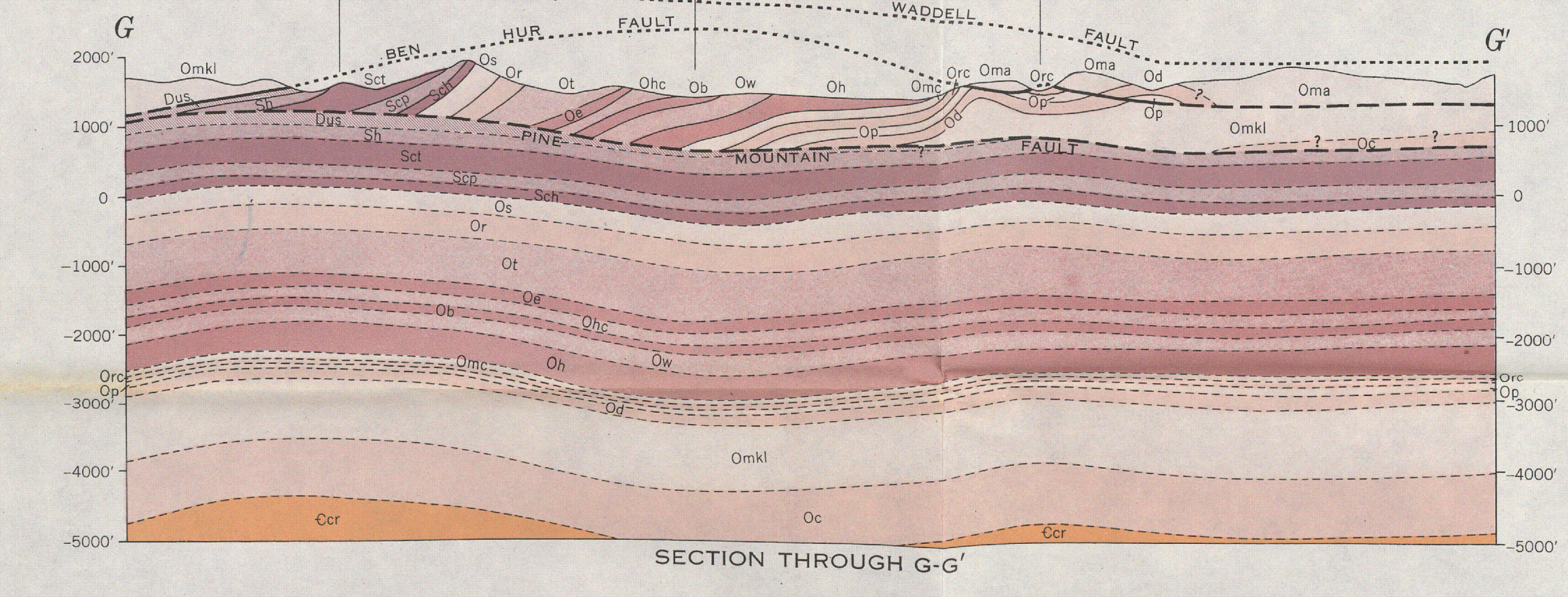

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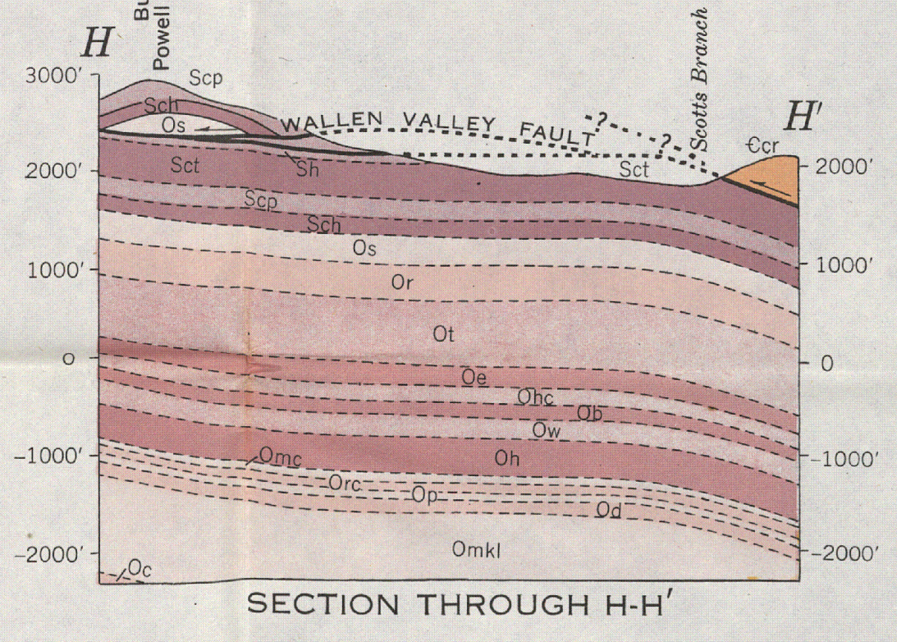

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INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.

GEOLOGIC MAP AND SECTIONS OF THE JONESVILLE DISTRICT, LEE COUNTY, VIRGINIA, AND HANCOCK COUNTY, TENNESSEE

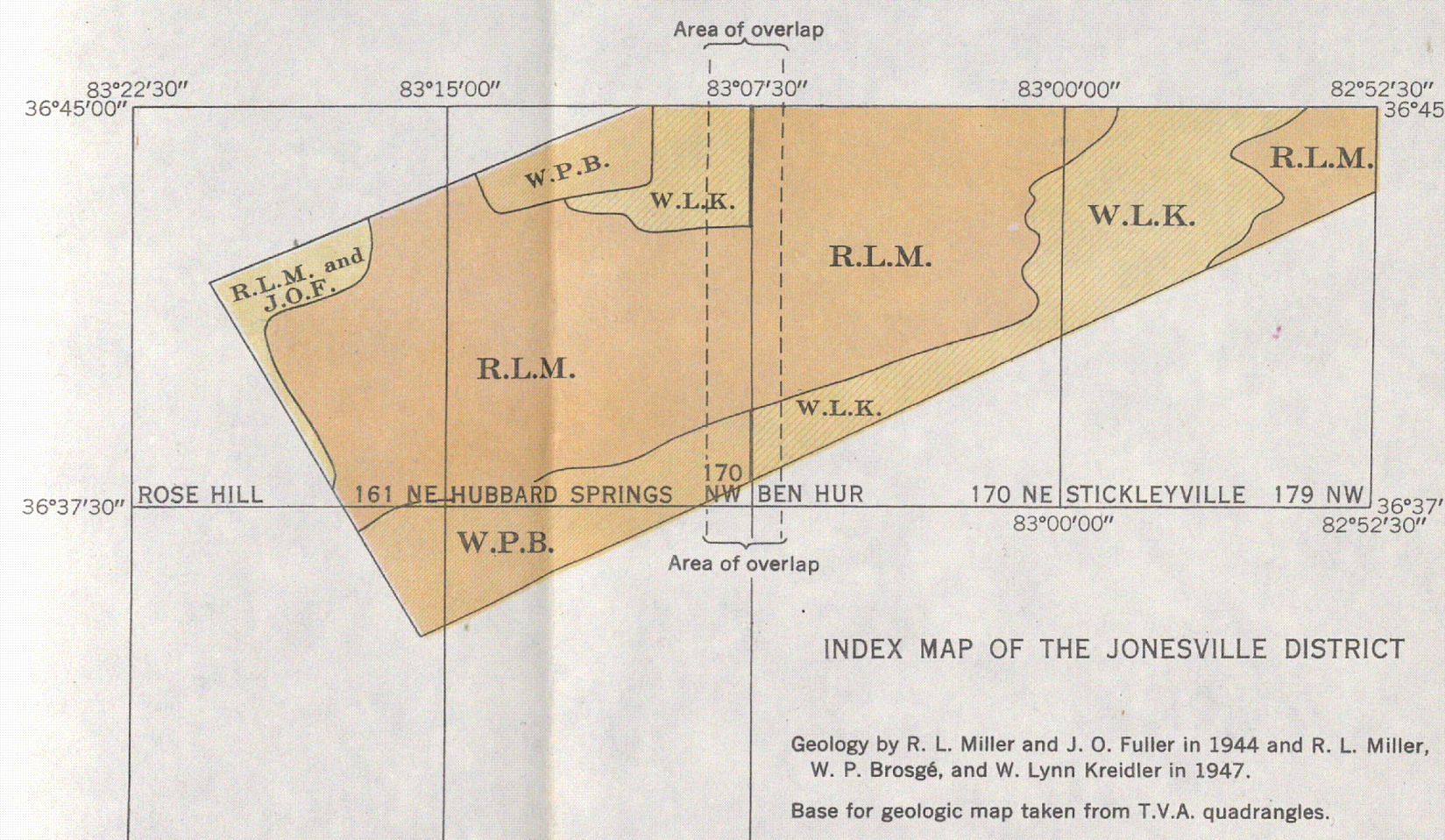
Scale 1:24,000

1 0 4 Miles

5000 0 10,000 Feet

Contour interval 20 feet
Datum is mean sea level

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



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Base for geologic map taken from T.V.A. quadrangles.

EXPLANATION

QUATERNARY

Qal
Alluvium

Qaf
Alluvial fan
In places Qafh and Qafl indicate high-level and low-level fans

Qt
Talus
Extensive cover, largely talus

Qtl 28'
Low terrace
Number indicates altitude above Powell River

Qtm
Middle terrace

Qth Qg
High terrace, Qth; high-level gravels, Qg

DEVONIAN

Upper Devonian

Dus
Upper Devonian shale
Lower part of Chattanooga shale of early writers

SILURIAN

Sh
Hancock dolomite
Same as Cayuga dolomite in Virginia Geological Survey Bulletin 71

Sct
Clinton shale

Scp
Sch
Clinch sandstone
Poor Valley Ridge member, Scp*; and Hagan shale member,* Sch

ORDOVICIAN

Upper Ordovician

Os
Sequatchie formation

Or
Reedsville shale

Middle Ordovician

Ot
Trenton limestone

Oe
Eggleston limestone

Ohc
Hardy Creek limestone
Same as Hardy Creek member of Moccasin limestone in Virginia Geological Survey Bulletin 71

Ob
Ben Hur limestone
Same as lower member of Moccasin limestone in Virginia Geological Survey Bulletin 71

Ow
Woodway limestone
Same as platy member of Lowville limestone in Virginia Geological Survey Bulletin 71

Oh
Hurricane Bridge limestone
Same as redbed member of Lowville limestone in Virginia Geological Survey Bulletin 71

Omc
Martin Creek limestone
Same as Lenoir limestone (after Charles Butts) in Virginia Geological Survey Bulletin 71

Orc
Rob Camp limestone
Same as Mosheim limestone (after Charles Butts) in Virginia Geological Survey Bulletin 71

Op
Poteet limestone
Poteet limestone and Dot limestone shown as Murfreesboro limestone (after Charles Butts) in Virginia Geological Survey Bulletin 71

Od
Dot limestone
Dot limestone and Poteet limestone shown as Murfreesboro limestone (after Charles Butts) in Virginia Geological Survey Bulletin 71

Lower Ordovician

Knox group

Omkl Oma Ok Olv
Mascot, Kingsport, and Longview dolomites
In places Mascot dolomite, Oma *; Kingsport dolomite,* Ok *; and Longview dolomite,* Olv *, have been mapped separately*

Oc
Chepultepec dolomite

CAMBRIAN

Upper Cambrian

Ꞓcr
Copper Ridge dolomite

Ꞓcr Ꞓm Ꞓmc Ꞓml
Copper Ridge dolomite, Maynardville limestone, Chances Branch dolomite member of Maynardville limestone, and Low Hollow limestone member of Maynardville limestone south of Wallen Valley fault
These units not mapped seperately, but each is indicated by corresponding symbol where recognized

Ꞓm Ꞓmc Ꞓml
Maynardville limestone
Chances Branch dolomite member, Ꞓmc *; and Low Hollow limestone member,* Ꞓml*, not mapped separately, but each is indicated by corresponding symbol where recognized*

—c——s—
Geologic contact
Probable error in location less than 200 feet. C *at good exposure of contact. Stromatocerium zone,* s

- - - - - - -
Geologic contact
Probable error in location less than 400 feet

....
Geologic contact
Probable error in location may exceed 400 feet

—F— U D
Fault
Probable error in location less than 200 feet. F *at good exposure of fault.* D*, downthrown side;* U*, upthrown side*

— — — —
Fault
Probable error in location less than 400 feet

....
Fault
Probable error in location may exceed 400 feet

—?——?——
Probable fault

R
Reverse fault
R *on upthrown side*

T
Overthrust fault
T *on overthrust side*

⊥32
Strike and dip of beds

⊥43
Strike and dip of overturned beds

⊕
Horizontal beds

+
Strike of vertical beds

Anticlinal axis

Synclinal axis

——1000——
Structure contours at 200 foot intervals on top of Chepultepec dolomite in overthrust block
Datum is sea level

☼
Dry hole with show of gas

○
Abandoned or dormant well
Did not reach potential oil-bearing formations

⚒Fe
Abandoned iron mine

⚒RM
Quarry for road metal

⚒L
Quarry for lime

⚒S
Quarry for sand

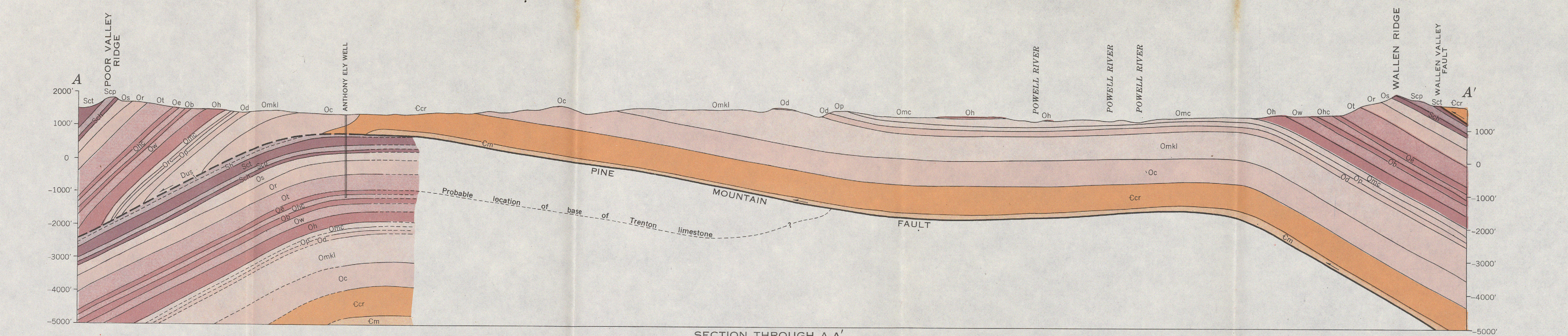
○Dus
Exposure of Upper Devonian shale outside of mapped area

Fig. 4 →
Locality at which photograph or sketch was made showing direction of view, and number of figure in report

LIST OF WELLS

Drilled in the Jonesville district to January 1950

1. D. C. McClure 1
2. Charles Phipps 1
3. M. H. Snodgrass 1
4. Candy Cawood 1
5. Anthony Ely 1



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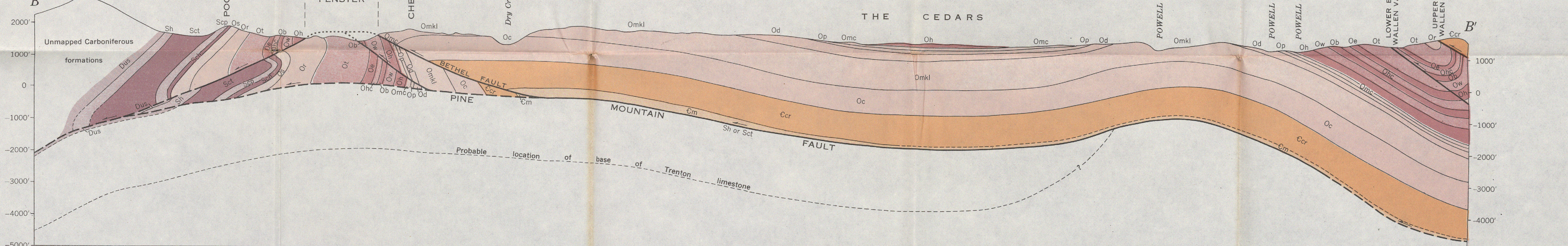

SECTION THROUGH B-B'

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Scale 1:24,000

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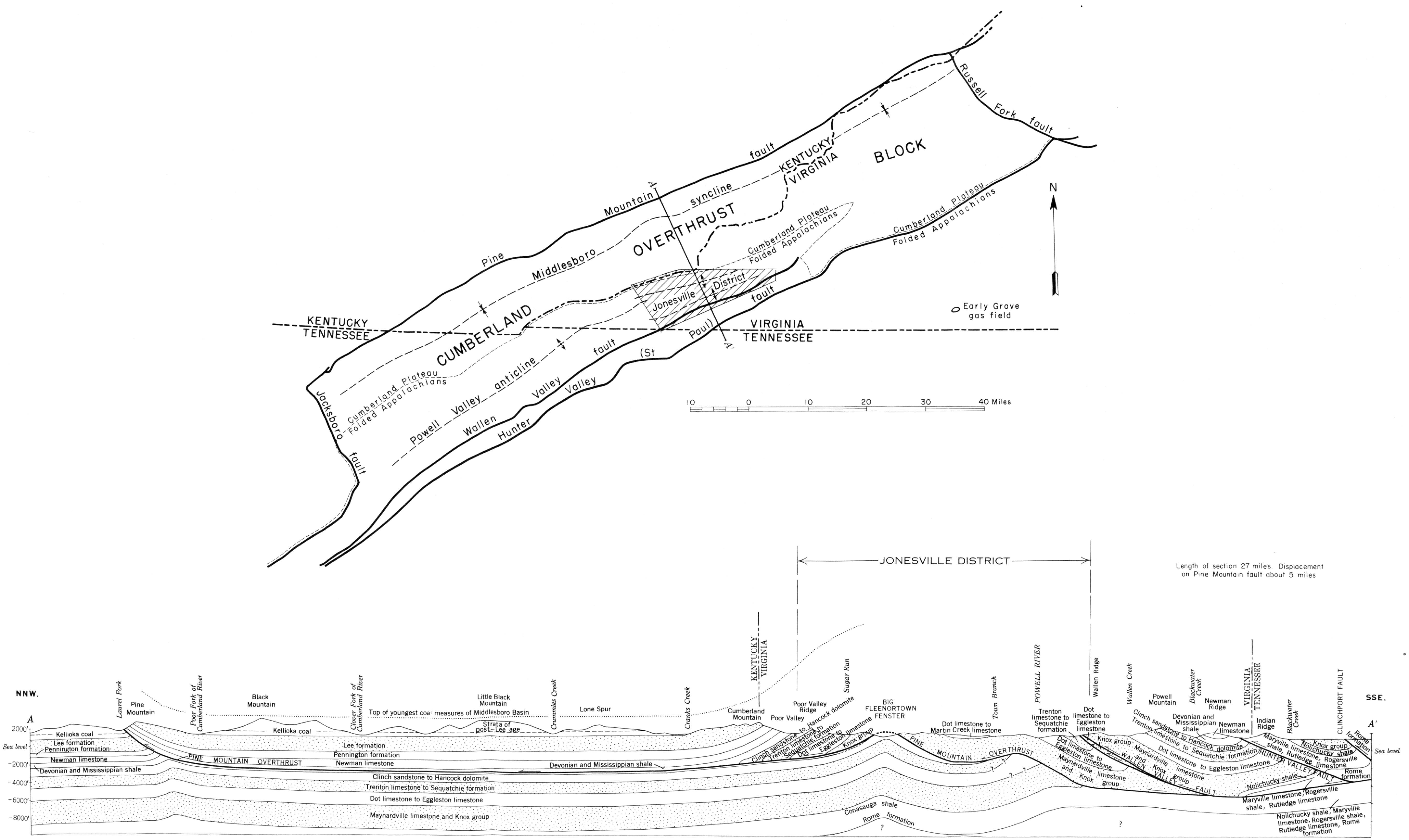
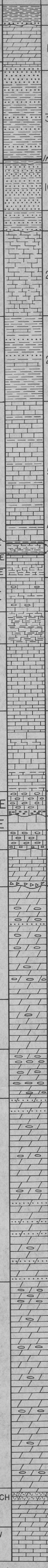
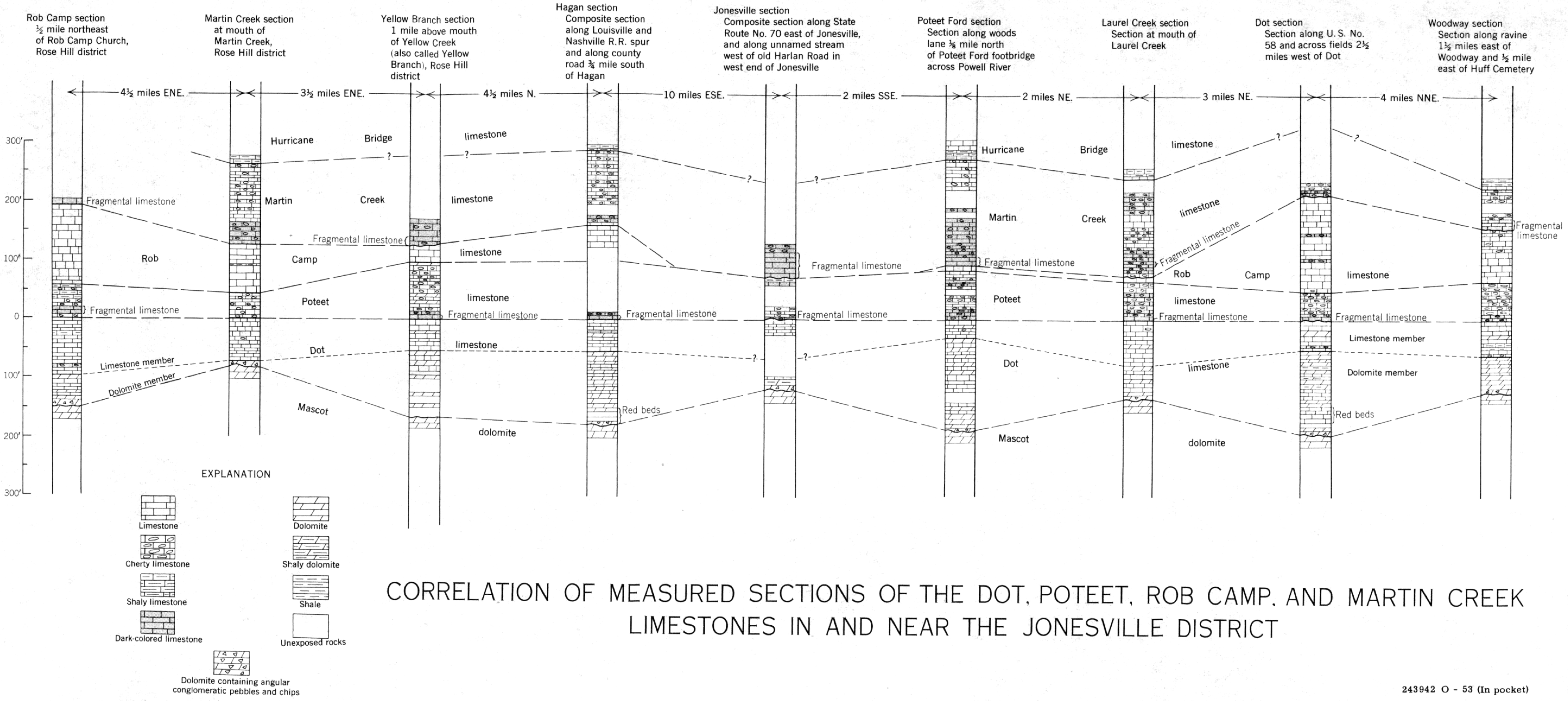


OUTLINE MAP AND GEOLOGIC STRUCTURE SECTION OF THE CUMBERLAND OVERTHRUST BLOCK

AGE			FORMATION AND MEMBER		SECTION	THICKNESS IN FEET	DESCRIPTION
DEVONIAN			UPPER DEVONIAN SHALE			80+	Gray and black fissile shale. Locally has a pebbly sandstone a few inches thick at base. Upper part of this unit not exposed in district.
			UNCONFORMITY				
SILURIAN			HANCOCK DOLOMITE	DOLOMITE MEMBER		168-188	Basal pebbly sandstone, overlain by bluish-gray ribbon limestone or mottled limestone. Upper part consists of massive-bedded, gray, fine-grained dolomite. Formation becomes dominantly limestone at east edge of district. As here used, formation includes only beds of Cayugan age.
				LIMESTONE MEMBER			
			CLINTON SHALE			315-394 Iron bed	Green and red shale, with platy interbeds of fine- and medium-grained sandstone. Zone of massive-bedded medium-grained sandstone locally present at top. One or more beds of hematitic "iron ore" in lower part.
			UNCONFORMITY				
			CLINCH SANDSTONE	POOR VALLEY RIDGE MEMBER		100?-250	Fine- to medium-grained, buff to greenish-white sandstone in beds a few inches to 2 feet thick, with interbeds and partings of green shale. Sandstone dominant in lower part, shale most abundant in upper part.
				HAGAN SHALE MEMBER		65-129	Green shale with a few interbeds of fine-grained sandstone in lower part, and of fine- and medium-grained sandstone in upper part.
			UNCONFORMITY				
ORDOVICIAN	UPPER ORDOVICIAN		SEQUATCHIE FORMATION			274-438	Green and red calcareous siltstone, with colors mottled and interbedded. Contains zones of muddy limestone that are abundantly fossiliferous. Lower part is of Maysville age; remainder of Richmond age.
			REEDSVILLE SHALE			282-358	Gray and greenish-gray shale, with interbeds of fine-grained sandstone and of coarsely crystalline, highly fossiliferous limestone. Shale is predominant, especially in the float.
	MIDDLE ORDOVICIAN		TRENTON LIMESTONE			560-600 *Bentonite*	Coarsely-crystalline, dark-gray, highly fossiliferous limestone with shale partings in lower part; medium-crystalline and finely crystalline, less fossiliferous limestone with shale partings in upper part.
			EGGLESTON LIMESTONE	UPPER MUDSTONE MEMBER		*Bentonites* 145-165	Buff-weathering, earthy, calcareous siltstone composes all of lower member and most of upper member. Middle member consists of thin-bedded, fine-grained pure limestone which is moderately fossiliferous. Two thick bentonite beds are about 12 feet and 55 feet below top of formation, respectively.
				MIDDLE LIMESTONE MEMBER			
				LOWER MUDSTONE MEMBER			
			HARDY CREEK LIMESTONE			93-151	Even-bedded, tan, dense, fine-grained limestone, with abundant and characteristic oval chert nodules in a few beds. Relatively unfossiliferous except for top 10 feet. Named from Hardy Creek, Jonesville district.
			BEN HUR LIMESTONE			127-153	Buff-weathering, shaly and crumbly limestone, with a few interbeds of purer crystalline limestone. Named from exposure in Louisville and Nashville Railroad cut west of Ben Hur.
			WOODWAY LIMESTONE			256-288	Cryptocrystalline tan and gray limestone with interbeds and zones of medium-crystalline limestone. Prominent zone of *Stromatocerium rugosum* at base. Named from exposures on slope of Wallen Ridge east of Woodway.
			HURRICANE BRIDGE LIMESTONE			288-368	Cryptocrystalline, tan and gray, thin-bedded limestone with prominent zones of massive-bedded cryptocrystalline birdseye limestone, and zones of buff- and red-weathering argillaceous shaly limestone. Named from exposures along and near road southeast of Hurricane Bridge.
			MARTIN CREEK LIMESTONE			40-182	Dark-gray and brown, oily-smelling limestone with abundant chert nodules in lower part; tan cryptocrystalline limestone with abundant chert nodules in some zones in upper part. Locally has a zone of coarsely crystalline fragmental limestone at or near base. Named from exposures at mouth of Martin Creek in Rose Hill district (Back Valley quadrangle).
			UNCONFORMITY				
			ROB CAMP LIMESTONE			0-153	Very massive-bedded, very dense, cryptocrystalline, tan and dove-gray limestone with abundant small patches of white crystalline calcite. Zones of thinner-bedded limestone containing chert nodules are present in eastern part of Jonesville district. Named from exposures northeast of Rob Camp Church in Rose Hill district (Colman Gap quadrangle).
			POTEET LIMESTONE			45-97	Gray, brown, and tan, dense, fine-grained limestone with abundant chert nodules. Darker-colored limestone predominant in lower part, lighter-colored limestone predominant in upper part. Locally has zone of coarsely crystalline fragmental limestone at or near base and one or more beds of dolomitic limestone higher up. Named from exposures along lane north of Poteet Ford.
			UNCONFORMITY				
			DOT LIMESTONE			120-193	Dolomitic limestone weathering yellow or red and with characteristic rounded surfaces in lower part; tan, dense, fine-grained limestone in upper part. Normally contains no zones of chert nodules, but locally one or more zones of chert nodules are present near top. Prominent conglomeratic zone of chert and dolomite pebbles at base. Named from exposures along State Highway 70 just west of Dot, but type section taken in Louisville and Nashville Railroad cut at Hagan.
			UNCONFORMITY				
	LOWER ORDOVICIAN	KNOX GROUP	MASCOT DOLOMITE			169-565	White, finely crystalline dolomite in upper part, and interbedded finely and coarsely crystalline dolomite in lower part. Contains abundant non-oolitic, white-weathering chert in beds, lenses, nodules, and masses. Beds of sandstone as much as 10 feet thick locally present in upper part.
			KINGSPORT DOLOMITE			119-272	Light-gray to white, medium-crystalline to coarse-crystalline saccharoidal dolomite. Contains little chert.
			LONGVIEW DOLOMITE			98-272	White, finely crystalline dolomite and white to tan, medium-crystalline dolomite. Abundant white-weathering chert in beds, lenses, and nodules. Chert mostly non-oolitic.
			CHEPULTEPEC DOLOMITE			702-776	Lower part consists of light-brown, medium-crystalline to coarse-crystalline, saccharoidal dolomite and light-gray to tan, finely to medium-crystalline argillaceous dolomite. Prominent sandstone at base, and other beds and lenses of sandstone and sandy dolomite numerous, especially near base. Upper part similar but contains more argillaceous dolomite and less saccharoidal dolomite. Sandstone and sandy dolomite present only near top. Chert sparingly present, mostly oolitic.
CAMBRIAN	UPPER CAMBRIAN		COPPER RIDGE DOLOMITE			840±	Lower part consists of brown and dark-gray, coarsely and medium-crystalline dolomite with pronounced petroliferous odor; upper part consists of white and light-gray, cryptocrystalline and coarsely crystalline dolomite. Thin beds and lenses of oolitic white-weathering chert present throughout, but especially abundant near top.
			MAYNARDVILLE LIMESTONE	CHANCES BRANCH DOLOMITE MEMBER		160-209	Gray, finely crystalline, laminated dolomite with interbedded mottled limestone near base and interbedded dark medium-crystalline dolomite near top.
				LOW HOLLOW LIMESTONE MEMBER		142-172	Gray cryptocrystalline ribbon limestone in lower part and mottled limestone in upper part; interbedded fine-grained dolomite near top. Base not exposed in Jonesville district.

Total thickness of sedimentary rocks 6,360 feet ±

COLUMNAR SECTION OF ROCKS EXPOSED IN THE JONESVILLE DISTRICT

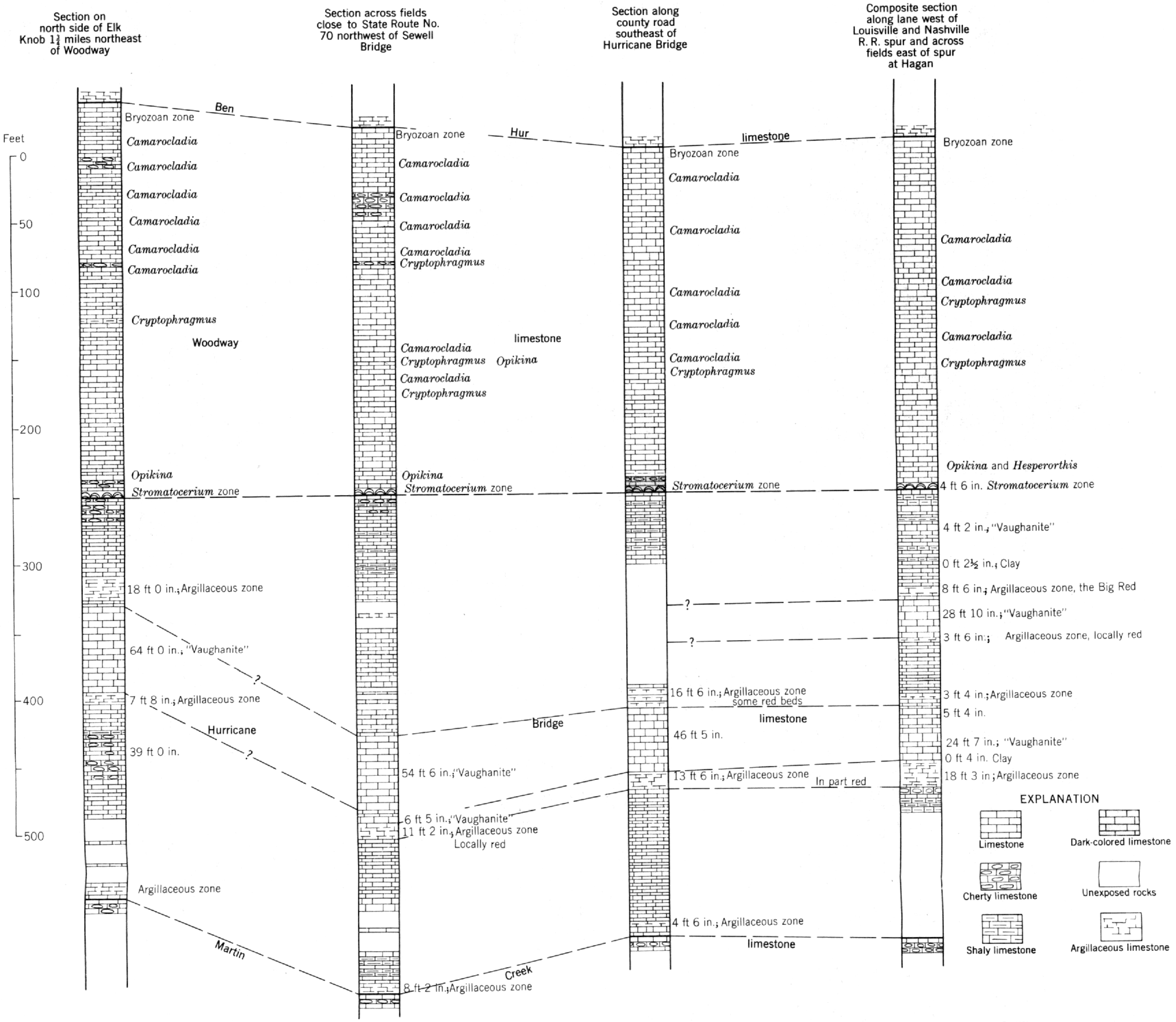


CORRELATION OF MEASURED SECTIONS OF THE DOT, POTEET, ROB CAMP, AND MARTIN CREEK LIMESTONES IN AND NEAR THE JONESVILLE DISTRICT

243942 O - 53 (In pocket)

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BULLETIN 990 PLATE 5

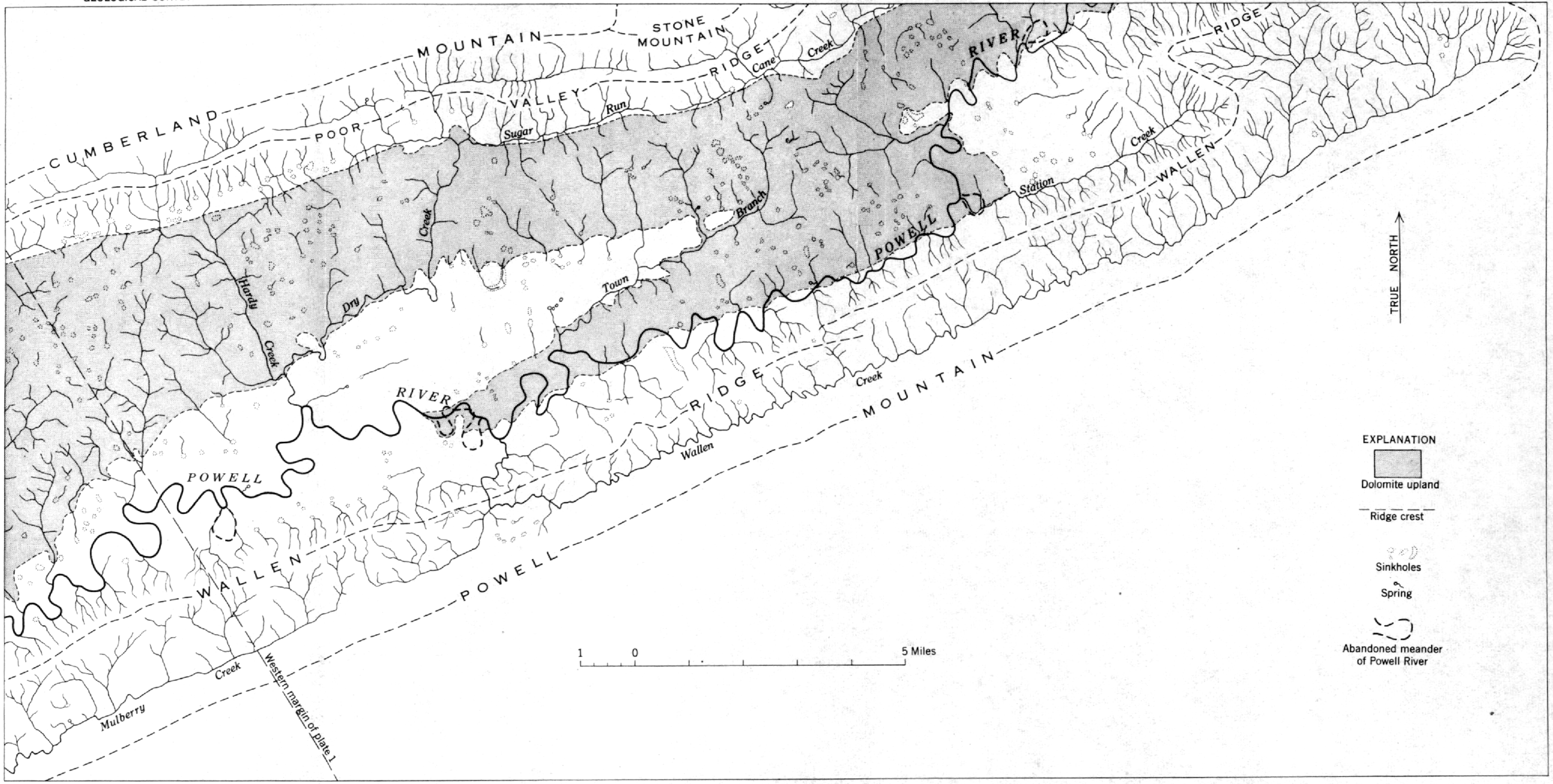


CORRELATION OF MEASURED SECTIONS OF HURRICANE BRIDGE AND WOODWAY LIMESTONES IN JONESVILLE DISTRICT

243942 O - 53 (In pocket)

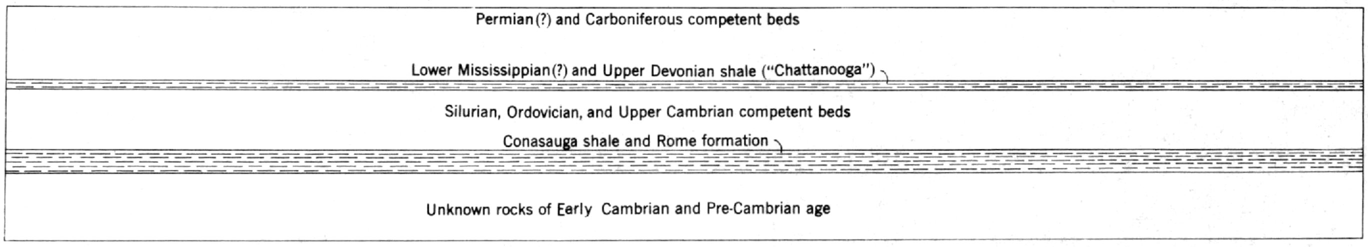
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BULLETIN 990 PLATE 6

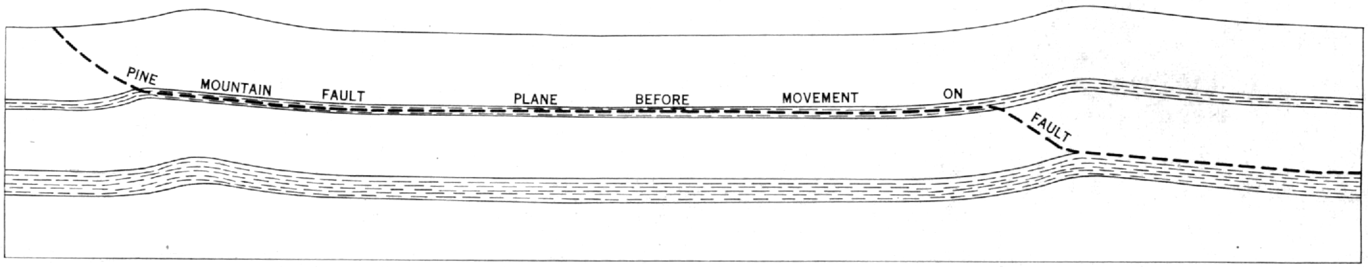


DRAINAGE MAP OF THE JONESVILLE DISTRICT AND ADJACENT AREA TO THE WEST

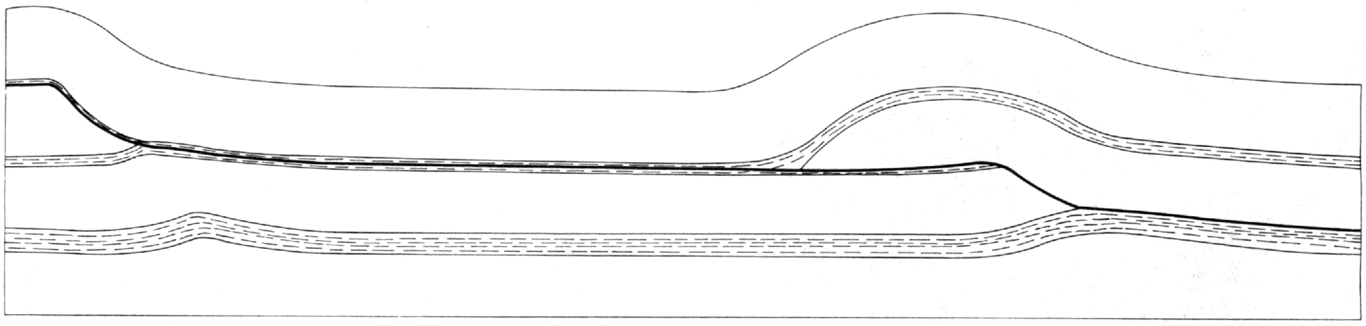
243942 O - 53 (In pocket)



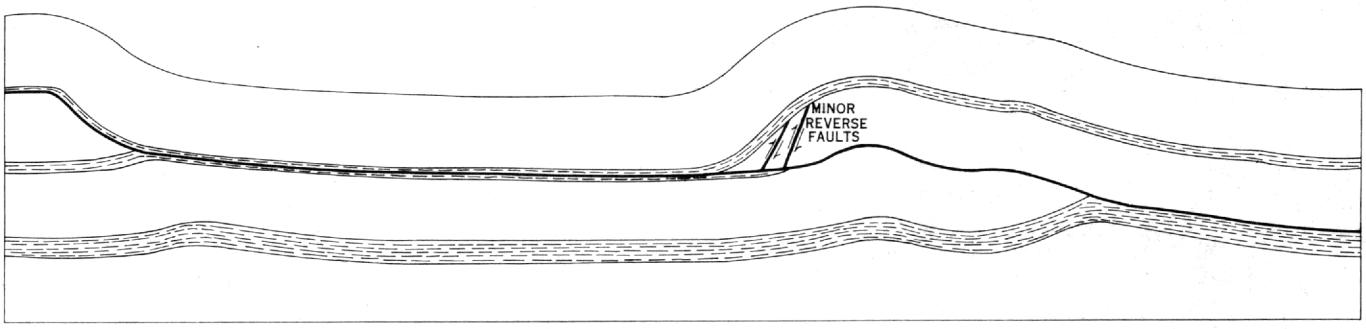
A. AFTER DEPOSITION OF PALEOZOIC SEDIMENTS BUT BEFORE BEGINNING OF DEFORMATION



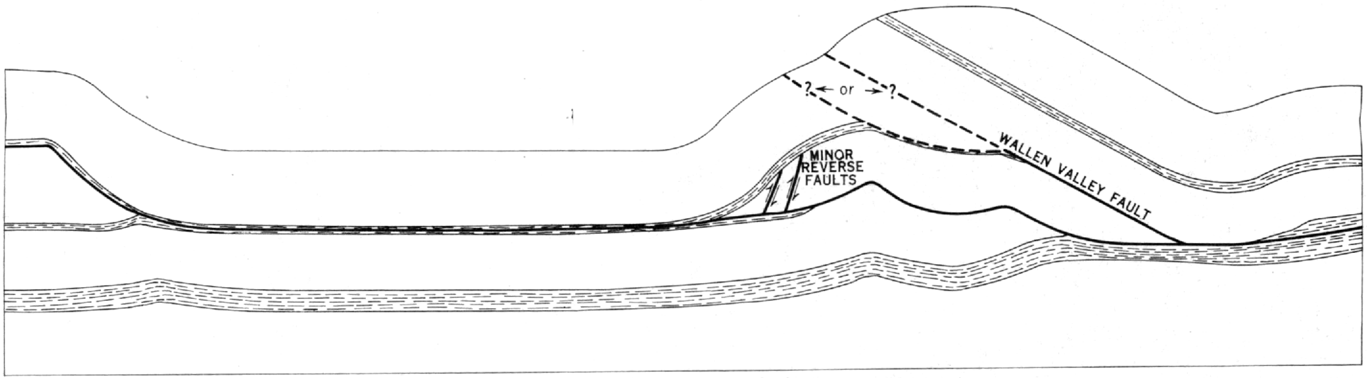
B. AFTER SLIGHT WARPING. POSITION OF INCIPIENT PINE MOUNTAIN FAULT IS INDICATED



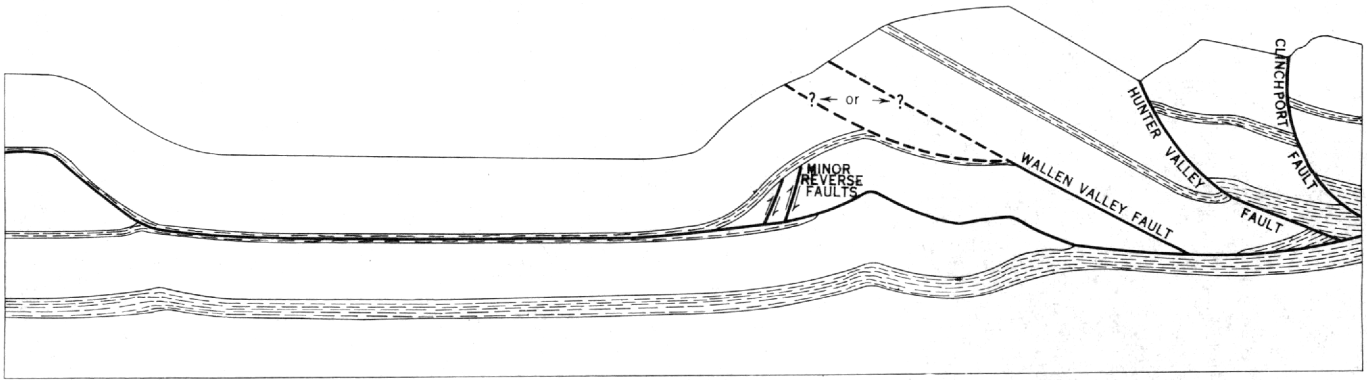
C. AFTER 4 MILES OF DISPLACEMENT ALONG PINE MOUNTAIN FAULT



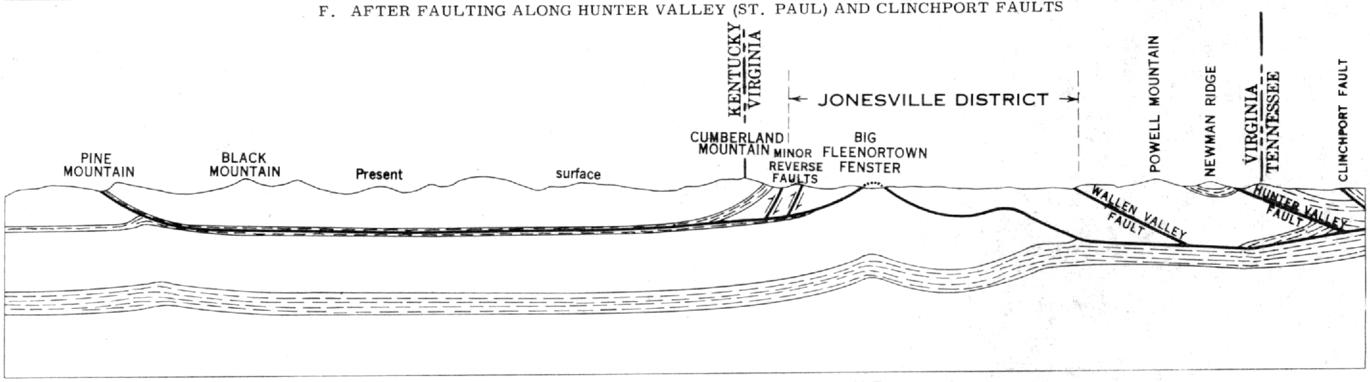
D. AFTER COMPLETION OF MOVEMENT ALONG PINE MOUNTAIN FAULT



E. AFTER FAULTING ALONG WALLEN VALLEY FAULT



F. AFTER FAULTING ALONG HUNTER VALLEY (ST. PAUL) AND CLINCHPORT FAULTS



G. AFTER EROSION TO PRESENT PROFILE

Length of sections 27 miles. No vertical exaggeration. Erosion during the period of deformation has been disregarded

SECTIONS SHOWING THE STRUCTURAL HISTORY OF THE JONESVILLE DISTRICT

243942 O - 53 (In pocket)

INTERPRETATION OF RECORDS OF IMPORTANT WELLS DRILLED IN AND NEAR THE JONESVILLE DISTRICT