STATE OF TENNESSEE

DEPARTMENT OF CONSERVATION

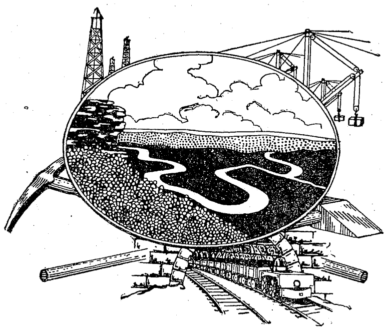
DIVISION OF GEOLOGY

BULLETIN 60

THE CUMBERLAND PLATEAU OVERTHRUST AND GEOLOGY OF THE CRAB ORCHARD MOUNTAINS AREA, TENNESSEE

BY

RICHARD G. STEARNS



NASHVILLE, TENNESSEE

1954

STATE OF TENNESSEE

FRANK G. CLEMENT, *Governor*

DEPARTMENT OF CONSERVATION

JIM McCORD, *Commissioner*

DIVISION OF GEOLOGY

W. D. HARDEMAN, *State Geologist*

CONTENTS

ILLUSTRATIONS

THE CUMBERLAND PLATEAU OVERTHRUST AND GEOLOGY OF THE CRAB ORCHARD MOUNTAINS AREA, TENNESSEE

By RICHARD G. STEARNS
Assistant State Geologist

INTRODUCTION

Geology

For more than 150 years the physiographic region known as the southern Appalachians has attracted the attention of geologists. It is a region in which many fundamental concepts of geology have been developed. The western part of the southern Appalachian region has less structural complexity than the eastern part and consists of a series of semi-district plateaus comprising the physiographic feature known in Tennessee as the Cumberland Plateau.

Gently dipping strata characterizing most of the Cumberland Plateau present such a contrast to the intense structure of the Valley and Ridge province to the east that the plateau formerly was not considered to have been involved in the mountain building processes that produced the complex Valley and Ridge structure. Structural features observed within the plateau were considered to be anomalous and to have only local significance. The Cumberland Plateau is underlain by rocks of the Pennsylvanian system. This physiographic province extends in a northeast-southwest direction across eastern Tennessee from Kentucky into Alabama. Pennsylvanian and other strata dip steeply northwestward along its eastern margin, but throughout most of the plateau strata dip gently southeastward off the flank of the Nashville dome.

To the east of the Cumberland Plateau lies the Valley and Ridge province which is characterized by imbricate faulting and folding. Steeply dipping strata along the eastern margin of the plateau have formerly been considered to mark the western limit of faults and folds of the Valley and Ridge type. There are, however, areas of considerable structural disturbance within the Cumberland Plateau, seemingly isolated from the Valley and Ridge structures. The most prominent of these features are the Sequatchie Valley anticline and the Pine Mountain thrust block (Fig. 1).

The Sequatchie Valley anticline is an asymmetrical fold which is overturned to the west and broken on the west side by a thrust fault throughout most of its length. This single anticline extends for more than 200 miles northeastward from central Alabama to Cumberland County in east-central Tennessee. Near its northeastern end it becomes less prominent and forms a line of low anticlinal mountains called the Crab Orchard Mountains (Fig. 1 and Pl. 1). At the northeast end of the anticline, however, the Emory

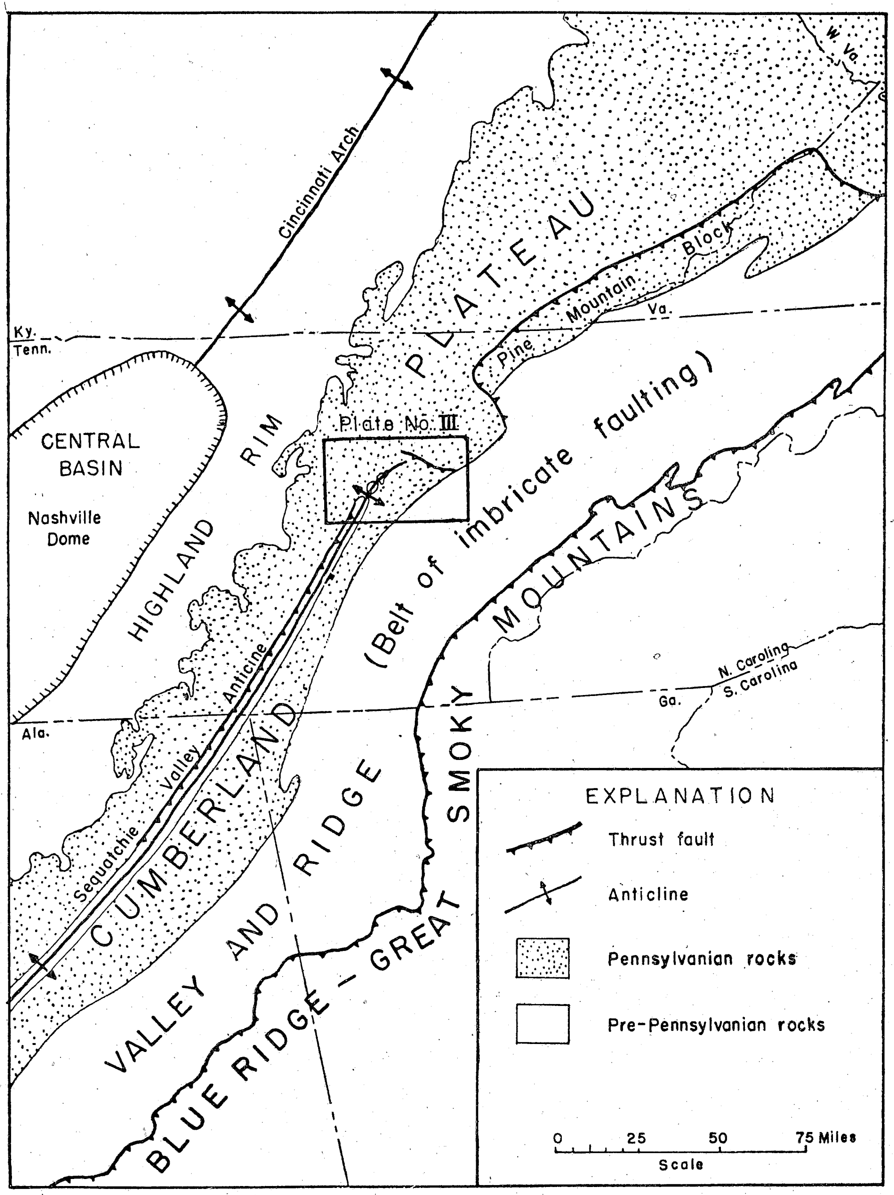


Figure 1. Major Structural and Physiographic Features of the Southern Appalachian Region

River fault zone strikes southeastward nearly at right angles to the anticline, until it merges with the Valley and Ridge province.

The Pine Mountain block is a low angle overthrust sheet which is bounded on the west by the Pine Mountain thrust fault. This fault extends for about 120 miles from Campbell County in northeastern Tennessee northeastward to east-central Kentucky. It is terminated at each end by cross faults which connect the Pine Mountain fault with the Valley and Ridge province. The Jacksboro fault of Campbell County, Tennessee is the southwestern boundary of the Pine Mountain block, whereas the Russell Fork fault of Pike County, Kentucky is its northeastern termination.

In the Lantana area, several miles west of the southern end of the Crab Orchard Mountains, another disturbed zone was recognized. This disturbance was believed to be isolated.

Present Investigation

The unusual structural pattern of the region attracted the interest of geologists in Tennessee, and the writer was encouraged to begin a detailed study. Mapping was begun in the area which includes portions of the Sequatchie Valley anticline and the seemingly isolated Lantana disturbances. This area is included in the Ozone, Hebbertsburg, Dorton, and Fox Creek 7½ minute quadrangles (Fig. 2). For convenience this group of quadrangles will be referred to as the Crab Orchard Mountains area. The writer also made a reconnaissance study of the structural belt between Lantana and Harriman. The detailed study of the structure is being continued by Robert Mitchum, who in the summer of 1951 mapped in detail the Lancing and Camp Austin quadrangles.

Field mapping was done primarily during the summers of 1949 and 1950. The writer mapped the Ozone quadrangle, assisted by J. W. Jewell, in 1949. In 1950 the writer mapped the Hebbertsburg quadrangle while J. W. Jewell and B. Rascoe mapped the Dorton and Fox Creek quadrangles (Fig. 2).

Field work was also carried on at other times during 1949, 1950, 1951, and 1953 including additional visits to the area mapped in detail as well as several weeks of reconnaissance mapping of geologic features brought to light by the detailed work.

Previous Investigations

The earliest reference to the structural geology of this area is by Safford (1869) in his "Geology of Tennessee." Safford was the first to define the Sequatchie Valley anticline and to recognize that the Crab Orchard Mountains are its northeastern termination. He also noted the presence of the outlying Lantana disturbances west of the Crab Orchard Mountains.

The Crab Orchard Mountains and part of the Sequatchie Valley were first mapped by Hayes and Keith as parts of the Kingston (Hayes, 1894) and Wartburg (Keith, 1897) folios. They did not map either the Emory River fault or any of the Lantana faults west of the Sequatchie Valley anticline.

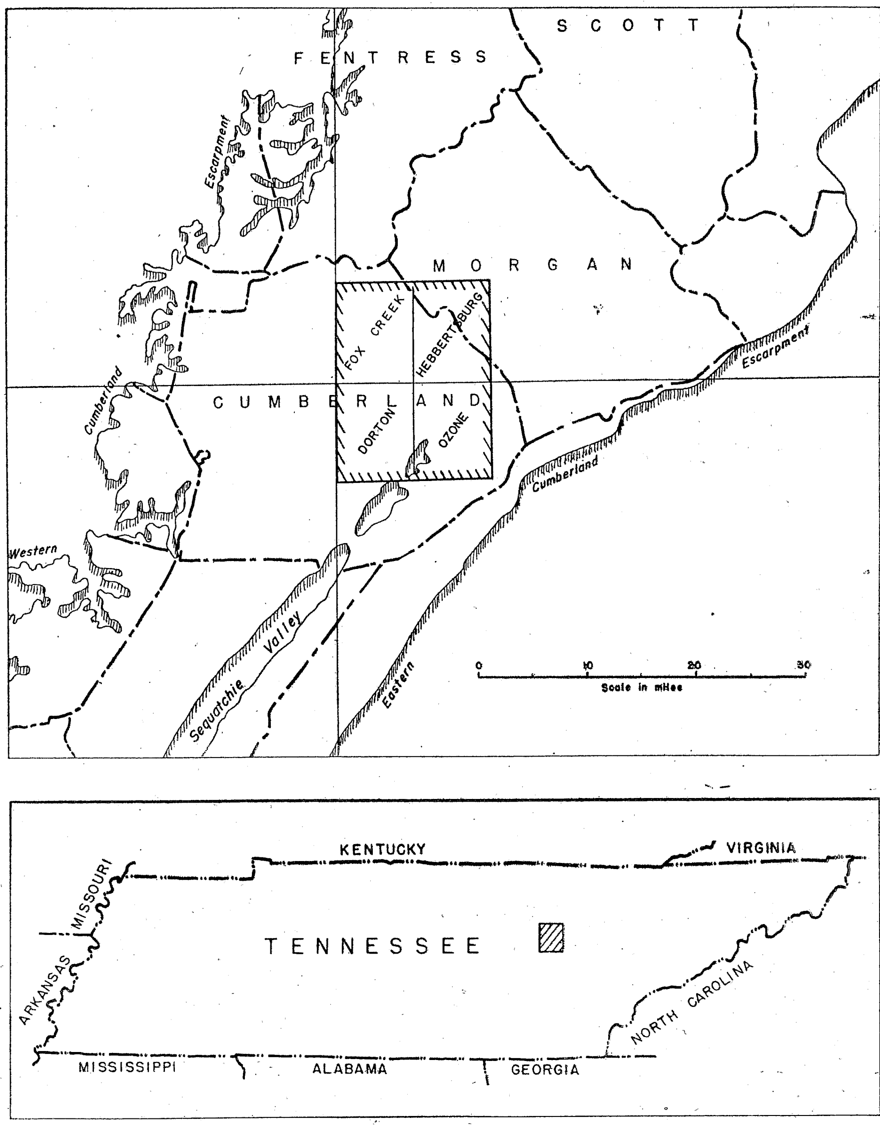


Figure 2. **Location of the Crab Orchard Mountains Area**

Jillson (1919) described the Emory River fault zone. He recognized that the Sequatchie Valley anticline disappears just south of the Emory River fault, and he also mentioned some of the structures present where the Emory River fault meets Hatfield Mountain. He concluded that the Emory River fault continues on northwestward beyond this junction.

Butts and Nelson (1925) mapped the Lantana faults on the Crossville quadrangle, but did not recognize the true significance of the faults

they mapped. The stratigraphy of the Pennsylvanian of Tennessee was known only generally until Nelson (1925) reported on the Tennessee coal field south of the Tennessee Central Railroad and Glenn (1925) reported on the coal field north of this railroad. Nelson subdivided the lower Pennsylvanian beds into formations, several of which are used in this report. Glenn considered them a single formation.

Rodgers (1950) noted that the Emory River and Lantana faults are largely connected by ridges shown on recent topographic maps. He interpreted the topographic features connecting the areas of known faults as anticlines. He concluded that this pattern bounds an incipient thrust sheet similar to the Pine Mountain block, whose main manifestation is the Sequatchie Valley anticline, and on this basis outlined the mechanics of its formation.

Acknowledgments

The project was initiated while H. B. Burwell was state geologist and continued under H. W. Ferguson. Special thanks are due W. D. Hardeman, present State Geologist of Tennessee, who not only actively aided in field mapping and critically read the manuscript, but directed and encouraged the writer in many ways during all phases of this investigation.

John W. Jewell and Bailey Rascoe mapped the Fox Creek and part of the Dorton quadrangles under the writer's direction. The writer is greatly indebted for their permission to use information derived from the mapping. In addition to this, Mr. Jewell assisted the writer in mapping the Ozone Quadrangle when the field work was begun, and contributed considerable time on many subsequent reconnaissance trips.

Dr. C. W. Wilson, Jr. of Vanderbilt University first suggested that the writer select the Crab Orchard Mountains area as a research project. He also critically read the manuscript.

Dr. E. C. Dapples of Northwestern University spent several days in the field with the writer. He directed and encouraged the writer in many ways and later critically read the dissertation manuscript from which this report is primarily derived.

Miss Alice L. Clements of the Tennessee Division of Geology did most of the drafting of maps, sections, and figures.

F. M. Alexander, Assistant State Geologist, did the final editing and proofreading.

STRATIGRAPHY

General Statement

The Pennsylvanian strata which underlie the Cumberland Plateau in Tennessee are referred to the Pottsvillian series on the basis of plant fossils. This series has been further subdivided into groups on a lithologic basis. In the Crab Orchard Mountains area most of the upper groups have been removed by erosion. The lowermost group, known as the Lee group, is more resistant to erosion because it contains a large proportion of sandstone, and is therefore widely preserved.

Lithology

Pennsylvanian strata in Tennessee, as in all of the Appalachian coal field, consist almost entirely of clastic material. The most abundant lithologic types are sandstone, siltstone and shale with associated coal and underclay. Calcareous concretions occasionally occur in the shales.

Lithology of the Pennsylvanian strata is characteristically variable. This variation often makes correlation difficult even between nearby exposures. Vertical variation may be quite complex, but a crude rhythm is usually evident. This rhythmic sedimentation was first noted in the southern Appalachian area by Wanless (1945, p. 129). He outlines the general sequence as follows:

> "This (depositional cycle) begins with a massive basal sandstone, unconformable on underlying strata. This sandstone grades up into siltstone or sandy shale, and the shale may contain sandstone partings and fossil plants. The siltstone is followed by underclay, which is often divided by shale or siltstone and may have siltstone or sandstone at the top. The coal zone follows and often includes several benches of coal spread through an interval of as much as 20 feet. The coal zone is overlain by shale which is generally plant-bearing in the immediate roof and which may contain ironstone or occasionally impure limestone bands or concretions . . . This may grade up into sandy shale or siltstone to the next higher sandstone, or the sandstone may cut out part or all of the upper shale and rest on the coal or even cut below the level of the coal."

Pennsylvanian strata exposed in the Crab Orchard Mountains area displayed this sequence repeated several fold. Each cycle is characterized by prominence of the basal sandstone lithology and insignificance of the limestone and siderite ironstone lithologies. Because of prominent development of the basal sandstone, the obvious gross sequence is an alternation of units which consist mainly of sandstone with units of less resistant siltstone and shale.

The shale divisions, the so-called "soft" units, characteristically consist of shale and siltstone, and may contain coals and underclay. In addition, there are often beds of sandstone and siltstone in these units. Similarly, the sandstone, or "hard" units, may also contain shaly units which are often prominent and may in turn contain coal beds and thin sandstone layers. This crude rhythm of sedimentation is complex in detail and both the "hard" and "soft" units often contain lithologic types which are characteristic of the other units.

Lateral variability appears to be almost as typical as vertical variability. Thin sandstones present in the shale units are usually discontinuous, and shales often grade laterally into siltstone or sandy shale. Also, the shaly partings in the sandstone units often disappear or may thicken rapidly within short distances. Fortunately for correlation purposes, such changes are ordinarily of detail only and "hard" and "soft" units preserve their identity over considerable areas.

Certain lithologic types tend to be remarkably continuous over large areas. These are the coals with their associated underclays, and the massive, quartzose, conglomeratic sandstones. Certain coals and sandstones are useful as key beds and with the alternation of sandstones and shales provide a dual basis for lithologic sub-division of the Pennsylvanian strata.

Lee Group

Nearly all of the Pennsylvanian strata in the Crab Orchard Mountains area are referred to the Lee Group. Strata assigned to the Lee are differentiated from beds of the underlying Mississippian and the overlying younger Pennsylvanian on a lithologic basis. Primarily, the distinction is based upon the preponderance of sandstone and conglomerate.

The lower limit of the Lee group is the base of the Pennsylvanian system. This contact is recognized by a distinct difference in lithology between the overlying and underlying (Pennington) strata, and in many areas an unconformity may be recognized. Red and green shale (often mottled), limestones and olive colored siltstones are characteristic of the Pennington. Pennsylvanian beds are usually gray plant-bearing shale, coal beds and sandstone. In addition to these criteria, it is customary in Tennessee to place carbonaceous gray shales in the Pennsylvanian where they do not lie below a lithologic type characteristic of the upper Mississippian.

There is a widespread, though not necessarily universal, unconformity at the base of the Lee. Nelson (1925, p. 39) states: ". . . the Lee group was deposited on the top of the very irregular eroded Pennington formation (upper Mississippian)." Glenn (1925, p. 14) states: "The base of the Lee rests unconformably on the shales and thin limestones that form the top of the Pennington . . ." Stearns (1949) demonstrated that the Lee of Franklin County, Tennessee was deposited on an irregular Pennington erosion surface. In the Crab Orchard Mountains area, this contact is poorly exposed, and there is no evidence of erosion. Therefore, the base of the Pennsylvanian is here determined only by the change in lithology.

In each area where the term "Lee" has been used by various authors, a prominent sandstone in the local section has been designated as its upper limit. Hence, the top of the Lee is not always at the same stratigraphic position. In the Crab Orchard Mountains area the upper limit of the Lee is herein defined as the top of the Rockcastle sandstone in accord with the subdivision of Glenn (1925).

Formations

Lee beds exposed in the Crab Orchard Mountains area are subdivided into formations by the lithologic criteria already discussed. The sequence of formations is as follows:

- Pennsylvanian System
  - Pottsvillian Series
    - Duskin Creek formation
    - Lee group
      - Rockcastle sandstone
      - Vandever formation
      - Bon Air sandstone
      - Whitwell shale
      - Sewanee conglomerate
      - Gizzard formation
- Mississippian System
  - Pennington formation

There are three stratigraphic markers within this sequence of strata which are most useful in defining positions within the Lee. They are the upper strata of the Mississippian referred to the Pennington formation, the Sewanee conglomerate and the Rockcastle sandstone. The Sewanee and Rockcastle are distinctive since they are widely conglomeratic; whereas the Pennington is the uppermost unit containing significant amounts of red shale and limestone.

The Gizzard formation consists of all Pennsylvanian strata below the Sewanee conglomerate. It is defined entirely in terms of marker beds because its upper limit is the base of the Sewanee conglomrate and its lower limit is the top of the Pennington formation. All strata between these two horizons are assigned to the Gizzard regardless of the proportion of sandstone or shale present.

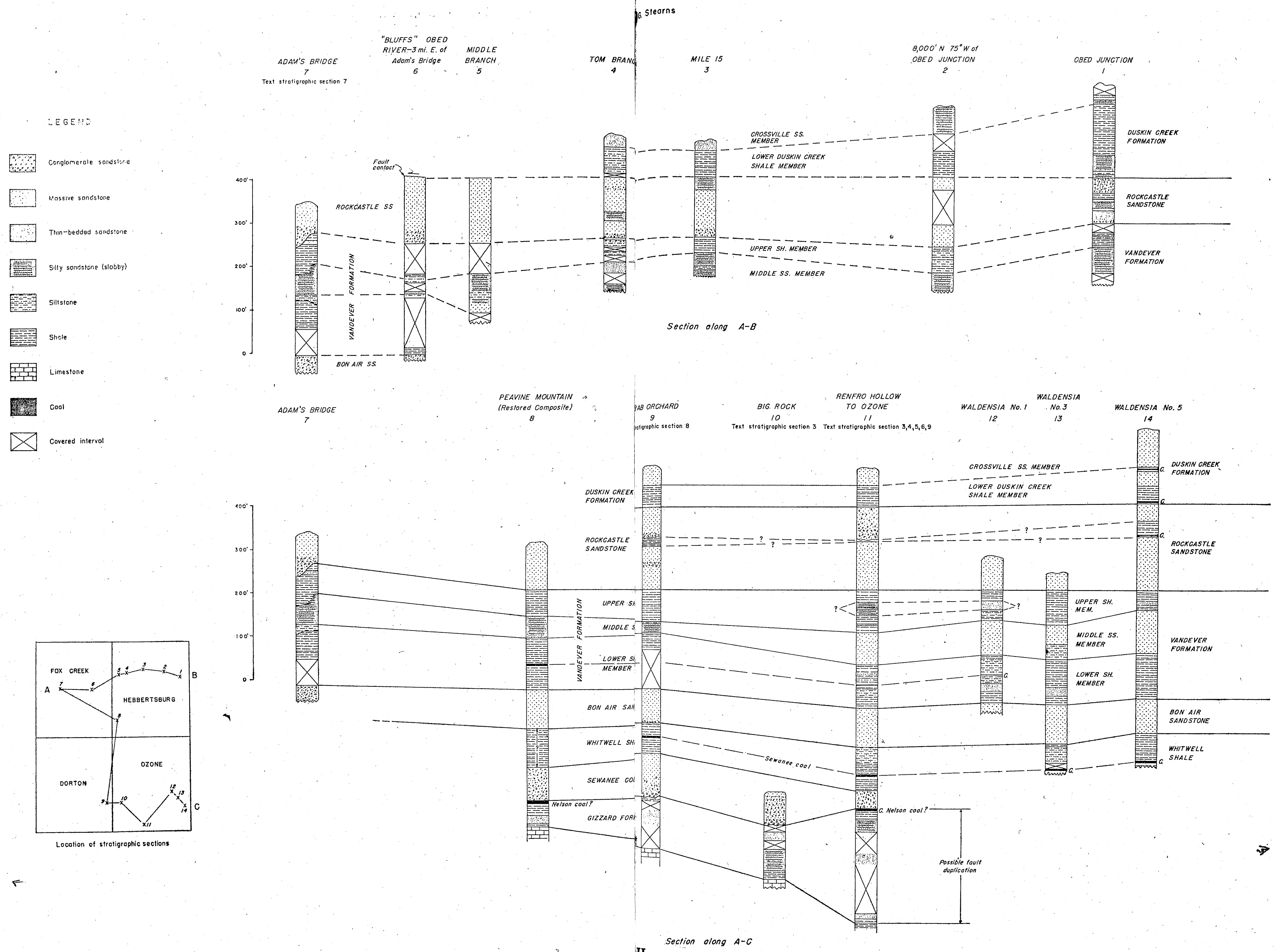
The interval between the base of the Sewanee and the top of the Rockcastle is a sequence of alternating sandstone and shale formations limited at the top and base by these two marker formations. Each formation in this sequence is characterized by a great predominance of either sandstone or shale. Conglomeratic sandstone characterizes the Sewanee. The overlying shaly strata are referred to the Whitwell shale. The Whitwell shale is in turn overlain by the Bon Air sandstone. This sandstone is overlain by another shale sequence, the Vandever formation, including all of the (usually) shaly beds between the Bon Air and the Rockcastle sandstone. The top sandstone, the Rockcastle, is conglomeratic. All strata above the Rockcastle are included in the Duskin Creek formation which, like the Gizzard, contains both prominent sandstone and shale units, often in repetitive order. The most representative stratigraphic sections in the area are graphically shown on Plate 2.

Pennington Formation

Description of the Pennington formation is important in demonstrating the lithologic distinction between Mississippian and Pennsylvanian strata. The systemic contact is readily found because of the striking color difference between the Pennsylvanian and the underlying Pennington (Mississippian). Pennsylvanian strata have drab gray colors, whereas the Pennington contains considerable thicknesses of red and green strata. The red color is especially prominent and often may be seen along roads cutting through this interval.

SECTIONS OF LEE STRATA IN THE FOX CREEK, HE|SBURG, DORTON AND OZONE QUADRANGLES, TENNESSEE

No. II



II

Distribution

In the Crab Orchard Mountains area, this formation is exposed only in the southwestern part of the Ozone quadrangle and adjacent corner of the Dorton quadrangle. Here, Pennington and older strata crop out where they are elevated by the Sequatchie Valley anticline. This is the northeastern limit of exposure of these strata along this anticline and the beginning of the Crab Orchard Mountains which are directly underlain entirely by Pennsylvanian strata.

Thickness and Lithology

The Pennington characteristically contains variegated red and green shales, dark red and olive gray siltstones, and minor amounts of argillaceous limestone. Variegated red and green shales contain small quantities of silt.

Few good exposures of the Pennington occur in the Crab Orchard Mountains area, and nowhere is a complete section exposed. In part, failure to produce a good outcrop is due to the non-resistance of the shales and to falling talus from overlying Pennsylvanian strata.

In Crab Orchard Cove there is indirect evidence that the Pennington is disturbed by a very low angle thrust fault so that measured thicknesses of such poorly exposed beds are suspect. However, one complete section is obtained from a log of an oil well drilled on Peavine Mountain several miles north of the outcrop area. In this locality, the aspects of the Pennington differs from the outcrop area in the greater proportion of limestone reported, although limestone is commonplace in older Mississippian beds. Lithology and thickness reported in the boring are listed in Stratigraphic Section 1, below:

Stratigraphic Section—1

Drillers log of a well drilled on Peavine Mountain in the southwestern part of the Hebbertsburg quadrangle.

Gizzard formation	
shale	
Pennington formation	
limestone	31 feet
red shale	7 feet
limestone	24 feet
sandstone	20 feet
alternating shale and limestone	45 feet
red shale	5 feet
limestone	39 feet
red shale	30 feet
limestone	12 feet
black shale	10 feet
limestone	35 feet
red shale	2 feet
Glen Dean formation	
limestone	
Total thickness of Pennington	260 feet

The upper part of this formation is exposed along U. S. Highway 70 east of Crab Orchard. Since bedding planes of the shale are obscured by

weathering, accurate dips could not be obtained and the thicknesses given are only approximate. Stratigraphic Section 2 serves to illustrate the general character of the Pennington in the area of exposure. This locality is the only place in the Crab Orchard Mountains area where the systemic contact was seen.

Stratigraphic Section—2

Section of Pennington shale along U. S. Highway 70 east of Crab Orchard (Locality No. 11, Plate 2).

Gizzard formation	
Shale, gray, carbonaceous, silty, micaceous. (Carbonaceous material probably plant remains).	
Pennington formation	
Siltstone, dark grayish-red, micaceous, massive, appears gradational with overlying Gizzard	2 feet
Shale, dark, olive-green, clayey, weather into small plates	8 feet
Shale, medium gray, clayey, massive, contains *Fenestella*	12 feet
Covered interval	5 feet
Shale, variegated red and green, red predominates (estimated)	50 feet
Covered interval (estimated)	100 feet
Glen Dean formation	
Limestone, dark gray, dense.	
Total thickness of Pennington (maximum)	177 feet

Gizzard Formation

The Gizzard formation is defined by Butts and Nelson (1925, p. 6) as "... the part of the Lee group below the Sewanee conglomerate." Therefore it may be widely recognized regardless of considerable variation in thickness and lithology.

Distribution

This formation is present in the subsurface over nearly all of the Crab Orchard Mountains area, but is exposed only in the southern portion of the Ozone quadrangle and in the southeast corner of the Dorton quadrangle. Here, its area of outcrop is slightly more extensive than that of the Mississippian strata. Exposures are poor due to talus from the overlying units and the poor cliff forming qualities of Gizzard sandstones.

Thickness and Lithology

In its outcrop area the estimated thickness of the Gizzard formation ranges from 200 to 300 feet, whereas a total of only 60 feet is reported in the logs of 2 wells drilled on Peavine Mountain several miles north of the outcrop area. Thus, there appears to be a distinct tendency to thicken toward the southeast. Probable faulting within this formation causes uncertainty as to the true Gizzard thickness just as in the case of the Pennington. Even so, this unit must be in excess of 100 feet in thickness.

The Gizzard formation includes sandstone, shale and a coal bed with its associated underclay. The sandstones of this formation are fine-grained, hard, thin-bedded and non-conglomeratic. Shales are characteristically gray, silty and contain no recognizable plant fossils. However, flakes and films of carbonaceous material are often concentrated on the bedding planes. Black, pyritic shale is present at or near the top of this formation in several localities, while in other places a well developed coal is present at the same position.

At no place in the Crab Orchard Mountains area is a complete, or nearly complete, section of this formation exposed; most sections being largely covered as in the case of the underlying Pennington formation. A composite section is derived from measurements along the foot trail leading up the Crab Orchard Mountains from Crab Orchard to Big Rock and along U. S. Highway 70 in Renfro Hollow as follows:

Stratigraphic Section—3

Composite section of Gizzard formation along a foot trail leading up Crab Orchard Mountain from Crab Orchard to Big Rock, and in Renfro Hollow along U. S. Highway 70 (Plate II, Nos. 10, 11).

Sewanee conglomerate	
Conglomeratic sandstone	
Gizzard formation	
Coal, blocky, hard (begin Renfroe section)	1-4 feet
Underclay, light gray, clayey, massive	2 feet
Shale, dark gray, pyritic, silty	10 feet
Shale, light gray, sandy	6 feet
Sandstone, thin-bedded, fine-grained, light gray (begin Big Rock section)	40 feet
Covered interval	60 feet
Sandstone, light gray, thin-bedded, fine-grained	30 feet
Covered interval	22 feet
Shale, silty, carbonaceous, medium gray	29 feet
Covered interval (probably shale)	16 feet
Pennington formation	
Limestone, medium-grained, fragmental, argillaceous, light gray	
Total thickness of Gizzard formation	217 feet

In the southeast corner of the Dorton Quadrangle exposures are poor, but there appears to be much more sandstone within the Gizzard, perhaps nearly 200 feet.

It is noteworthy that there is a widespread coal and black shale horizon immediately at the top of this formation. The coal, known as the "Nelson" coal by local miners, is the only one present in the Gizzard formation. On Peavine Mountain where the Gizzard is only 60 feet thick, it directly underlies the Sewanee conglomerate and also immediately underlies the Sewanee in Renfro Hollow where the Gizzard is more than 100 and perhaps 300 feet thick. The "Nelson" coal may be seen where it has been mined or prospected in many other areas in the vicinity of Crab Orchard and along several of the creeks draining into Crab Orchard Cove. Wherever the top of the Gizzard formation is exposed, either this coal or very carbonaceous pyritic shale is present.

The fact that the marked northward thinning of this formation is not accompanied by more than local disappearance of the "Nelson" coal horizon established that the thickening of the Gizzard to the southeast primarily is an original variation in the depositional thickness and is not a result of post-Gizzard-pre-Sewanee erosion. It is not known, however, whether Gizzard thinning is due primarily to wedging or westward overlap at the base.

Relationship to Underlying Strata

In the Crab Orchard Mountains area the systemic contact is exposed at only one locality (see Stratigraphic Section—2). Here, the Pennington apparently grades conformably upward into the Gizzard. Since this locality is in an area of thick Gizzard, disappearance of the usual pre-Gizzard unconformity is not surprising inasmuch as unconformities commonly decrease both in number and magnitude when traced into areas of thicker deposition.

Sewanee Conglomerate

The Sewanee conglomerate was named by Safford (1893, pp. 89-98) from exposures at Sewanee, Tennessee on the campus of the University of the South. It is a very prominent cliff-forming unit over most of the Tennessee coal field, and because of its characteristic lithology and topographic expression, it is a most useful marker bed.

Distribution

In the Crab Orchard Mountains area the Sewanee conglomerate, like the Gizzard formation, is exposed only in the southern and eastern parts of the Ozone quadrangle, and in the southeast corner of the Dorton quadrangle. It is well exposed in and near Crab Orchard Cove and also as inliers in the gorges of Crab Orchard Creek, Piney Creek, Mammy's Creek and Millstone Creek. There are also two small inliers on the northwest side of the Crab Orchard Mountains at Rich Gap and Ellis Gap. Excellent exposures of the Sewanee can be seen along U. S. Highway 70 both east and west of the village of Crab Orchard.

Thickness and Lithology

The average thickness of the Sewanee is about 80 feet in the area mapped. A minimum thickness of 20 feet was observed in Mine Cove east of Crab Orchard, and a maximum of 100 feet are exposed in a cut along U. S. Highway 70 just west of Crab Orchard.

Everywhere the lithology is characteristic and consists of fine to coarse-grained, conglomeratic, quartzose sandstone. This information usually contains many comparatively large, milky white, quartz pebbles which range up to 2 inches in diameter (Fig. 3). Individual pebbles may be concentrated along bedding planes. Locally, massive beds are dominated by pebbles and granules with little sand matrix. The Sewanee conglomerate contains little else but clean quartz sand and quartz pebbles.

In the area covered by this report the Sewanee consistently contains quartz pebbles in its lower part only. Pebbles may be present in the upper part, but fine-to medium-grained sandstone is usually found in this position. In Mine Cove where the minimum thickness of the Sewanee conglomerate occurs, it is conglomeratic only in the lower 10 feet; whereas, in areas in which it is much thicker, a little over a mile to the northwest, it is conglomeratic throughout. West of Crab Orchard where the thickest section was observed, the Sewanee is conglomeratic only within 200 feet of the base.

Relationship to Underlying Strata

The Sewanee conglomerate rests unconformably on the Gizzard formation in the Crab Orchard Mountains area. In areas where the base of the Sewanee is well exposed, it is almost always irregular and contains, within a distinctive zone, debris derived from older units. Primarily, such redeposited material consist of quartz pebbles, fragments of shale and sandstone in a matrix of very poorly sorted detritus; and on the outcrop, the zone is cemented and partially replaced by limonitic material.

It is noteworthy that the ferruginous conglomerate, about three feet above the base of the thickest section of the Sewanee west of Crab Orchard, is present immediately at the base at Big Rock where the Sewanee is slightly thinner, and not present in Mine Cove where the thickness of the Sewanee is at a minimum. This suggests that there was an uneven erosion surface of Gizzard just before deposition of the Sewanee; oldest Sewanee was deposited in topographic depressions. The position of the "iron" zone, locally well developed, suggests a subsequent bog condition into which

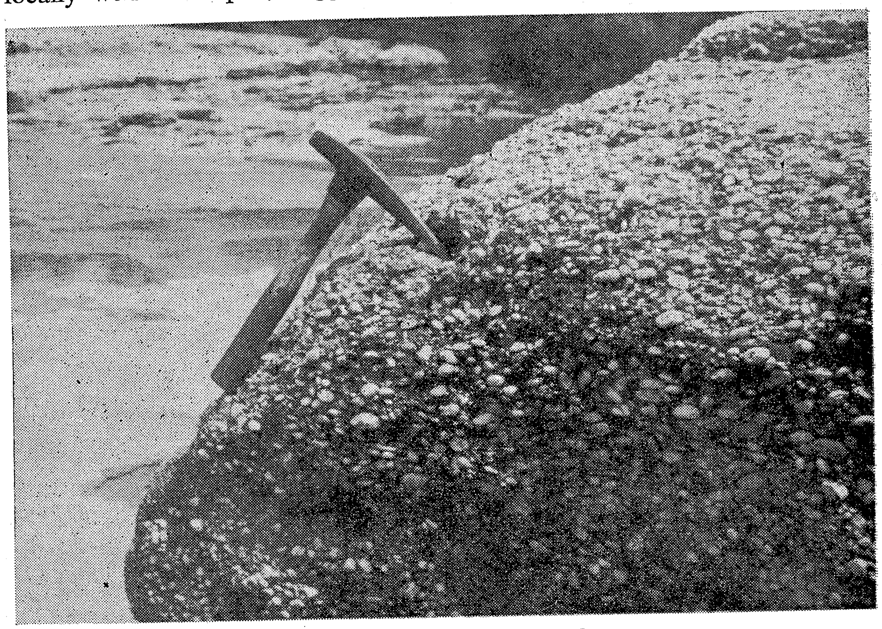


Figure 3. Typical Conglomeratic Sewanee

fragments were carried from local high areas of Gizzard strata still subject to erosion. Still later the bulk of the Sewanee, furnished from another source, was deposited over this zone and over the areas of pre-Sewanee "hills."

This interpretation of the significance of the ferruginous conglomerate implies that over much of the area around Crab Orchard Cove the Nelson coal horizon was removed by pre-Sewanee erosion, inasmuch as at Mine Cove this coal is present directly under thin conglomerate having no basal "iron" zone (inferred post-Gizzard-pre-Sewanee hill). Also, because this same coal horizon is present directly under the conglomerate at Peavine Mountain to the west where the Gizzard itself is comparatively thin, the Gizzard cannot have been eroded progressively deeper toward the west. From this reasoning it may be said again that the thinning of the

Gizzard toward the northwest is not primarily due to pre-Sewanee erosion but to original deposition.

Whitwell Shale

Butts and Nelson (1925, p. 7) named the Whitwell shale from exposures near Whitwell, Marion County, Tennessee. This shale formation includes all strata between the top of the Sewanee conglomerate and the base of the Bon Air sandstone.

Distribution

In the Crab Orchard Mountains area the Whitwell shale is well exposed over an area approximately coextensive with that of the Sewanee conglomerate in the southern and western parts of the Ozone quadrangle, and in the adjacent corner of the Dorton quadrangle. Also, structure is responsible for the appearance of Whitwell shale at Pilot Knob Mountain in the Hebbertsburg quadrangle, Ellis gap in the Ozone quadrangle and Hyders Ridge in the western part of the Dorton quadrangle. These inliers are poorly exposed, much contorted by faulting, and yield little stratigraphic information.

Thickness and Lithology

In the area of exposure the average thickness of the Whitwell shale is about 85 feet. Maximum thickness is 100 feet, and minimum thickness is about 60 feet. Thinner sections may be seen but they are attributed to post-depositional squeezing as the underlying Sewanee conglomerate is sheared and contorted at every locality where the Whitwell is less than 60 feet thick.

The lithology of this formation consists primarily of gray, silty, carbonaceous shale. In addition, there are thin, fine-grained, impure sandstones and siltstones which grade both laterally and vertically into shale. Coal is a very important constituent of the Whitwell shale as it contains the most extensively mined coal horizon, the Sewanee coal, of the Tennessee coal field (Fig. 4). This coal is mined in the Crab Orchard Mountains area although not as extensively as in former years. It is especially valuable because of its coking characteristics. Black, pyritic shales and siltstones are found in the immediate roof of the coal which contain a well preserved fossil flora.

A typical section (Stratigraphic Section—4) measured in Renfro Hollow illustrates the characteristic lithology of this formation and the position of the Sewanee coal.

Stratigraphic Section—4

Section of Whitwell shale in Renfro Hollow east of Crab Orchard (Plate II, No. 11).

Bon Air sandstone

Sandstone, light gray, massive, fine-to medium-grained, quartzose

Whitwell shale

Shale, gray, silty, carbonaceous, contains thin lenses of argillaceous sandstone	43 feet
Shale, black, silty, carbonaceous, pyritic, contains siliceous concretions and many plants	8 feet

Coal (Sewanee)	3 feet
Underclay, silty, grades down into—	1 foot
Shale, gray, silty, carbonaceous	28 feet
Sewanee conglomerate	
Sandstone, conglomeratic, grading upward into shale of the Whitwell	
Total thickness of the Whitwell shale	83 feet

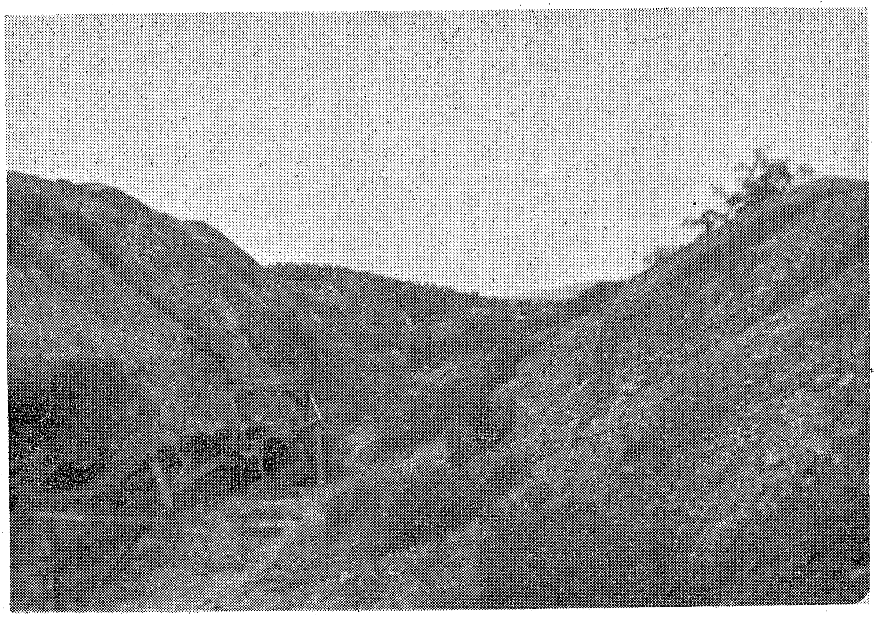


Figure 4. Abandoned Strip Mine in Steeply-dipping Sewanee Coal. Located 2 Miles South of Crab Orchard.

Relationship to Underlying Strata

The Whitwell shale rests conformably on the Sewanee conglomerate. Along U. S. Highway 70 in Renfro Hollow (Stratigraphic Section—4) the contact is well exposed. Here, the upper part of the Sewanee consists of alternating thin, shaly and sandy beds which progressively become the Whitwell shale, and the selection of a contact between the two formations is purely arbitrary.

Bon Air Sandstone

Although this sandstone was named "Herbert" by Nelson (1925, pp. 49-50) from exposures on the Herbert Domain, Bledsoe County, Tennessee, it was previously named "Bon Air" by Campbell (1899) from exposures at the town of that name in White County, Tennessee.

Distribution

A large area of outcrop of this formation occurs in the Ozone quadrangle. It is also exposed in the Hebbertsburg and Dorton quadrangles where it has been elevated by thrust faulting and arching, and in the gorges of Clear Creek and the Obed River.

Thickness and Lithology

Thicknesses of 80 to 100 feet of Bon Air sandstone occur in the Crab Orchard Mountains area. This persistent thickness together with the Bon Air cliff forming qualities make this formation a most useful unit for structural mapping in areas where the Sewanee conglomerate is below drainage.

Throughout most of the Crab Orchard Mountains area the Bon Air sandstone consists of fine to medium-grained, quartzose and sub-graywacke sandstone; but in the gorges of Clear Creek and Obed River in the northwest part of the area, it is conglomerate greatly resembling the Sewanee. Here, only the upper 30 feet or so are exposed (Plate II, No. 7).

In the southern parts of the Ozone and Dorton quadrangles this formation commonly has a thin, basal, ferruginous, shale pebble conglomerate

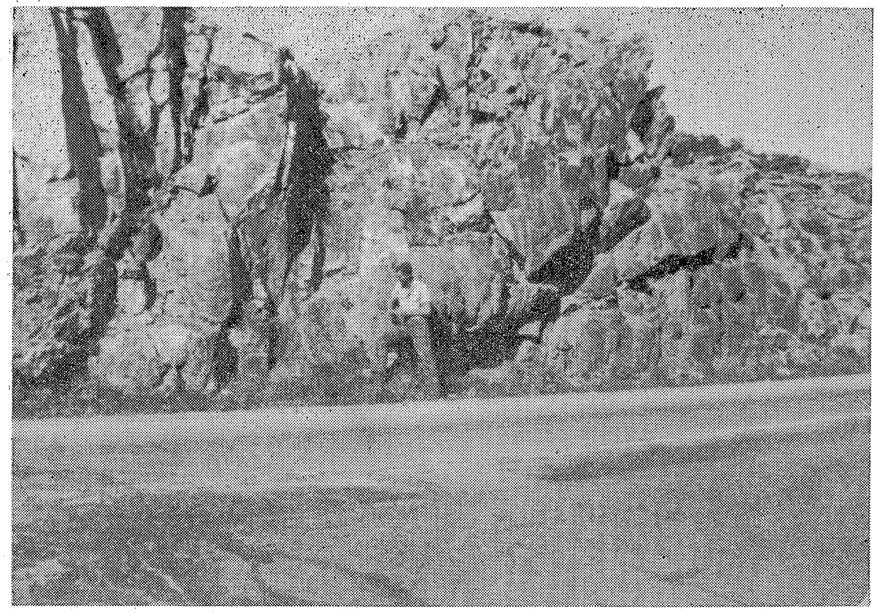


Figure 5. Contorted Bon Air Sandstone Along U.S. Highway 70 West of Crab Orchard.

like that of the lower Sewanee and in many localities this basal zone contains a few small quartz pebbles. At the head of Piney Creek on the south side of Luper Mountain in the northern part of the Ozone quadrangle the basal 10 feet of the Bon Air is conglomeratic, but this is an exceptional occurrence.

Several sections of the Bon Air sandstone are plotted on Plate II. A typical section of the Bon Air measured along U. S. Highway 70 between the village of Ozone and Renfro Hollow follows:

Stratigraphic Section—5

Section of Bon Air sandstone measured along U. S. Highway 70 just west of Ozone (Plate II, No. 11).

Vandever shale
Shale, silty, light gray

Bon Air sandstone

Sandstone, light buff to gray, very fine-grained, grades rapidly upward into overlying shale	12 feet
Sandstone, single massive bed of fine-grained sandstone	10 feet
Sandstone, thin-bedded, fine-grained	20 feet
Sandstone, medium-grained, massive beds	40 feet

Whitwell shale
Shale, gray, silty

Total thickness of the Bon Air .... 82 feet

West of Crab Orchard along the Tennessee Central Railway (Dorton quadrangle) the Bon Air is 90 feet thick and fine-grained throughout. A thin shale (20 feet or less) occurs near the base of the formation. In the western part of the Dorton quadrangle this sandstone is exposed in the Hyders Ridge area of complex structure. In this locality it is characteristically a pink, fine-grained sandstone containing occasional shale pebbles. Locally, the Bon Air is medium-grained or even contains small pebbles. Its thickness cannot be determined due to faulting and folding.

Relationship to Underlying Strata

The Bon Air sandstone rests unconformably on the underlying Whitwell shale. Wherever this contact is exposed, it can be seen that the base of the Bon Air is irregular and generally contains a conglomerate zone similar to that at the base of the Sewanee conglomerate.

Vandever Formation

All of the usually shaly strata below the Rockcastle sandstone and above the Bon Air sandstone are referred to the Vandever formation. This shale formation was named by Butts (1916, pp. 107-110) from the small mining village of Vandever in southern Cumberland County. It is widely exposed in the Ozone quadrangle, and is also locally exposed by thrust faulting in the Hebbertsburg quadrangle.

This shaly formation may be divided into three units by means of a persistent, though only locally prominent, middle sandstone member. As the middle sandstone is poorly exposed and exerts so little influence on the topography of the area, detailed tracing was not feasible (Fig. 6), and the Vandever formation was mapped as a single unit in the Crab Orchard Mountains area. Inasmuch as this is a thick and composite unit, general sections will first be described. Then the three divisions will be separately discussed. Stratigraphic Section 6 is typical of this unit in the Ozone quadrangle.

Stratigraphic Section—6

Section of Vandever formation measured along U. S. Highway 70 just west of Ozone (Plate II, No. 11).

Rockcastle sandstone
Sandstone, light brown-gray, massive and cross-bedded, medium-grained, quartzose

Figure 6. **Thin Middle Vandever Sandstone Member Along the Railroad just West of Crab Orchard.**

Vandever formation

Upper shale member

Shale, light gray, silty	30 feet
Sandstone, gray, flaggy, fine-grained, micaceous, carbonaceous, contains a 6 in. shale parting 12 feet above base	20 feet
Shale, dark gray, carbonaceous, silty, contains thin beds of fine-grained, impure sandstone, largest is 2 feet thick and 21 feet above base	40 feet

Middle sandstone member

Sandstone, light gray to buff, silty, micaceous, thin-bedded	70 feet

Lower shale member

Shale, gray, silty, micaceous, carbonaceous, contains several thin, discontinuous silty sandstone and siltstone beds	50 feet
Sandstone, gray, silty, fine-grained, micaceous	4 feet
Shale, dark gray, silty, carbonaceous	10 feet
Coal "rash"	1 foot
Shale, gray, silty, carbonaceous	50 feet

Bon Air Sandstone
Sandstone, light buff, blocky beds, very fine-grained, quartzose

Total thickness of Vandever formation .... 275 feet

A typical section of the Vandever of the northwestern area is exposed at Adams Bridge in the gorge of the Obed River as follows (Stratigraphic Section—7):

Stratigraphic Section—7

Section of Vandever formation measured along the rural road crossing the Obed River at Adams Bridge 2 miles west of the western border of the Hebbertsburg quadrangle (Plate II, No. 7).

Rockcastle sandstone	
Sandstone, light brown-to pink, massive and cross-bedded, conglomeratic, medium grained, little matrix	
Vandever shale	
Upper shale member	
Shale, dark gray, carbonaceous, clayey, alternating with thin bands of coal	1 foot
Underclay	6 inches
Shale, dark gray to buff, very silty, contains large carbonaceous plant fragments	15 feet
Sandstone, gray, massive and cross-bedded, fine-grained. Locally this is cut out with all of the overlying shale by the irregular base of the Rockcastle sandstone	12 feet
Shale, light-to dark gray, silty, micaceous, carbonaceous	40 feet
Middle sandstone member	
Sandstone, medium gray, hard, medium-grained, alternating in massive beds with gray, micaceous siltstone, upper 25 feet grade laterally into shale within 100 yards. Quarried here for road metal	70 feet
Lower shale member	
Siltstone, gray, thin-bedded, micaceous, alternating with thin beds of fine-grained, silty sandstone, grades upward into the sandstone above, channels 10 feet into the underlying shale	15 feet
Siltstone and silty shale, thinly laminated in alternating units, becomes increasingly silty upward	45 feet
Sandstone, gray, impure, silty	15 feet
Covered interval (probably shale and siltstone)	55 feet
Bon Air sandstone	
Sandstone, brown and pink, clean, massive, conglomeratic. Thickness exposed along creek level	30 feet
Total thickness of Vandever formation	268½ feet

Lower Shale Member

Distribution

Widespread exposures of the lower shale member occur in the Ozone and Dorton quadrangles on the flanks of the Crab Orchard Mountains. Also, it is locally exposed in structurally disturbed areas in the southern part of the Hebbertsburg quadrangle and on Hyders Ridge in the Dorton quadrangle where it has been elevated by faulting.

Thickness and Lithology

Both outcrop and subsurface data show that this member maintains a consistent thickness of slightly over 100 feet. Stratigraphic Section—6 shows a thickness of 115 feet, and several wells near this section also penetrated this same thickness of lower shale (see Plate II). West of Crab Orchard along the Tennessee Central Railroad there is a thicker interval (150 feet), mostly covered, between the Bon Air sandstone and middle Vandever sandstone. Inasmuch as the underlying Bon Air sandstone is contorted and sheared at this locality, some thickening of this member may be due to folding or faulting in the shale. In the Fox Creek quadrangle (Stratigraphic Section—7) it is 130 feet thick. On U. S. Highway 70 at the western edge of the Dorton quadrangle is the thinnest known section (50 feet); but, it is also thin (75 feet) at the western edge of the Fox Creek quadrangle in the gorge of the Obed River.

Shale which is normally silty and carbonaceous makes up the greater part of the lower shale member, and it contains a greater proportion of dark colored constituents than any other Lee shale in this area. Thin, discontinuous sandstone and siltstone beds are present, and in some areas a thin coal seam may be found.

A discontinuous coal bed is present near the middle. This coal has been mined and prospected at several localities in the Crab Orchard Mountains area and normally occurs about 50 feet below the top of this member (see Stratigraphic Section—6). Generally the bed is thin and the only mine of any consequence is on Peavine Mountain in the southwestern part of the Hebbertsburg quadrangle. In this locality, about 40 feet below the middle sandstone, the coal has been squeezed into pockets which are as much as 20 feet thick. This coal may be equivalent to the Lantana coal of the Crossville quadrangle.

Relationship to Underlying Strata

The contact between the lower Vandever shale member and the underlying Bon Air sandstone is conformable. This stratigraphic break is abrupt, but there is no evidence that it represents more than a change from deposition of coarse to fine sediments.

Middle Sandstone Member

Thickness and Lithology

The thickness of the sand member varies from a maximum of 90 feet in the southeastern corner of the Ozone quadrangle to a minimum of less than 20 feet in the western part of the Ozone quadrangle and the southern part of the Dorton quadrangle. Fine-grained, thin-bedded, sub-graywacke sandstone is the dominant lithologic type, but thin beds of silty shale and siltstone are often included.

Typical sections of this formation have already been described (see Stratigraphic Sections—6-7). In these sections the middle sandstone member is thick and consists almost entirely of sandstone. Along the Tennessee Central Railroad west of Crab Orchard, however, and along the road north of Crab Orchard near Pine Ridge this unit is from 8 to 25 feet thick and consists of very silty and carbonaceous, sub-graywacke sandstone.

Of special interest is Section 7 where about 25 feet of middle sandstone can be seen grading into and interfingering with, upper shale member beds. The uniform thickness of the underlying lower shale, in the area where the most pronounced thinning of the middle sandstone occurs, suggests that this stratum does not thin by means of its basal portions grading into the underlying shale. Rather, the thinning is attributed either to gradation into overlying shales (see Section 8) or wedging within the sand itself.

Upper Shale Member

Thickness and Lithology

The upper shale thins to the north and west. Its maximum thickness, like that of the middle sandstone occurs in the southeastern part of the Ozone quadrangle where the shale is about 90 feet thick (see Stratigraphic Section—6). West of Crab Orchard this formation is 50 feet thick, and the same thickness was measured on Peavine Mountain in the southwestern corner of the Hebbertsburg quadrangle. In the northern part of the Fox Creek quadrangle Stratigraphic Section—7 indicates 68½ feet of upper shale. On U. S. Highway 70 at the western edge of the Dorton quadrangle there is 70 feet of upper shale.

Silty shale dominates this formation and thin sandstone units also are included. No important coal beds are known to the writer to occur within the upper shale in this area. A conformable contact occurs between the shale and the underlying middle sandstone member. Indeed, they actually interfinger (see Stratigraphic Section—7).

Rockcastle Sandstone

Wanless, (1945, pp. 16, 26, 35) named the Rockcastle sandstone from exposures in Rockcastle Cove near Jamestown, Fentress County, Tennessee. The Rockcastle, like the Sewanee conglomerate, maintains its characteristics over most of the Tennessee coal field. Because of its comparativly uniform thickness, characteristic lithology and excellent topographic expression it is a very useful stratigraphic key unit, and tracing this unit is a main basis for much of the structural mapping.

Distribution

Due to its resistance to erosion much of the Crab Orchard Mountains area is immediately underlain by the Rockcastle sandstone. In general, this formation is exposed in the structurally "high" areas; whereas, the structurally "low" areas are underlain by younger Duskin Creek strata. Where structural elevation is a maximum, the Rockcastle is removed by erosion and older Pennsylvanian strata are the surface beds. Exposures of this formation are conveniently seen along U. S. Highway 70 both east and west of Crab Orchard.

Thickness and Lithology

There is a slight thickening of the Rockcastle to the southeast. A maximum thickness of 200 feet is found in the southeastern part of the Ozone quadrangle, but over most of the Crab Orchard Mountains area the Rockcastle is about 150 feet thick. The minimum known thickness is at Adams Bridge (locality of Stratigraphic Section—7) where it is 120 feet thick.

Quartzose, fine- to coarse-grained, massive and cross-bedded sandstone is characteristic of this formation, and in most exposures it contains a few small, scattered quartz pebbles. Also, the Rockcastle contains a

widespread shaly unit with a coal horizon which divides this formation approximately in half. The upper part of the Rockcastle rests unconformably on this unit and in places where this shaly unit is not present, an unconformable sandstone contact may be seen in the same position (see Stratigraphic Section—9). The shale unit is well developed along the Tennessee Central Railroad west of Crab Orchard where it is 11 feet thick and contains two thin coals (Stratigraphic Section—8).

Stratigraphic Section—8

Section of Rockcastle sandstone measured along the Tennessee Central Railroad just west of Crab Orchard (Plate II, No. 9).

Duskin Creek formation	
Shale, dark gray, thinly laminated, silty	
Rockcastle sandstone	
Upper sandstone	
Sandstone, light gray, quartzose, grading from fine-grained at the top to coarse and conglomeratic at the base, unconformity at the base	50 feet
Middle shale	
Shale, dark gray, clayey, paper thin beds	3 ft. 6 inches
Coal "rash"	2 inches
Shale, very dark gray, clayey, paper thin beds	6 feet
Shale, gray, carbonaceous, laminated	1 foot
Coal	4 inches
Siltstone, gray, laminated	3 inches
Lower sandstone	
Sandstone, gray fine to medium-grained, scattered small quartz pebbles, quartzose	100 feet
Vandever formation	
Shale, gray, carbonaceous, silty	
Total thickness of the Rockcastle	161 ft. 5 inches

A section of somewhat thicker Rockcastle was measured at Ozone in the southeastern part of the Ozone quadrangle. Here, the middle shale unit is represented by a thin, coarse, impure, carbonaceous siltstone.

Stratigraphic Section—9

Section of Rockcastle sandstone measured along U. S. Highway 70 at Ozone (Plate II, No. 11).

Duskin Creek formation	
Shale, gray to brown, silty, micaceous	
Rockcastle sandstone	
Upper sandstone	
Sandstone, gray to buff, medium to coarse-grained, massive and cross-bedded, many pebbles in the lower 40 feet, unconformity at the base	60 feet
Middle shale	
Siltstone, dark gray to brown, contains thin uneven laminae of fine sandstone, carbonaceous, micaceous, cut out laterally by the upper sandstone within 100 feet—maximum thickness	5 feet

Lower sandstone

Sandstone, light gray, fine to medium-grained, massive flaggy and cross-bedded, conformable at base..........110 feet

Vandever formation

Shale, gray, silty, carbonaceous

Total thickness of the Rockcastle ....175 feet

About 1 mile northeast of Ozone where the railroad crosses Millstone Creek, the middle shaly unit is again well exposed and contains one 8 inch coal bed. At Obed Junction in the northeastern part of the Hebbertsburg quadrangle the middle shale contains a coal horizon. The Rockcastle is also split by a shale unit at Wolfpen Branch in the northern part of the Fox Creek quadrangle. This unit again contains a coal seam. In the eastern part of the Dorton quadrangle a 12 foot silty, rather massive clay appears at about this position.

Relationship to Underlying Strata

The Rockcastle sandstone rests unconformably on the Vandever shale in

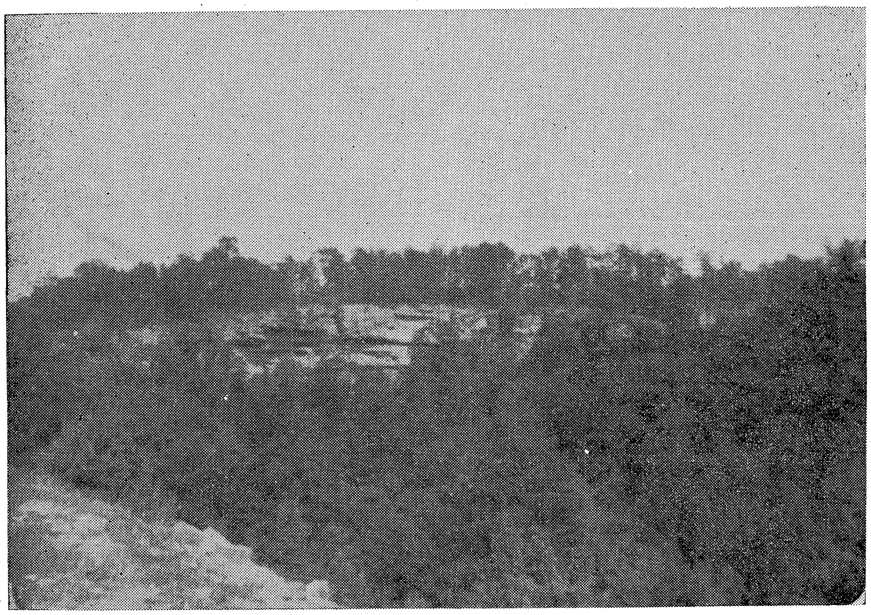


Figure 7. **Cliffs of Rockcastle Sandstone at Ozone.**

the Crab Orchard Mountains area. In the southeastern part of the Ozone quadrangle no unconformity is recognized below the Rockcastle. To the northwest at Adams Bridge in the Fox Creek quadrangle (Stratigraphic Section—7), the base of the Rockcastle cuts unevenly into underlying strata of reduced thickness.

Duskin Creek Formation

The Duskin Creek formation was named by Nelson (1925, p. 53) from exposures along a tributary of the Piney Creek in Rhea County, Tennes-

see. All post-Rockcastle strata in this area of the Tennessee coal field are included in this formation. In part, these may be equivalent to strata referred to the Lee group in Kentucky.

Distribution

Exposures of the Duskin Creek are widely found over an area which is only slightly less extensive than that underlain by the Rockcastle. Duskin Creek beds are preserved in structurally "low" areas and as outliers in areas of little disturbance. In the Hebbertsburg and Dorton quadrangles large areas are underlain by these strata, and in the northwestern and southeastern corners of the Ozone quadrangle extensive exposures occur far down the flanks of the Crab Orchard Mountains anticline. Scattered outliers occur in Fox Creek quadrangle.

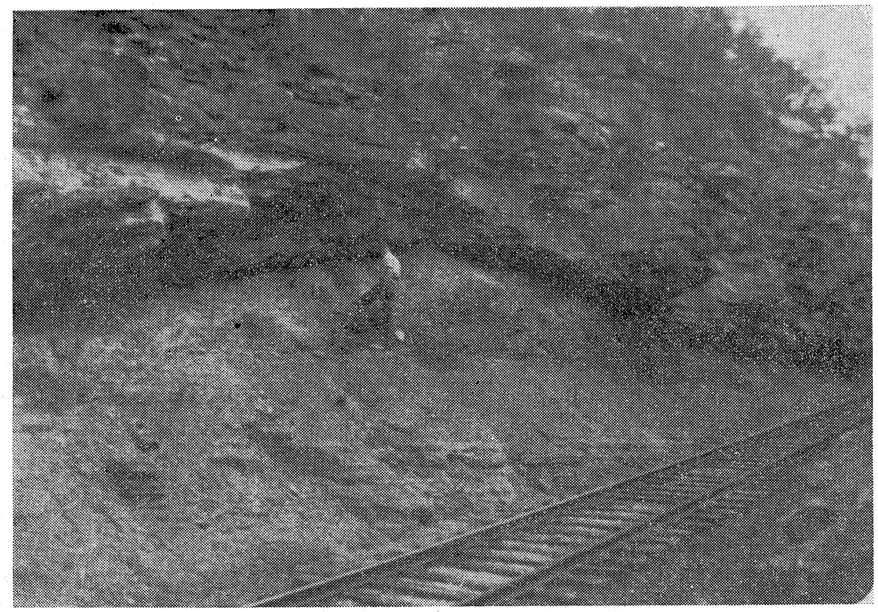


Figure 8. **Crossville Sandstone Member of the Duskin Creek Formation Resting Unconformably on the Lower Shale Member East of Ozone.**

Thickness and Lithology

Inasmuch as the Duskin Creek formation consists of all strata above the Rockcastle, its top is not necessarily clearly defined or recognizable. However, in the Crab Orchard Mountains area it contains four well defined alternating sandstone and shale units so that thicknesses and lithologies may be compared. These four units are; (1) a lower shale, (2) the Crossville sandstone member, (3) an upper shale, and (4) an upper sandstone.

The lower shale has an average thickness of about 40 to 50 feet over most of the Ozone, Dorton, and Fox Creek quadrangles but thickens rapidly to the northeast until in the northeast corner of the Hebbertsburg quadrangle, it is more than 140 feet thick. Dark silty shale is the characteristic lithology, but in many localities this member contains a large proportion of coarse siltstone. This lithology is prominent in the northern part of the Ozone quadrangle along the western flank of the Crab Orchard Mountains anticline and is also prominent in the southeast part of the Dorton quadrangle. Normally the shale grades downward into the underlying Rockcastle through a short interval of siltstone so that the base of the lowermost Duskin Creek unit must be arbitrarily selected.

The Crossville sandstone, which is the only member in the Duskin Creek to which a name has been given (Wanless 1945, p. 37), is known to vary in thickness from 70 feet to more than 100 feet. In most areas it is the youngest unit present so that it is often thinner due to erosion. Fine-grained, quartzose, non-conglomeratic sandstone is characteristic of this member. It is usually massive and cross-bedded, but in some localities the bedding is even and flaggy. Such beds are known as Crab Orchard stone and are sought as building stone especially those colored with various shades of brown, red and purple in Liesegang diffusion patterns (Fig. 9). Clay pellets often occur scattered throughout the massive sandstone beds, but these are not peculiar to the Duskin Creek because the Rockcastle locally has such a lithology in the Dorton quadrangle. An unconformity occurs at the base of this sandstone and is well displayed where the contact is exposed along the railroad on the south side of Mammy's Creek (Fig. 8).

The upper shale and sandstone units are only locally preserved on small hills in the northwestern corner of the Ozone quadrangle. Their lithology is generally like that of the lower Duskin Creek units. Both of these units are poorly exposed and therefore yield little information. Approximately 80 feet of shaly beds comprise the shale unit, and a maximum of about 60 feet of the upper sandstone is present.

Relationship to Underlying Strata

Previous mention has been made to the gradational contact between the lower shale unit and the underlying Rockcastle sandstone. Since the lower shale and the Rockcastle do not exhibit complimentary changes in thickness, this contact probably represents a consistent gradational change in deposition from coarse to fine sediments.

Lithology of Lee Strata

Lee strata of this area include sandstone, shale, siltstone, coal, underclay, and limestone in about that order of abundance. The lithology of each type is described as it may throw light on conditions of deposition.

Quartzose Sandstone

Such sandstones are characteristically massively bedded although occasionally thin beds occur. They usually contain well sorted sediments whose average grain-size distribution ranges from medium-grained to conglomeratic. Cross-bedding is common. Fore-set beds, in general, have steep dips and very little curvature. Quartzose sandstones usually rest unconformably upon underlying strata and commonly contain a basal zone of ferruginous redeposited material. Individual beds of such sandstones are usually uneven and give the appearance of indicating many minor erosional intervals. The Sewanee, Bon Air, and Rockcastle are examples of this sandstone type maintaining such lithology over large areas.

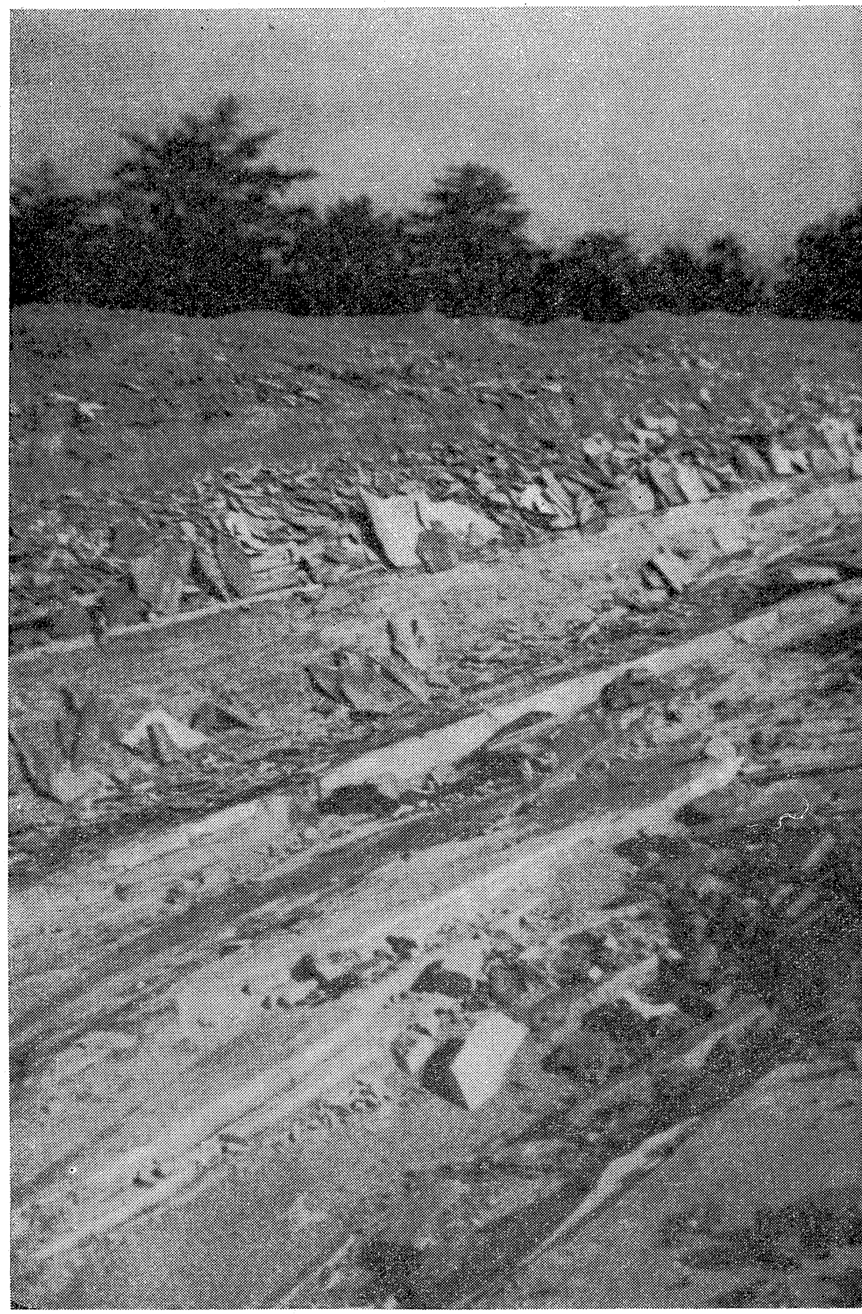


Figure 9. **Quarry in the Crossville Sandstone North of Crab Orchard. Dip is about 20 degrees.**

Sub-graywacke Sandstone

Bedding of these sandstones is characteristically slabby to blocky and fairly regular. They are characteristically fine-grained and poorly sorted containing considerable proportions of silt and often carbonaceous material. Ripple marks are often evident, and occasionally cross-bedding may be observed. This type of sandstone usually grades into, and interfingers with, adjacent siltstone and shale beds, and often shaly partings occur between sandstone beds. Units of such sandstone usually are conformable with underlying strata, but occasionally basal irregularity is observed sometimes with a basal "iron" zone containing shale pebbles and other redeposited fragments. The Middle Vandever sand member as well as numerous other thin sands within shaly units are of this type.

Siltstone

Siltstone refers to beds having the appearance of sandstone but containing material largely of silt size. This lithologic type is not common in Lee beds, but is found in rather thin units in shale formations. Lee siltstones are usually gray in color due largely to carbonaceous material and contain abundant plant impressions rather well preserved on bedding laminae.

Shale

Shale is second only to sandstone in abundance and varies from sandy to clay shale. Colors range from very light gray to nearly black depending on the amount of carbonaceous matter present. Bedding varies from paper-thin to a quarter inch or so although some gray shales display virtually no bedding and grade into underclay. Shales are gradational with underlying sandstones and are commonly unevenly eroded where overlain by quartzose sandstones.

Shales usually contain carbonaceous plant remains, often well preserved, and may contain many thin layers of coal. Pyritic, black shales commonly are associated with coal horizons and, in some cases, siliceous nodules occur in these beds. Underclays are thin, very local, and not easily differentiated from the underlying shale.

Coal

Coal beds are variable in thickness and often occur only locally. Where a coal bed pinches out, a zone of very dark shale is commonly found at that horizon. In the absence of coal the associated underclay is difficult to distinguish from massive gray shale.

Limestone

Only one occurrence of true limestone was observed in the area investigated by the writer. This occurrence was just below the base of the Rockcastle sandstone in the northeastern part of the Hebbertsburg quadrangle. It is a very thin, discontinuous bed of gray silty limestone both overlain and underlain by dark shale with paper-thin laminae. No fossils were seen in this limestone.

Environments of Deposition

According to most authors, Lee beds seem to have been deposited in an aqueous environment including delta, marsh, lake or lagoon, stream and shallow sea environments. Lithologic and petrographic characters of some beds tend to clarify their depositional environments, but by far the bulk of strata do not yield conclusive evidence.

Large scale cross-bedding, ripple marks, coarse texture and mineralogy of the quartzose sandstones suggest that considerable energy attended their deposition. The large cross-beds appear to be fore-set beds; whereas, the very evenly bedded, gently ripple marked beds, such as is sought as building stone, suggest deposition in a comparatively quiet body of water. Good sorting and lack of unstable minerals in such sandstones suggest rather slow deposition or long weathering of source material.

Sub-graywacke sandstones, on the other hand, exhibit less evidence of their depositional environment. In general it may be said that less energy is involved in their deposition since they lack cross-bedding and have only small ripple marks. Also, there is common lamination involving alternate layers of silt and fine sand with considerable amounts of carbonaceous material. This may signify deposition in a marsh into which coarse clastic material filtered at intervals or perhaps shallow, rather stagnant, water in lagoons, lakes or shallow seas which were, in any event, at least near the site of vegetation growth. Massively bedded siltstones seem to represent about the same type of environment.

Shales apparently represent a variety of environmental conditions. The black, pyritic, plant-bearing shales may represent stagnant marsh conditions much like conditions of coal formation except that more clastic material was available. The associated coals also evidently represent marsh conditions. Most shales lack diagnostic evidence of depositional conditions, but the well preserved plant remains suggest deposition close to if not at the site where plants grew. In many cases shales consist only of laminated, silty clay lacking plant remains except for unrecognizable carbonaceous fragments which could have been deposited at considerable distances from the areas of plant growth. The one calcareous bed observed failed to yield evidence as to whether it is fresh water or marine.

In summary, it seems that a generally aqueous continental or transitional marine-to-continental environment is indicated for Lee beds of this area. Although deposition in rather large bodies of water is indicated in many cases, there is no proof that either marine or fresh water conditions prevailed during deposition of the bulk of the sediments.

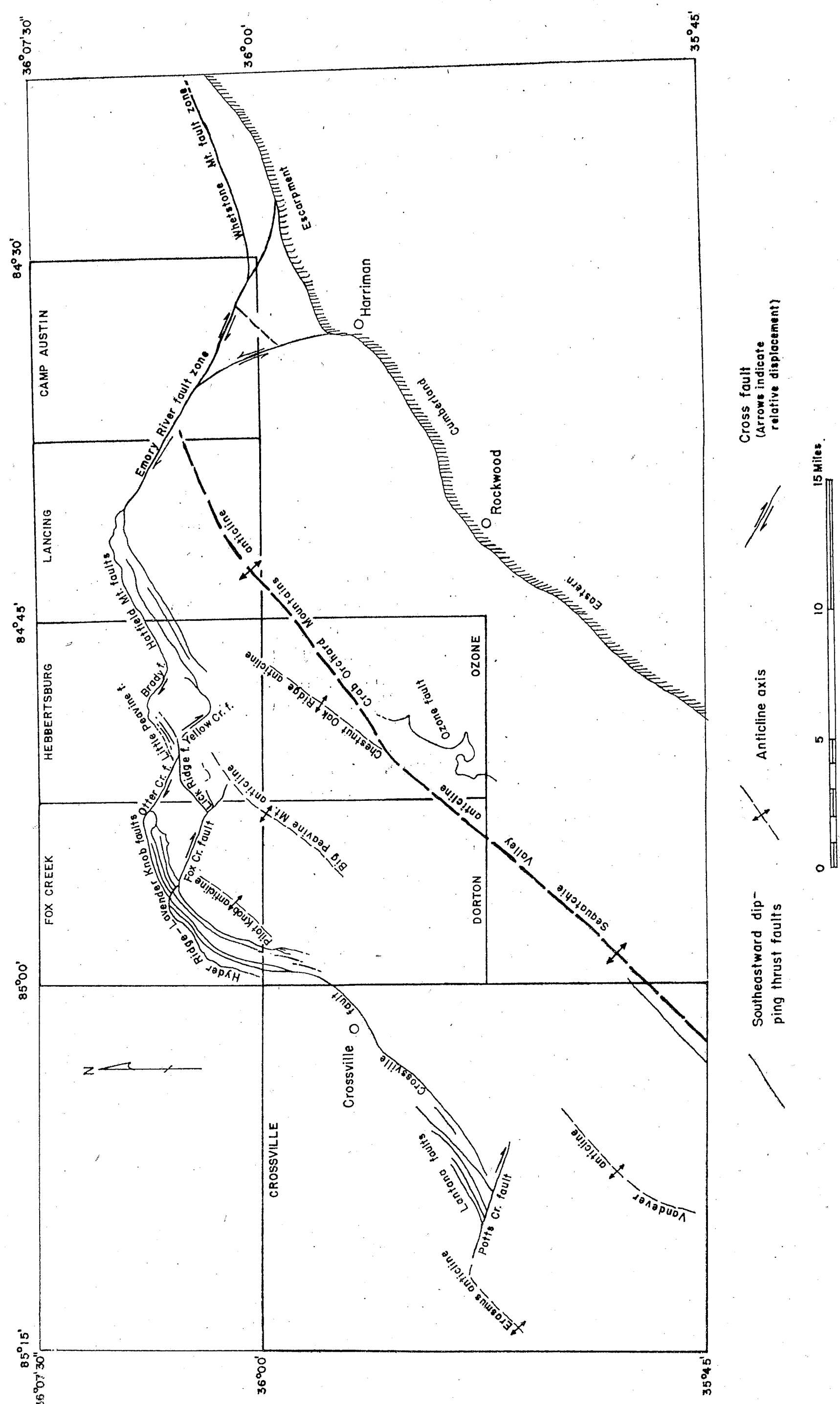


Plate III. Structural Features Associated with the Northern End of the Sequatchie Valley Anticline

STRUCTURE

Major structural features in and adjacent to the Crab Orchard Mountains area include the Sequatchie Valley anticline and a belt of thrust and tear faults north and northwest of the anticline. The entire known areal pattern made by these features may be seen on Plate III and that part mapped in detail on Plate IV, the structural contour map of the Crab Orchard Mountains area.

Sequatchie Valley Anticline

This anticlinal fold extends for more than 200 miles from Blount County, Alabama, to Cumberland County, Tennessee, where it terminates just east of the Crab Orchard Mountains area. Throughout most of its length its topographic expression is the Sequatchie Valley from which the anticline's name in Tennessee is taken. The Crab Orchard Mountains which occur at the northern end of the valley are due to massive Pennsylvanian sandstones sufficiently resistant to form this prominent unbreached anticlinal ridge. The anticline is broken on its steeper northwest flank by a thrust fault which terminates near the head of the Sequatchie Valley and does not continue into the Crab Orchard Mountains. The anticline in the Crab Orchard Mountains area gradually diminishes northeastward (see Plate IV) until it disappears at the Emory River fault in the eastern part of the Lancing quadrangle (see Plate III). Five to 20 degrees dips prevail on the southeast flank of the anticline, but on the northwest flank dips are much steeper ranging from 25 to 60 degrees. Flattening of dip is very rapid along the steep northwest flank, from 60 to less than 10 degrees in a distance of about 200 yards. On the southeast flank dip dies out very gradually to the southeast.

In the east-central part of the Ozone quadrangle the anticline bifurcates (see Plate IV). The northwest fold (Chestnut Oak Ridge anticline) is relatively minor but continues to the north border of the Ozone quadrangle along the same strike as the main anticline to the southwest. It ends abruptly at the north border of the Ozone quadrangle. The main anticline however, changes strike and bears more toward the east (Crab Orchard Mountains). With the exception of local crushing along the steep northwest limb of the Sequatchie Valley anticline, beds are generally not intensely deformed. Very intense crushing and tight folding, however, occur in restricted stratigraphic horizons on both flanks. For example, in the southeastern part of the Ozone quadrangle, beds of the Gizzard formation are contorted and sheared, whereas, overlying and underlying beds have only gentle dip. Farther to the northeast in this quadrangle the Sewanee conglomerate is sheared and folded to such an extent that it is very difficult to discern bedding. In each of these instances underlying and overlying strata are not contorted. The significance of these stratigraphically localized zones of contortion will be discussed later.

A thrust fault here named the Ozone fault, occurs on the southeast flank of the Sequatchie Valley anticline at the southern border of the Ozone quadrangle. Although this fault is separated from the fault system west of the anticline, it is important because the fault plane is exposed for a mile down dip, thus permitting an insight into behavior of faults at depth in this area. As far as this fault plane is exposed down the dip, it primarily follows bedding so that stratigraphic throw is slight. The Bon Air sandstone and Whitwell shale are here repeated so that they overlay each other throughout a distance of at least a mile. Relative to bedding about

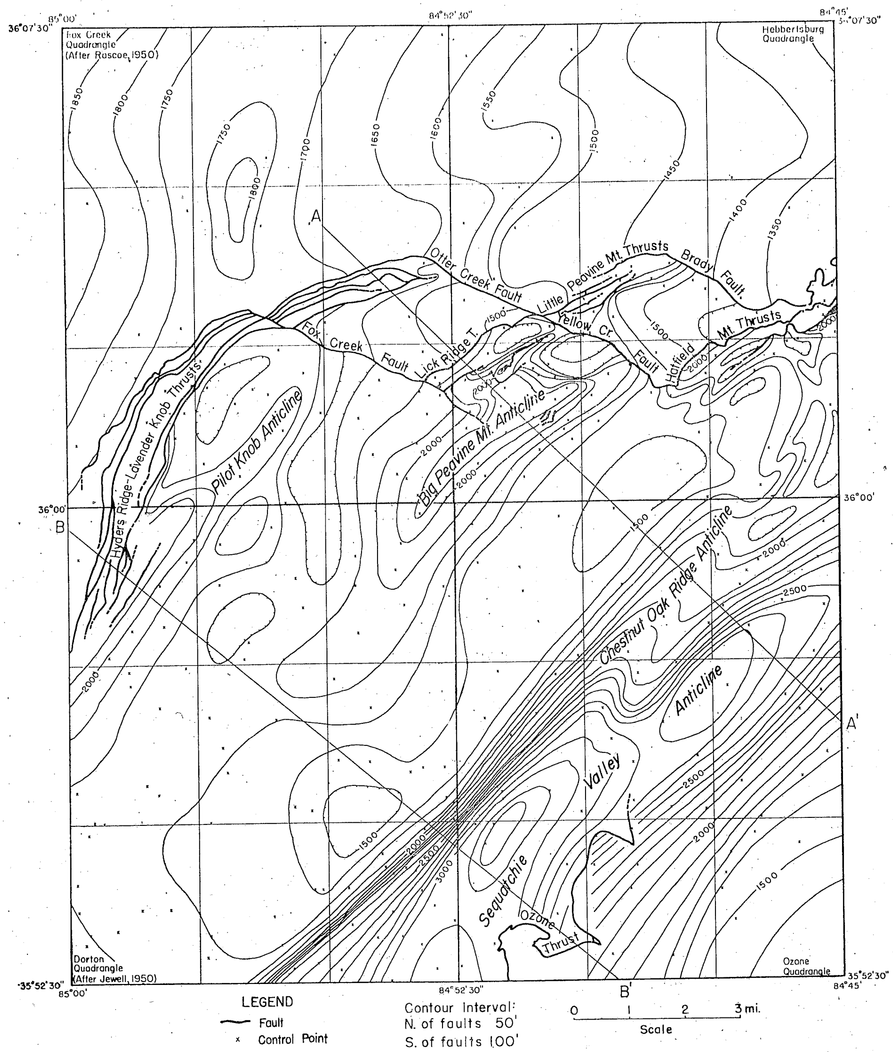


Plate IV. Structure Contour Map, Drawn on Top of the Rockcastle Sandstone

200 feet of vertical movement is therefore represented. On the hanging wall beds are intensely crushed and contorted; but below the fault plane only minor fractures in shale and squeezing of coal occur. Thus, above the thrust the Bon Air sandstone is strongly contorted, but below the thrust this same sandstone is nearly undisturbed.

Three significant relationships are shown by this fault; (1) very low angle of faulting relative to bedding, (2) large amount of horizontal movement and small vertical movement, and (3) intense contortion of beds immediately above the fault plane and only slight deformation of beds below. These relationships proved most useful in interpreting structures which will be subsequently discussed as they illustrate on a relatively small scale the type of faulting which is believed to affect the entire region.

Belt of Thrust and Cross Faults

Northwest and north of the Crab Orchard Mountains is a long continuous belt of intense structural deformation. This belt consists chiefly of a series of en-echelon southeastward dipping thrust faults connected by cross faults and associated anticlines. This belt has been mapped from the Lantana area on the southwest to the edge of the Valley and Ridge province at Elverton and Harriman as shown on Plate III.

Thrust Faults

The thrust faults in the belt strike northeast and their planes dip southeast. Southeastward dip of the fault planes ranges from less than 10 degrees to about 50 degrees. Thrust faults occur generally in zones of restricted width within which there are several faults. Thrusts either merge with cross faults or terminate along strike in small, sharp asymmetrical anticlines overturned to the northwest. As in the case of the Ozone fault, rocks above the fault planes are characteristically crushed and contorted, but beds below are undisturbed. Where several faults occur close together, however, beds both above and below fault planes may be crushed if such beds are between two thrust planes.

Thrust zones are generally marked by prominent ridges due to dip of resistant sandstone beds. These zones are from east to west—the Hatfield Mountain faults, Little Peavine Mountain faults, Lick Ridge faults, Lavender Knob faults, Hyders Ridge faults, Crossville fault, Lantana faults, and Erasmus "anticline" (see Plate III).

HATFIELD MOUNTAIN FAULTS

The Hatfield Mountain faults comprise the easternmost thrust zone of the pattern. Three faults make up this zone where the writer mapped it in detail in the Hebbertsburg quadrangle. Along the northwestern fault highly contorted beds of Rockcastle sandstone are thrust over the Duskin Creek. Just northeast of Brady Branch this fault turns northwestward and forms the Brady cross fault. The middle fault is associated with steeply dipping beds and dips about 50 degrees to the southeast. Throw is variable along this fault. Rockcastle sandstone is thrust over the Duskin Creek formation to the northeast, but to the southwest throw increases until Bon Air Sandstone is thrust over the Duskin Creek formation. There is a rather abrupt end to this fault as it turns sharply northwest to form the Yellow Creek cross fault. The southeasternmost thrust diminishes abruptly in magnitude to the southwest and terminates in an asymmetrical anticline. Although the fault extends only a short distance into the Ozone quadrangle, greatest throw occurs here as Sewanee conglomerate is locally thrust over the Duskin Creek formation.

LITTLE PEAVINE MOUNTAIN FAULTS

The Little Peavine Mountain faults occur about two miles northwest of the southwestern extension of the Hatfield Mountain fault zone. They lie between the Brady cross fault and the Yellow Creek-Otter Creek cross fault line (Plate IV). Slippage along these thrusts appears minor because no single fault in this zone is continuous between the limiting tear faults. Of the five faults making up this zone three do not connect with either tear fault but terminate at each end in sharp anticlines. Throughout most of this zone the thrust plates consist of successively repeated slices of Rockcastle.

LICK RIDGE FAULT ZONE

The Lick Ridge fault zone is nearly continuous with the Little Peavine faults (see Plate IV) but slightly offset to the northwest by the Otter Creek cross fault. Throughout a two mile zone one major fault is continuous. This thrust joins the Otter Creek cross fault on the northeast and the Fox Creek cross fault on the southwest. The main Lick Ridge fault thrusts Rockcastle sandstone over the Duskin Creek formation at a low angle judging by the 15 degree dip of beds on the hanging wall side. Near its northeast end where it joins the Otter Creek cross fault, however, dips are much steeper ranging up to 80 degrees to the southeast. Only two other thrust faults are known along Lick Ridge and both of them are minor. One joins the Fox Creek tear fault and the other fault terminates at both ends in minor anticlines.

Considerably more throw occurs along the minor Lick Ridge fault that joins the Fox Creek cross fault. Near the junction of these faults beds as old as lowermost Vandever shale are thrust over the Duskin Creek formation. Like other terminating thrusts this one ends in an anticline to the northeast. Along the other minor thrust the Rockcastle sandstone is thrust over the Duskin Creek formation, and this fault dies out on either end in anticlines.

LAVENDER KNOB—HYDERS RIDGE FAULTS

The Lavender Knob-Hyders Ridge faults extend southwestward from the end of the Otter Creek cross fault across the Fox Creek and Dorton quadrangles (see Plate IV). Five southeast dipping thrust faults compose the Lavender Knob-Hyders Ridge zone. In the Lavender Knob zone successive sheets of Rockcastle sandstone, and in some cases Duskin Creek beds, are thrust over one another. Beds as old as Sewanee conglomerate are involved in the Hyders Ridge area, but poor exposures make stratigraphic determinations difficult. Three of the five thrusts end near the southwest corner of the Fox Creek quadrangle, but two continue into the Dorton quadrangle where they are involved in a complex area of minor thrust faults. All five thrusts merge with the Otter Creek fault to the northeast.

CROSSVILLE FAULT

The Crossville fault was first mapped by Butts and Nelson (1925) as a normal fault terminating north of Crossville. This fault, which is actually a thrust fault, continues along the southeast outskirts of Crossville and joins the Hyders Ridge fault zone in the Dorton quadrangle. As in the case of similar faults to the east, beds on the southeast or upthrown side of the Crossville fault are contorted and dip southeast forming a continuous prominent ridge. This fault was traced southwestward to the Lantana fault zone of Butts and Nelson (1925).

LANTANA FAULTS

The Lantana faults were interpreted by Butts and Nelson (1925, p. 21) as normal in type. They state: "the fault planes are assumed to be very steep or nearly vertical as the generally surrounding conditions do not appear to indicate any considerable horizontal movement such as would be involved in overthrusts . . ." These faults, however, are continuous with the thrusts to the northeast and intense crushing may be seen in this fault zone. Therefore, they also must be thrust faults similar to those mapped in more detail to the northeast. The Lantana faults end abruptly, as do other thrusts of this system, at a cross fault termed the Potts Creek fault by Butts and Nelson.

ERASMUS DEFORMATIONAL LINE

The Erasmus deformational line (Butts and Nelson 1925) was interpreted as an anticline with gentle dips on its southeast limb and nearly vertical dips on its northwest limb. The present writer observed crushing of heavy sandstone units in this vicinity, and Butts and Nelson reported similar conditions farther to the southeast along this same strike. Thus, instead of a simple asymmetrical anticline this feature is probably broken on the northwest limb by a thrust giving the appearance of an unnaturally sharp anticlinal crest.

Butts and Nelson (1925, p. 20) report that structural disturbances continue several miles southwestward from this "anticline" along the same strike as far as Spencer, Van Buren County. This demonstrates that this regional thrust belt extends farther to the southwest than has been mapped.

Cross Faults

The thrust faults just described are interrupted and connected by several northwest trending cross faults which limit the zones of thrusting and invariably merge with or become at least one thrust of each zone. From east to west these transverse lines of faulting are: the Emory River fault, Brady fault, Otter Creek-Yellow Creek fault. Fox Creek fault and Potts Creek fault. The location of these faults may be seen on Plates III and IV.

Where a significant amount of throw occurs along these faults, beds on the southwest side are commonly raised relative to those on the northeast side. Often there is no appreciable vertical offset on these faults, the movement having been primarily lateral. In such cases the faults still may be traced by the trends of associated crushed rock.

EMORY RIVER FAULT ZONE

The Emory River fault zone was described by Jillson (1919) who interpreted it as an overthrust from the southwest. He believed that it extended northwestward beyond the Hatfield Mountain area up Clear Creek in the northwestern part of the Lancing quadrangle, and that the southwest has risen relative to the northeast block. Rodgers correctly suggested (1950, p. 676) that the zone does not cross the Hatfield Mountain "anticline" but swings into this structure.

The writer traced this fault as far southeast as Camp Austin in the Camp Austin quadrangle. Near Camp Austin the fault zone splits. According to C. W. Wilson, Jr., John W. Jewell, and R. M. Mitchum, Jr. (personal communication), one split joins the Valley and Ridge structural system just north of Harriman, Tennessee, and the other joins the Valley at Elverton Gap.

Although some "crowding" occurred along this fault, most of the movement is attributed to slippage along its strike. Locally no evidence of appreciable throw can be seen. Such is the case in the central and eastern part of the Camp Austin quadrangle where this fault was seen at Camp Austin and along Highway U. S. 27. Northwest of Camp Austin the fault displays appreciable throw, and beds on the southwest side are considerably elevated above the same strata on the northeast side.

Northwest of Camp Austin the surface trace of this fault is, for the most part, on the southwest side of the Emory River. Flat-lying beds are exposed on both sides of the stream to within a mile southeast of Nemo. At Nemo the river changes direction and crosses and recrosses the fault. Contrary to the pattern suggested by Jillson (1923), this fault does not continue up clear Creek past Hatfield Mountain. It swings abruptly southwestward at Hatfield Mountain and merges with the Hatfield Mountain thrust belt.

BRADY FAULT

The Brady fault is the next cross fault to the southwest. Generally, beds adjacent to this fault are poorly exposed, but in the gorge of Daddy's Creek excellent exposures occur. Here it may be seen that intense compression attended this faulting as massive beds of the Rockcastle are folded and crushed. In addition to the main fault there are three subsidiary faults. Two of these faults are so close together that they were mapped as one. The subsidiary faults, however, are not traceable beyond the gorge. Beds southwest of this fault are generally elevated above the corresponding beds to the northeast. Vertical offset is about 100 feet near the Hatfield Mountain thrust and is nearly 300 feet on the northeast end of Little Peavine where this fault merges with the Little Peavine thrusts.

YELLOW CREEK FAULT

The Yellow Creek fault with certain modifications shows relationships similar to the Brady fault. This cross fault is formed by one of the Hatfield Mountain thrusts turning northwest. It was traced from here northwestward toward the area where the Little Peavine Mountain and Lick Ridge thrusts join the Otter Creek cross fault. Here again, beds southwest of the fault are elevated relative to beds on the northeast side. This offset decreases to the northwest; but even where vertical offset is slight, the fault can be traced by scant exposures and loose blocks of crushed sandstone. Such data indicate that it joins the Otter Creek cross fault.

Excellent exposures of the Yellow Creek cross fault occur in the gorges of Daddys Creek and Yellow Creek. At these localities it is a steeply dipping fault overthrust from the southwest. In this vicinity Bon Air sandstone is thrust against Rockcastle sandstone at a high angle. The upthrown Bon Air continues unbroken around the turn where this cross fault becomes the center of the three Hatfield Mountain thrusts.

OTTER CREEK FAULT

The Otter Creek fault extends from the junction of the Little Peavine and Lick Ridge thrusts northwestward into the Fox Creek quadrangle where it merges with the Lavender Knob thrust fault (see Plate IV). Like the preceding cross faults it exhibits some vertical movement but this effect is slight.

FOX CREEK FAULT

The Fox Creek fault extends northwestward from Peavine Mountain near the western edge of the Hebbertsburg quadrangle (see Plate IV). It terminates in the Lavender Knob-Hyders Ridge thrust faults of the Fox Creek quadrangle by offsetting these thrusts about 2000 feet. There is little vertical offset at the Lavender Knob thrusts to the northwest, but considerable upthrow of the south side occurs to the southeast near Big Peavine Mountain. This fault terminates on the southeast at Big Peavine Mountain in intensely contorted beds of the Bon Air sandstone.

POTTS CREEK FAULT

The Potts Creek cross fault, mapped by Butts and Nelson (1925), joins the Erasmus "anticline" with the Lantana thrusts. This fault is the southwesternmost cross fault mapped at present, although continued tracing of the fault system may disclose others.

Big Peavine Mountain Structure

This structure extends from the southeastern part of the Hebbertsburg quadrangle southwestward into the Dorton quadrangle (see Plate IV). Elevations on the Rockcastle sandstone show that it is superficially an anticline. Several lines of evidence show that this structure is not a conventional anticline, but rather is a consequence of faulting and genetically associated with the fault system previously discussed. On this feature the Bon Air sandstone is intensely crushed and contorted; whereas, the over-lying beds are only gently warped conforming with the dip of the flanks of the "anticline." Such relationships suggest faulting beneath this bed. This stratigraphically localized deformation is reminiscent of the Ozone fault to the southeast where the Bon Air is similarly deformed.

Two wells have been drilled on this structure. These provide explanation of the anomalous relationships outlined above. In both wells a normal stratigraphic sequence was encountered downward from the Rockcastle to the Bon Air, and a normal sequence upward from the Pennington formation to the top of the Sewanee conglomerate. Between the undoubted Sewanee blow and undoubted Bon Air above there are about 800 feet of sandstone in several units separated by only a few feet of shale. Such a thickness of sandstone is many times greater than the normal Sewanee-Bon Air interval, and must be attributed to duplication by faulting. Repetition of lower beds by faulting readily accounts for the anticlinal structural relief in the overlying Rockcastle sandstone. These relationships are shown by cross section A-A on Plate V.

The broad flat top of the Big Peavine Mountain "anticline" suggests that duplication occurs for a considerable distance across its strike. This situation requires considerable horizontal movement in much the same manner as the Ozone fault. The thrust that formed this anticlinal feature does not outcrop in the vicinity, but is believed to outcrop as the Lavender Knob-Hyders Ridge thrust zone 5 miles to the northwest.

The Lavender Knob-Hyders Ridge thrust fault beneath Big Peavine Mountain, like the Ozone fault, must dip gently to the southeast probably following bedding for a great distance and changing its stratigraphic position about two hundred feet in five miles.

Interpretation

The previously discussed structural features form a continuous pattern of thrust and cross faults from near Elverton and Harriman, Roane County, to Clifty, White County. Probably this system extends farther to the southwest at least as far as Spencer in Van Buren County (Plate III). It consists of a series of southeast dipping thrusts offset by northwest trending en-echelon cross faults. This entire fault pattern is herein called the Cumberland Plateau overthrust.

When viewed regionally a striking similarity is seen between this system and the pattern of faults marking the Pine Mountain thrust block to the northeast (see Fig. 1 and Plate III). Similarity exists in the angular relationships of thrust and cross faults, general dimensions, and position with reference to regional structural patterns. Obvious differences are in the occurrence of six en-echelon cross faults and the presence of the Sequatchie Valley anticline with no counterpart to the northeast.

The close similarity in pattern suggests that these two structural systems are of the same nature; that is, they have the same origin and mechanics. To test this inference the nature of the Cumberland Plateau overthrust will be discussed and then compared with the known behavior of the Pine Mountain block.

Attitude of Fault Planes

Thrust faults of the Cumberland Plateau overthrust block have southeast dipping fault planes. No exception to this direction was observed. At the surface faults vary in dip from nearly horizontal to more than 40 degrees. At depth the attitude of these faults is not definitely known, but there are many indications that the fault planes are nearly parallel to the bedding over most of their extent and therefore nearly horizontal. This relationship has already been demonstrated for the Ozone thrust and the Lavender Knob-Hyders Ridge thrust beneath Big Peavine Mountain.

Southeastward from Big Peavine Mountain the faulting is believed to primarily follow bedding. This furnishes an explanation of the anomalous, stratigraphically restricted zones of crushing in the Sewanee and Gizzard on the flanks of the Sequatchie Valley anticline in the Crab Orchard Mountains. If these crushed zones are actually related to the fault under Peavine Mountain as postulated, this faulting has only moved downward another 'ela-

that
tua-
ıner
not
ıob-

vine
ably
osi-

tern
nty,
the
. It
ding
um-

tem
the
ion-
with
oc-
chie

ems
ics.
will
Pine

east
ved.
nore
wn,
l to
This
the

l to
ous,
l on
oun-
vine
ther

PLATE V

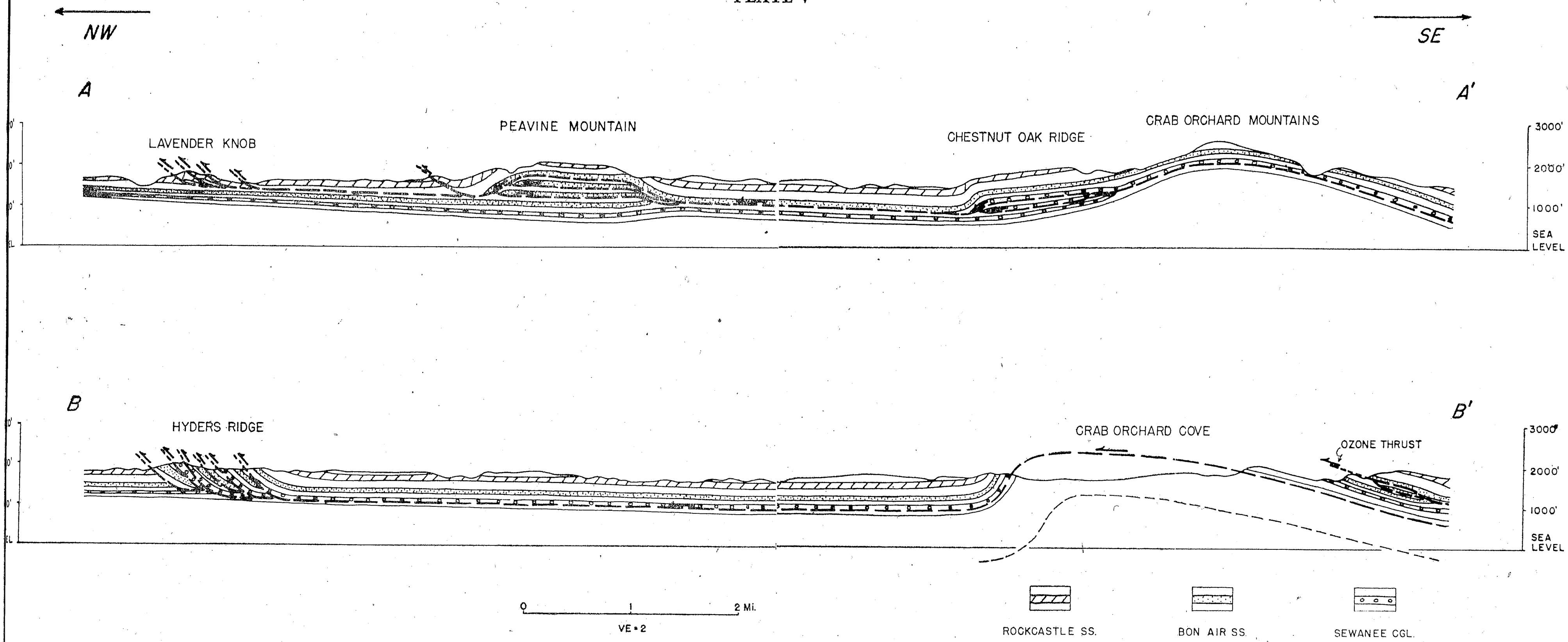


Plate V. Structure Cross-sections of the Crab Orchard Mountains Area (Geographic position of section lines are drawn on Plate I).

200 feet in the seven miles between Peavine Mountain and the Crab Orchard Mountains. Since these zones of crushing are present on both limbs of the Sequatchie anticline, the thrust sheet must also arch over this anticline. This implies that the main fault system is not directly related to the anticline, as illustrated on Plate V.

Where planes of cross faults may be measured or estimated, they dip steeply to the southwest. Because these faults turn and merge with, or become, thrusts at the surface their dip must flatten where they merge with the low angle fault planes at depth. The best illustration of this is the junction of the Yellow Creek tear fault and the Hatfield Mountain thrust zone. Here the beds associated with both faults may be traced continuously around this transition from thrust fault to cross fault. Such a gradual turn with no discontinuity in the upthrown side shows that these two faults are actually the same. Therefore, the amount of strike-slip on the cross fault is equal to the amount of heave on the thrust fault.

Another good illustration is the Emory River fault that merges with the low-angle extension of the Hatfield Mountain thrust to the southwest. At Harriman and Elverton the Emory River fault merges with the Chattanooga fault of the Valley and Ridge province (Rodgers 1952, Plates 7 and 8).

Movement Along Faults

Strike-slip along cross faults must be equal to heave on the associated thrusts. This is, of course, true only for the Emory River, Brady, Otter Creek and Potts Creek cross faults that limit the fault system to the northeast. Those extending southeastward into the thrust sheet have srike-slip depending on the relative movement of adjacent thrust blocks. In some of the thrusts there is no way of establishing from surface mapping the horizontal distance over which duplication occurs, and no reliable maximum estimate of movement can be made.

In the case of Big Peavine Mountain, however, subsurface data gives the amount of duplication and surface mapping gives approximately the horizontal distance over which duplication occurs. Such information leads to the conclusion that this apparent anticline is the result of approximately three miles of thrusting. The intimately associated Lavender Knob thrust must also represent about this amount of movement. Also, since the Lavender Knob thrust zone is directly connected to the whole en-echelon series of cross faults and tear faults, these must also have experienced the same magnitude of movement.

On a smaller scale the heave on the Ozone thrust is about a mile because duplicated beds were mapped over that distance across the strike. Since none of the Little Peavine thrusts are continuous between the limiting cross faults, this zone probably represents only about 1000 feet of movement. The Fox Creek cross fault extends into the overthrust mass. Strike-slip of about 2000 feet is estimated for this fault by offset of the Lavender Knob-Hyders Ridge faults.

Comparison with the Pine Mountain Block

NATURE OF THE PINE MOUNTAIN BLOCK

Previous investigations (Wentworth, 1921; Butts, 1927; Rich, 1934) established that the thrust and cross fault pattern outlines a low angle thrust sheet which has moved several miles to the northwest relative to underlying rocks. On the northwest this sheet is limited by the Pine Mountain thrust which is terminated at both ends by cross faults—the Russell Fork fault in Virginia and the Jacksboro fault in Tennessee.

Within the block are two longitudinal divisions—the Cumberland Mountain syncline to the northwest, adjacent to the Pine Mountain thrust fault, and the Powell Valley anticline to the southeast. The Powell Valley anticline is broad and flat-topped but becomes narrow and of less significance to the northeast. Fensters on this anticline expose Silurian beds underlying the Cambro-Ordovician (Butts, 1927). Such fensters mark the position of the thrust plane nearly twenty miles southeast of its outcrop along Pine Mountain.

Duplication of pre-Pennsylvanian beds, due to the thrusting, developed the Powell Valley anticline, and as the anticline diminishes in width northeastward, the amount of horizontal movement along the causal fault decreases. Thus, this block "rotated" about its northeast end. Movement of less than two miles is reported at its northeast end (Wentworth, 1921, p. 65) and greater than ten miles near its southwest end (Rich, 1934, p. 1588).

The low angle fault basal to this thrust sheet primarily follows two incompetent layers; shales in the lower and middle Cambrian Rome and Conasauga formations and the Chattanooga shale. Breaks in these incompetent beds are connected by a more steeply dipping fracture across the intervening competent beds (Rich, 1934, p. 1590). Figure 10 schematically shows the pattern of fractures in cross-section both previous and subsequent to movement; and also shows the nature of both the Cumberland Mountains syncline and Powell Valley anticline.

COMPARISON WITH THE FAULT SYSTEM OF THE CENTRAL CUMBERLAND PLATEAU

The Pine Mountain fault, like thrust faults of the Cumberland Plateau overthrust, dips comparatively steeply southeastward, as seen in outcrop, but flattens with depth to become a bedding fault. Also, where duplicated beds are not removed by erosion, the result is "anticlinal" features both in the case of the Pine Mountain overthrust (Powell Valley anticline) and the Cumberland Plateau overthrust (Peavine Mountain anticline). The primary attitude of the major fault plane is judged to be flat in both cases. The large number of en echelon cross faults of the Cumberland Plateau thrust are the counterpart of the single Jacksboro fault at the southwest end of the Pine Mountain thrust block. In both cases the cross faults, which are primarily strike-slip faults, have undergone some thrusting due to crowding.

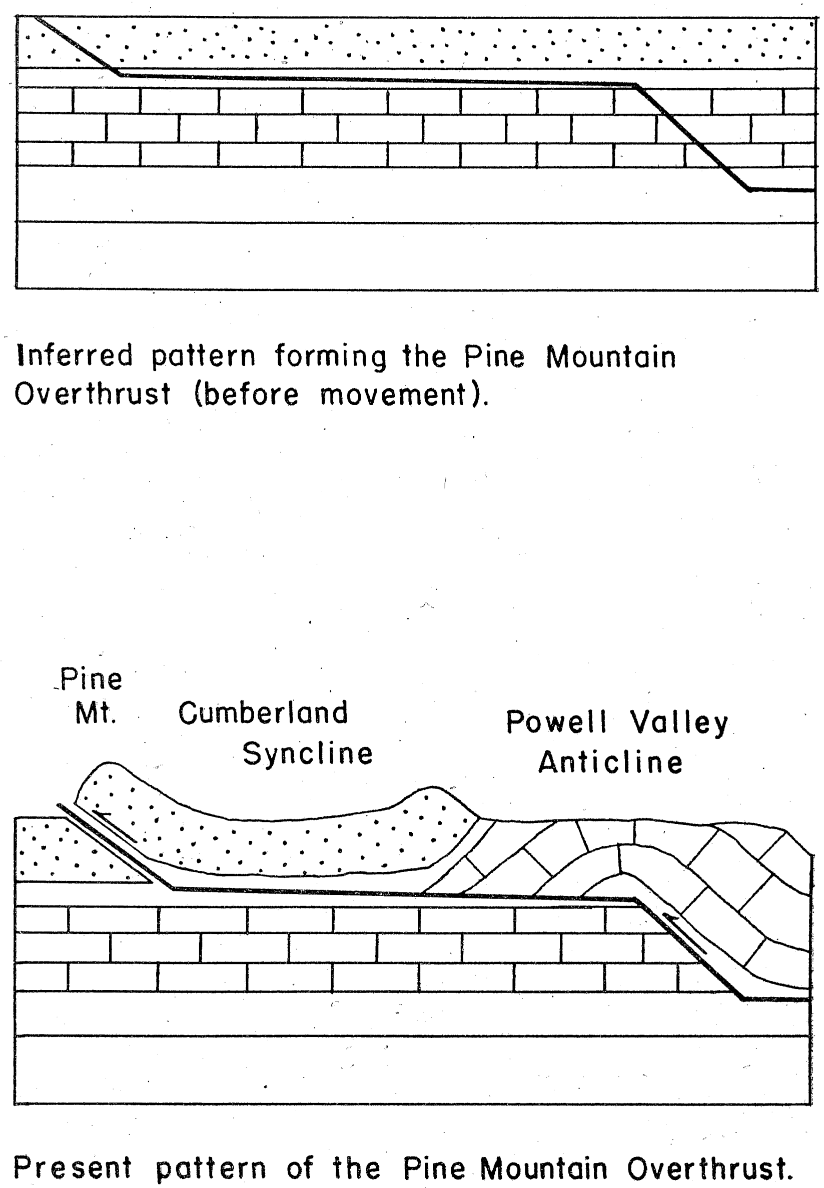


Figure 10. **Nature of the Pine Mountain Overthrust.**

Comparison of the pattern of these two fault systems strongly supports the inference that they have identical relationships and mechanics of formation. Judging by the behavior of the cross faults, the northeast end of the Cumberland Plateau overthrust is a mirror image of the southeast end of the Pine Mountain block. The swing of the Emory River fault into the en echelon cross and thrust faults corresponds mechanically with the turn of the Jacksboro fault into the Pine Mountain thrust.

Although these two major thrust sheets are similar in width across the strike from their western outcrops to the Cumberland Mountain front it is not certain that they have the same length. The Pine Mountain block is about 125 miles long, but the Cumberland Plateau thrust sheet has only been mapped for about 35 miles southwest of the Emory River, and is known to occur 15 miles southwestward beyond this point where it affects beds of the Pennington shale.

Insofar as the last known exposure was in the Pennington shale, the question may be raised as to whether this fault may extend farther southwestward hidden as a bedding fault, or faults, in the soft incompetent Pennington shale. In logging core taken from drill holes in Franklin County west of Orme, Marion County, the writer observed that Pennington shales were considerably sheared and contorted. Thus it is possible that most of the Pennsylvanian of southern Tennessee has been thrust northwestward even though there are no surficial indications of such movement. However, it is equally possible that this fault system dies out southwestward and does not affect the plateau in southern Tennessee.*

Rodgers (1950) believes that the Sequatchie Valley anticline itself is a result of a low angle thrust. The Cumberland Plateau thrusts terminate at the Emory River directly at the end of the Sequatchie Valley anticline. This coincidence make it tempting to speculate that the southwest end of the Cumberland Plateau thrust mass may also coincide with the southwest end of the Sequatchie Valley anticline in Blount County, Alabama. If these relationships are correct, then in areal dimensions the Cumberland Plateau thrust sheet is even more extensive than the Pine Mountain Block although the horizontal movement probably was much less.

Regional Significance of the Cumberland Plateau Overthrust

There are two very different concepts of Appalachian structure characterized by Rodgers as the "thick-skinned" and "thin-skinned" schools of thought. He states (1949, p. 1653):

> "The thick-skinned geologists . . . have reasoned from the broad low folds of the Appalachian Plateau to the hypothesis that the folds and faults of the Valley and Ridge province are the main manifestations of the Appalachian orogeny and that each continues separately to the basement. The thin-skinned geologists . . . have reasoned from the great low-angle

* After this bulletin went to press, faulting in the Gizzard was reported as far south as northeastern Grundy County by John W. Jewell and Edward T. Luther.

> thrust faults . . . , especially the Pine Mountain fault, to the hypothesis that the Paleozoic rocks of the unmetamorphosed part of the Appalachians, caught on the margin of intense deformation on the southeast, were stripped completely off the basement and piled up against the unyielding plateau in great rootless folds and imbricate thrust sheets underlain by a few bedding-plane faults of immense displacement."

Proponents of the "thick-skinned" concept, notably Ver Wiebe, have pointed to the Pine Mountain overthrust as an exception, a structural anomaly having no bearing on the essential structural pattern of the Ap-

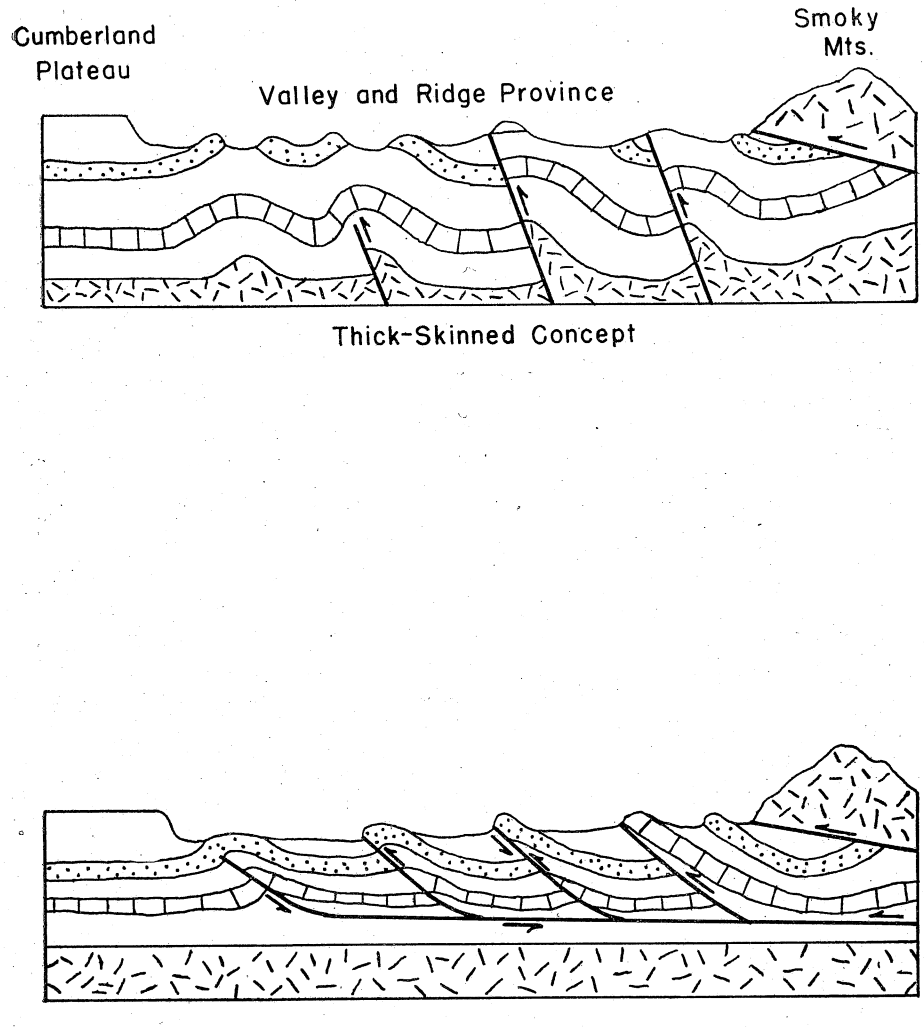


Figure 11. Concepts of Appalachian Structure.

palachian region. Proponents of the "thin-skinned" concept use this low angle thrust as a main proof of their contentions. This nearly horizontal thrust sheet involving rocks of the Cumberland Plateau led some geologists (Butts, 1927; Rich, 1934; Rodgers, 1949) to question the classic interpretation of the attitude of the faults at depth. Their alternate concept considers the younger sedimentary rocks to be sheared from the underlying crystalline basement along an extensive horizontal basal fault or sole. The observed steeply dipping faults merge with the sole fault at depth; so that the underlying basement rocks are essentially undisturbed. These two concepts are compared graphically on Figure 11.

The Cumberland Plateau overthrust markedly modifies the weight of evidence. This discovery establishes that along much of, if not the entire, length of the Southern Appalachian fault system low angle thrusting is the terminal structure to the west. This evidence, in conjunction with the previously known facts, lends additional support to the thin-skinned concept of Southern Appalachian Valley structure.

Structural Conclusions

The system of thrusting and cross faults, herein named the Cumberland Plateau overthrust, extends southwestward from the Emory River fault (Plate III) and is believed to bound a low angle thrust sheet fundamentally similar to the Pine Mountain block. From the fault outcrop the fracture extends southeastward, primarily along bedding planes of shales, at a shallow depth through seemingly undisturbed Pennsylvanian and upper Mississippian beds and has its roots in the faults of the Valley and Ridge. Thus, discordance between the Cumberland Plateau and the Valley and Ridge Province to the southeast is not as sharp as has been commonly supposed, and outlying structures of the Plateau are in fact intimately related to the structure of the Valley and Ridge.

This thrust sheet may extend southwestward to the vicinity of Birmingham, Alabama, at the southern end of the Sequatchie Valley anticline, a distance of well over 200 miles. Pennsylvanian, and perhaps some upper Mississippian beds, underlying all of the Cumberland Plateau south of Van Buren County, Tennessee, may have been thrust northwestward along the basal low angle fault. It is also possible that upper beds in the Black Warrior coal field of Alabama have experienced similar, but less, movement.

This thrust and the previously known Pine Mountain thrust indicate a western marginal belt of low angle thrusts along nearly the entire length of the Southern Appalachian valley. Discovery of the Cumberland Plateau overthrust therefore lends additional support to the thin-skinned concept of Southern Appalachian valley structure.

BIBLIOGRAPHY

Butts, C., and Nelson, W. A. (1925) "Geology and mineral resources of the Crossville quadrangle": Tennessee Div. Geol. Bull. 33-D.

——————(1927) "Fensters in the Cumberland overthrust block of southwest Virginia": Va. Geol. Survey Bull 28.

Glenn, L. C. (1925) "The northern Tennessee coal field": Tenn. Division of Geol. Bull. 33-B.

Hayes, C. W. (1894) "Kingston, Tennessee": U. S. Geol. Survey Geol. Atlas, Folio 4.

Nelson, W. A. (1925a) "The Southern Tennessee Coal Field": Tenn. Div. Geol. Bull. 33-A.

——————(1925b) "Geology of the Herbert Doman": Tennessee Div. Geol. Bull. 33-C.

Rascoe, B. (1951) "Geology of the Fox Creek quadrangle": unpublished master's thesis, Vanderbilt Univ.

Rich, J. L. (1934) "Mechanics of low angle overthrust faulting as illustrated by Cumberland thrust block, Virginia, Kentucky and Tennessee": Bull. Amer. Assoc. Petrol. Geol., vol. 18, p. 1584-1596.

Rodgers, John (1949) "Evolution of thought on structure of middle and southern Appalachians": Bull. Amer. Assoc. Petrol. Geol., vol. 33, No. 10, p. 1643-1654.

——————(1950) "Mechanics of Appalachian folding as illustrated by Sequatchie anticline, Tennessee and Alabama": Bull. Amer. Assoc. Petrol. Geol. vol. 34, No. 4, p. 672-681.

——————(1953) "Geologic Map of East Tennessee with explanatory Text": Tenn. Div. Geol., Bull. 58, Part II.

Safford, J. M. (1869) "Geology of Tennessee": Nashville, 550 p.

——————(1893) "The topography, geology, and water supply of Sewanee": Tenn. St. Board of Health Bull., vol. 8, No. 6, p. 89-98.

Ver Wiebe, W. A. (1936) "Geosynclinal boundary faults": Bull. Amer. Assoc. Petrol. Geol., vol. 20, No. 7, p. 910-938.

Wanless, H. R. (1945) "Pennsylvanian geology of part of the Southern Appalachian coal field": Geol. Soc. Amer. Memoir 13.

Wentworth, C. K. (1921) "Russell Fork fault of southwest Virginia": Jour. Geol., vol. 29, p. 351-369; Va. Geol. Survey Bull. 21, p. 53-66.