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LOW-ANGLE OVERTHRUST FAULTING, AS ILLUSTRATED BY THE CUMBERLAND PLATEAU—SEQUATCHIE VALLEY FAULT SYSTEM

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ABSTRACT. Detailed geologic mapping of the Sequatchie Valley fault, Sequatchie Valley, Tennessee, has indicated that the Sequatchie Valley fault dips to the southeast at a low angle in the northern part of the valley, at a moderate angle in the central portion, and at a low angle in the southern portion of the area mapped, near the Tennessee-Alabama state line. The evidence for a law angle of dip is the irregular trace of the fault and klippen immediately in front of the overthrust in the northern and southern portion of the valley. The trace of the Sequatchie Valley fault is straighter and klippen are absent in the central section. In the northern and southern sections, Ordovician to Mississippian formations are thrust over Mississippian shales; in the central section the foot wall formation is composed of massive limestone. Thus, the lithology of the foot wall is apparently the factor which governs the attitude of the fault surface.

The Cumberland Plateau overthrust and Sequatchie Valley fault are genetically related. This is shown by: (1) the fault pattern at the northern end of Sequatchie anticline, (2) the cross-sectional symmetry of the northern portion of Sequatchie anticline, and (3) drill hole data. The Cumberland Plateau overthrust, therefore, does not arch over Sequatchie anticline as a bedding thrust within Mississippian and Pennsylvanian formations, and Sequatchie Valley, Grassy Cove, and Crab Orchard Cove are not windows.

INTRODUCTION

Location and extent.—The Sequatchie anticline, a major structure of the Cumberland Plateau, parallels the regional strike of the Appalachians for a distance of over 200 miles (fig. 1). It extends "southwestward from the south side of the Emory River in Morgan County, Tennessee, nearly to the forks of the Black Warrior River in Walker and Jefferson Counties, Alabama . . . ". (Rodgers, 1950, p. 672).

Rodgers (1950, p. 672-674) gave the following description of the Sequatchie anticline:

> At its north end it is a low, nearly symmetrical arch in the Pennsylvanian rocks of the Cumberland Plateau, the uparched Pennsylvanian sandstone and conglomerate beds forming a prominent line of hills (the Crab Orchard Mountains). Traced southwest, the fold rises so that the Pennsylvanian rocks are breached, and the underlying Mississippian limestone is exposed in a series of topographic lows, the largest of which is Grassy Cove. A little southwest of Grassy Cove, the anticline rises sharply, exposing Ordovician carbonate rocks, which are the surface rocks along its crest for most of its length. Here the fold is markedly asymmetrical, its northwest flank being much the steeper, and only a little farther southwest that flank is broken by a thrust fault, whose increasing displacement thrusts Ordovician rocks over Mississippian rocks. The anticline retains approximately this magnitude for nearly 130 miles, to a point nearly 20 miles southwest of Guntersville, Alabama; the fault is present for most of this distance. Throughout this segment the anticline has been eroded to form a narrow and fertile valley, called Sequatchie Valley in Tennessee and Browns Valley in Alabama, and followed by the Sequatchie and Tennessee rivers. Beyond Guntersville, the fold passes in reverse order through all the stages exhibited at its northeast end and ends as a gentle symmetrical arch in the Black Warrior coal field.

In Tennessee the relief and pronounced linearity of the valley and the consistently rugged valley walls are the most striking topographic features of the structure. Maximum elevations of the eastern valley wall, which range from 2000 feet in the southern portion of Sequatchie Valley to 3000 feet at the head of the valley, are generally 100 to 400 feet greater than those of the western escarpment. The relief from the top of the Cumberland Plateau to the floor of the valley is consistently greater than 1000 feet throughout the length of the Sequatchie Valley in Tennessee.

PREVIOUS INVESTIGATIONS

The early geologic studies of the Sequatchie Valley and Cumberland Plateau were of the general geology or mineral resources of the area. Troost (1840) and Safford (1869) described the physiography, stratigraphy, and structural geology of the Sequatchie Valley in general terms. Hayes (1894a, 1894b, 1894c, 1895a, 1895b, 1896), assisted by M. R. Campbell, mapped much of Sequatchie Valley in Tennessee and Alabama; these geologists were the first to recognize that the anticline was faulted throughout most of its length.

Butts (1916) and Butts and Nelson (1925) considered the oil and gas possibilities of the southern part of Cumberland County, to the northwest of the head of the Sequatchie. Their work covers a small portion of the Sequatchie Valley in which they located the Sequatchie Valley fault in approximately the same position as the present writer. Nelson (1925) briefly described the Sequatchie Valley fault and the stratigraphy and economics of the coal measures in the Sequatchie Valley area.

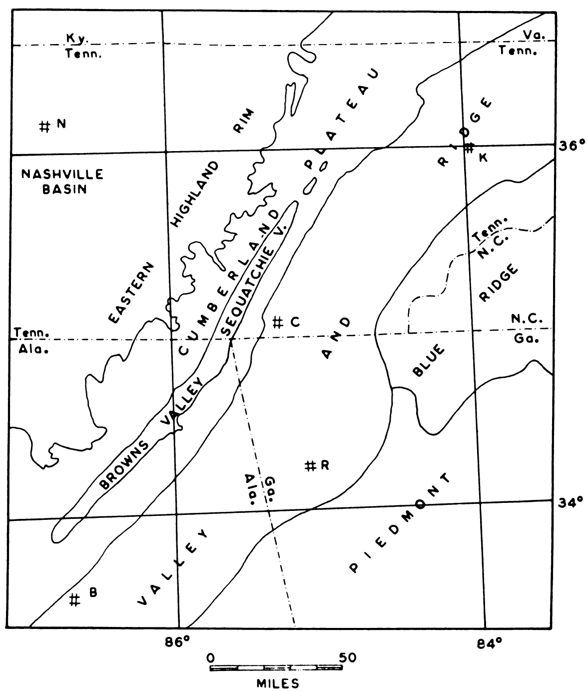

Fig. 1. Location and extent of Sequatchie Valley.

Investigations in the Sequatchie Valley region after 1925 were more concerned with the stratigraphy and structural geology of the area than with general and economic geology. Bassler (1932) published a generalized section of the formations exposed in Sequatchie Valley, Tennessee, compiled from notes furnished by E. O. Ulrich and Charles Butts. Wilson (1949) revised Bassler's concept of the pre-Chattanooga stratigraphy of the Central Basin and Sequatchie Valley.

Wentworth (1921) studied the Pine Mountain block, a low-angle overthrust block in the Cumberland Plateau about fifty miles northeast of Sequatchie anticline. He noted that the Pine Mountain block "is bounded on all four sides by overthrust faults and that it moved bodily to the northwest a distance of many miles" (1921, p. 352).

Butts (1927a) was the first to map fensters in this block. The papers of Wentworth and Butts precipitated the "thin-skinned" concept of Appalachian deformation, which maintains that overthrust faults expressed at the surface in sedimentary formations of the Valley and Ridge and Cumberland Plateau do not extend into crystalline rocks immediately below the surface structure, but rather extend for considerable horizontal distances in thin-bedded, incompetent units.

Rich (1934) and Rodgers (1950) speculated on the mechanics of overthrust faulting. Rich undertook to explain the mechanics of deformation of the Pine Mountain block. He further suggested that the Sequatchie anticline resulted from a low-angle overthrust similar to the Pine Mountain fault "but carried not so far". Rodgers also considered the Sequatchie Valley structure analogous to the Pine Mountain block. Stearns (1954, 1955), Wilson, Jewell, and Luther (1956), and Wilson and Stearns (1958) studied the stratigraphy and structural geology of the Cumberland Plateau of Tennessee. Their explanation of the structures of the Cumberland Plateau follows the "thin-skinned" concept as described by Rich. Swingle's (1961) explanation of the structural features along the eastern Cumberland escarpment, Tennessee, further attests to the low-angle nature of overthrust faults in these areas.

PRESENT INVESTIGATIONS

The present study is a continuation of investigations by Stearns (1954), Wilson, Jewell, and Luther (1956), and Wilson and Stearns (1958). The writer mapped the Sequatchie Valley overthrust block, Sequatchie Valley, Tennessee from June 1958 until May 1960, and completed mapping of the Grassy Cove quadrangle in the winter and spring months of 1961.

The purpose of this paper is to discuss the nature of the fault trace exposed within Sequatchie Valley, Tennessee, the influence of foot wall lithology on the attitude of the fault surface, and the relationship of the Sequatchie Valley structure to the Cumberland Plateau overthrust.

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Dr. C. W. Wilson, Jr. of Vanderbilt University accompanied the writer in the field at the start of work on the problem, pointing out lithologic units which he had recognized in Sequatchie Valley several years before.

Members of the staff of the Tennessee Division of Geology contributed substantial time and effort in assisting in this study. Dr. R. G. Stearns spent several days in the field with the writer. Mr. C. P. Finlayson aided in measuring Middle and Upper Ordovician stratigraphic sections in Sequatchie Valley, Tennessee.

Robert A. Laurence of the U. S. Geological Survey, Stuart W. Maher of the Tennessee Division of Geology, and John Rodgers of Yale University reviewed and contributed materially to the improvement of the manuscript.

STRATIGRAPHY

Paleozoic sedimentary rocks ranging in age from Ordovician to Pennsylvanian crop out in and adjacent to the Sequatchie Valley. The oldest formations exposed along the crest of the anticline are those of the Lower Ordovician portion of the Knox group. The cherty carbonates of the Knox group are over-

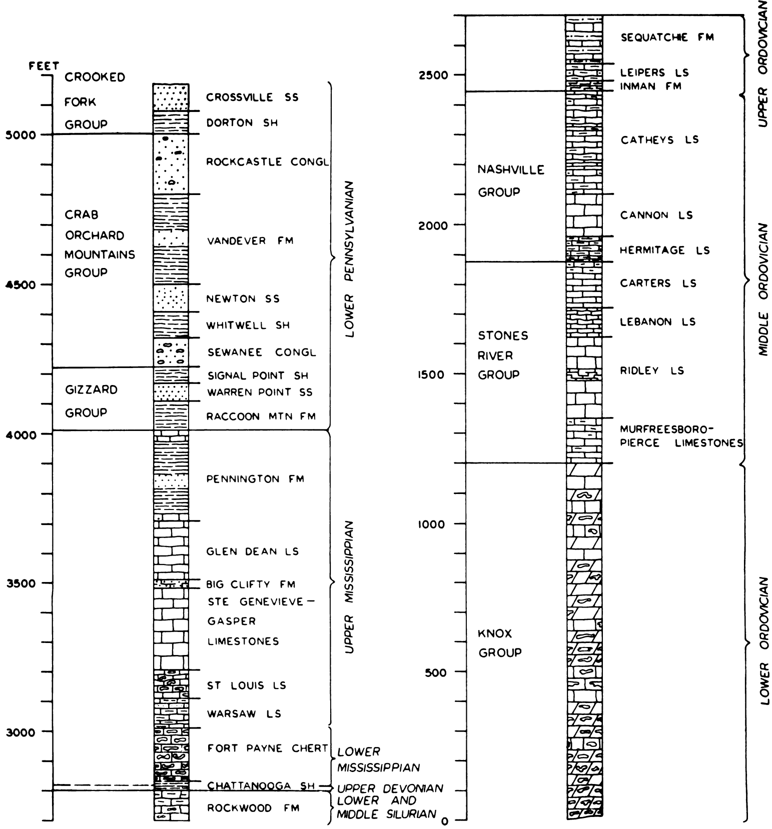


Fig. 2. Stratigraphy of the Sequatchie Valley region.

lain by limestones and shales of Middle and Upper Ordovician formations of the Stones River, Nashville, Eden, Maysville, and Richmond groups. Well exposed sections of calcareous shales and shaly limestones of Silurian age, Devonian-Missisippian black shale, Mississippian carbonates and fine-grained clastics, and Pennsylvanian fine- to coarse-grained clastics are also present. Figure 2 summarizes the stratigraphy of the region.

STRUCTURAL GEOLOGY

The Sequatchie Valley structure.—Wilson and Stearns (1958, p. 1294) described the Sequatchie Valley structure as follows:

> The isolated position, straightness, and length of this anticline have long been regarded as proof that basement rocks are involved in its structure at depth. Rich (1934), however, proposed that the anticline results from low-angle thrusting through Cambrian shales with roots far to the east in the Valley and Ridge province, and that the underlying basement is undisturbed. . . .
>
> Other writers have postulated that some of the low-angle thrusts of the Valley and Ridge province occur as bedding faults in Rome and Conasauga shale. During the Middle Ordovician the future site of Sequatchie Valley occupied a foreland shelf position and was not in the Appalachian geosyncline (Wilson, 1949, p. 323). It is believed that the Rome and lower Conasauga shales, which were restricted to the geosyncline, overlapped against the foreland near the present position of the Sequatchie Valley. This could account for the localization of the Sequatchie Valley structure, the bedding fault being deflected upward where the zone of easy slippage ends.

The Sequatchie anticline is asymmetrical throughout most of its length. The axial plane of the fold strikes N 20° to 30° E and dips 70° to 80° to the southeast in Tennessee. The axis plunges 5° to 10° to the northeast at the northern end of the structure, and at a low angle to the southwest at the southern end of the structure in Alabama (Adams and others, 1926, Geologic Map of Alabama). The rocks of the eastern limb of the fold strike N 20° to 30° E and dip 10° to 35° to the southeast. In contrast, the formations of the more intensely deformed western limb generally dip steeply to the northwest immediately adjacent to the trace of the Sequatchie Valley overthrust; in places they are overturned or complexly folded as the result of drag along the fault surface. Within half a mile northwest of the fault trace the beds flatten and dip gently to the northwest.

The western flank of the anticline is broken along most of its length by a generally southeastward-dipping overthrust. The writer has traced the fault for approximately 80 miles from Devilstep Hollow, Grassy Cove quadrangle, Tennessee, southwestward to the Tennessee-Alabama state line. The fault does not persist as a surface feature to the northeast of Devilstep Hollow; however, it was observed in an oil test well drilled by the Shell Oil Company in the Sequatchie anticline at the northern end of Crab Orchard Cove (Milhous, 1959, p. 80-82). Repetition of the Pennington formation, formations of the Gizzard group, and of the Sewanee conglomerate along the western valley wall to the north of Pikeville is evidence that the fault or a branch of it arches over the floor of Sequatchie Valley and extends northwestward under the Cumberland Plateau as a bedding thrust.

Stratigraphic displacement along the fault increases from a few hundred feet in the northern portion of Sequatchie Valley to approximately 2500 feet near Dunlap, Sequatchie County, Tennessee. This displacement persists southward to the Tennessee-Alabama state line. In Alabama, the displacement of the fault generally decreases from approximately 2200 feet near Stevenson, Jackson County, to nil at the southwestern terminus of the fault (Adams and others, 1926, Geologic Map of Alabama).

Massive limestones of Mississippian age are thrust over the Pennington formation at the head of Sequatchie Valley. The Sequatchie Valley fault trace was mapped about a mile along strike to the northeast of the valley proper, where it becomes unrecognizable in Upper Mississippian and Lower Pennsylvanian shale units. To the southwest, between the head of the valley and the town of Pikeville, the formations of the hanging wall are progressively older, until the upper units of the Knox group are involved in the faulting. In general, the formations of the Knox and Stones River groups are thrust over Mississippian limestones and shales from a point about four miles north of Pikeville southwestward into Alabama.

STRUCTURAL UNITS

The Sequatchie Valley structure, based on the nature of the fault trace, may be divided into three units in Tennessee, herein called the northeastern, central, and southwestern sections. Figure 3 illustrates this subdivision of the structure.

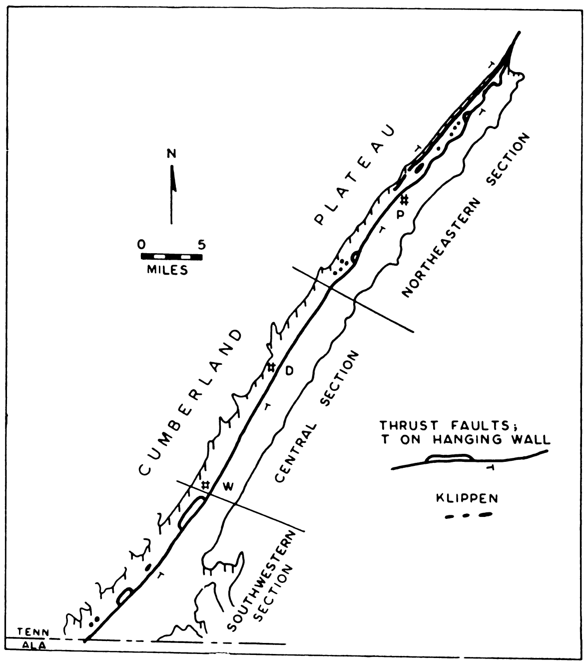


Fig. 3. Illustration of the Sequatchie Valley fault trace.

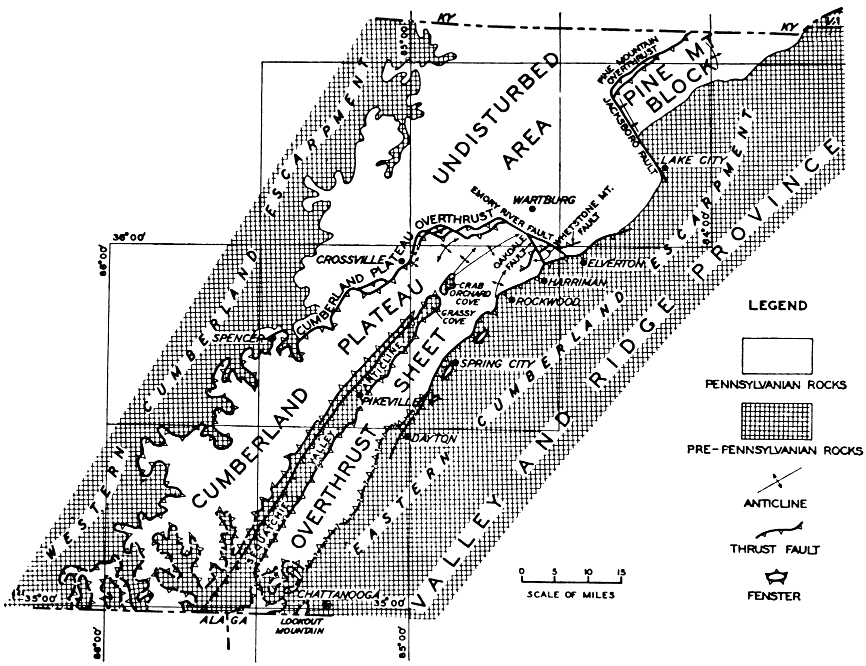


Fig. 4. Structural features of the Cumberland Plateau, Tennessee (Wilson and Stearns, 1958, fig. 2).

In the northeastern section the fault trace is irregular, and klippen of Fort Payne chert of the overthrust block are present northwest of and within the reentrant in the fault trace. In the central section the fault trace is comparatively straight, and klippen were not observed. The fault trace is again irregular in the southwestern section, and several klippen were mapped. Thus, the fault surface dips only slightly in the northeastern and southwestern sections and moderately in the central section.

The formations exposed in the foot wall are progressively older from the northern end of Sequatchie Valley southwestward to the Alabama state line. Ordovician to Mississippian formations of the hanging wall are thrust over the shales and sandstones of the Pennington formation in the northeastern section, over massive beds of the Glen Dean limestone in the central section, and over shales and sandstone of the Big Clifty formation and carbonates of the Ste. Genevieve-Gasper limestones in the southwestern section. From these observations it is concluded that the lithology of the foot wall is the governing factor in determining the attitude of the fault surface; the surface of the overthrust has a flatter dip where it crosses thin-bedded, shaly formations, and a steeper dip where it crosses massively-bedded, crystalline limestones.

RELATIONSHIP TO THE CUMBERLAND PLATEAU OVERTHRUST

Wilson and Sterns (1958, p. 1286) described the regional structure of the Cumberland Plateau thus:

> Structurally, the Cumberland Plateau in Tennessee is divided into three subprovinces: (1) an area undisturbed by thrust faulting, comprising less than half the province; (2) the Pine Mountain overthrust sheet; and (3) the Cumberland Plateau overthrust sheet. Both the Pine Mountain and Cumberland Plateau overthrusts are thin sheets that moved primarily along extensive bedding thrusts. The thin Cumberland Plateau overthrust sheet is interrupted by the deeper seated prominent Sequatchie Valley anticline.

Figure 4 illustrates the structural geology of the Cumberland Plateau according to the interpretation of Wilson and Stearns (1958).

The general relationships of the Cumberland Plateau overthrust to the Sequatchie anticline were described by the above mentioned writers:

> The Cumberland Plateau overthrust limits a thrust sheet, similar to the Pine Mountain block, which includes the southern half of the Plateau. The northern limit of the overthrust sheet is a complex series of faults, which crosses the plateau from Elverton on the east to Spencer on the west. The sheet continues southwestward as a bedding thrust along the western escarpment face at least as far as the southern border of Tennessee. It also crops out as a bedding thrust around Sequatchie Valley, Grassy Cove, and Crab Orchard Cove, making fensters of these valleys (Wilson and Stearns, 1958, p. 1290).

Detailed mapping in the Cumberland Plateau north and west of the head of Sequatchie Valley has demonstrated the presence of an integrated system of faults and anticlines (Stearns, 1954). These structures have been interpreted as representing a low-angle overthrust descending into lower and lower shaly units from northwest to southeast. Superficial anticlines are postulated to have formed as the thrust broke from a shale unit up across a competent formation and flattened in an overlying shale unit (Wilson and Stearns, 1958, p. 1292).

Figure 5 shows the relationship of the northern portion of the Sequatchie anticline to the Cumberland Plateau overthrust.

Any hypothesis concerning the relationship of the Cumberland Plateau overthrust and the Sequatchie Valley structure must account for a number of

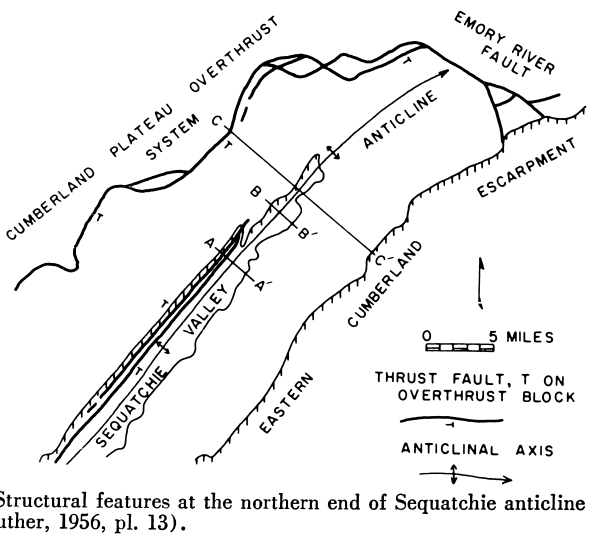
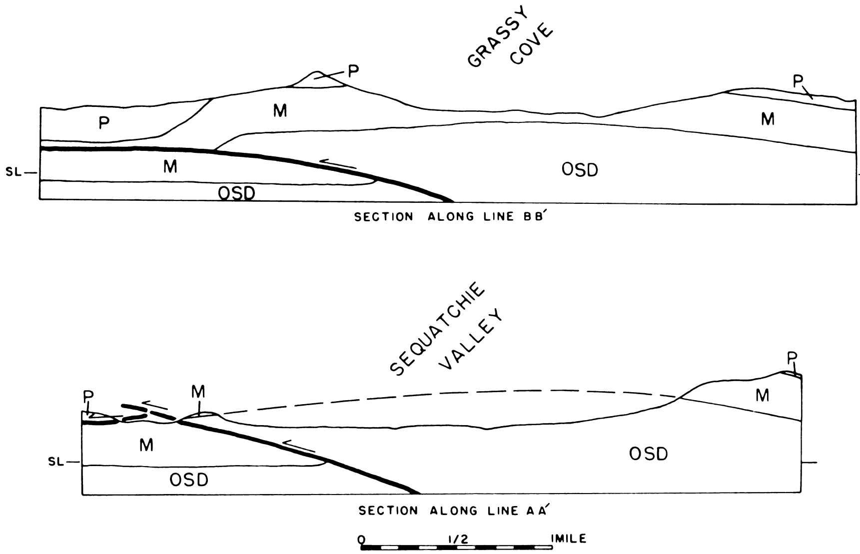


Fig. 5. Structural features at the northern end of Sequatchie anticline (after Wilson, Jewell, and Luther, 1956, pl. 13).



O ORDOVICIAN, S SILURIAN, D DEVONIAN, M MISSISSIPPIAN, P PENNSYLVANIAN

Fig. 6. Generalized cross sections of the Sequatchie anticline.

observations made by Wilson and Stearns (1958). According to these writers: (1) the Emory River cross fault at the northeast end of the anticline is "known to be a part of the superficial older Cumberland Plateau overthrust rather than a part of the Sequatchie Valley structure" (p. 1294); (2) the Sequatchie Valley fault as a surface feature ends near the head of the main valley, but the oil test at Crab Orchard Cove reveals its presence at depth 14 miles beyond the northeast end of the surface fault (p. 1294); and (3) deformation can be observed in the shaly horizons of Mississippian and Pennsylvanian formations in the "fensters" of Sequatchie Valley, Grassy Cove, and Crab Orchard Cove (p. 1291). According to Wilson and Stearns, the Cumberland Plateau overthrust descends to lower and lower stratigraphic horizons from northeast to southwest; they suggest that the fault is beneath the Sewanee conglomerate in the vicinity of the Sequatchie Valley, i. e., in the shales and siltstones of the Gizzard group or Pennington formation (Wilson and Stearns, 1958, fig. 7).

Hypotheses concerning the relationship of the Cumberland Plateau overthrust to the Sequatchie Valley structure must also account for several facts observed by the present writer. These are: (1) the Sequatchie Valley fault was traced to the northeast into the same units, the clastics of the Upper Mississippian and Lower Pennsylvanian formations, in which Wilson and Stearns locate the Cumberland Plateau overthrust in the vicinity of Sequatchie Valley; and (2) the symmetry of the fold, illustrated by figure 6, indicates that it was formed by low-angle overthrust faulting.

Based on the latter two observations and observations (1) and (2) of Wilson and Stearns, the present writer believes the Cumberland Plateau overthrust and the Sequatchie Valley fault were originally the same structure.

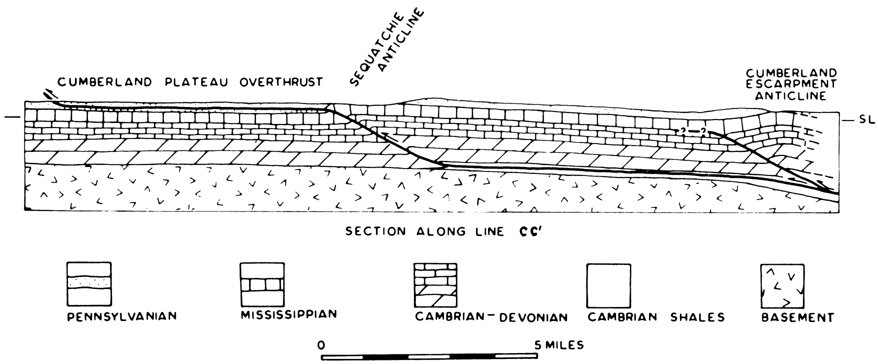


Fig. 7. Cross section of the Cumberland Plateau—Sequatchie Valley structure.

Figure 7 shows the generalized relationship between the Cumberland Plateau overthrust and the Sequatchie Valley structure.

If the interpretation that the Cumberland Plateau and Sequatchie Valley faults are one is correct, then the Cumberland Plateau overthrust does not extend to the east of Sequatchie anticline as a bedding thrust within Mississippian and Pennsylvanian formations, and Sequatchie Valley, Grassy Cove, and Crab Orchard Cove are not windows. In accordance with the writer's interpretation, deformation of Mississippian and Pennsylvanian rocks in "fensters" of Sequatchie Valley, Grassy Cove, and Crab Orchard Cove, previously attributed to movement along the Cumberland Plateau overthrust would be explained by drag folding resulting from the formation of the Sequatchie Valley structure.

CONCLUSIONS

1. The Sequatchie Valley fault and the Cumberland Plateau overthrust are the same structure; therefore, the Cumberland Plateau overthrust does not arch over Sequatchie Valley, Grassy Cove, and Crab Orchard Cove as a bedding thrust within Mississippian and Pennsylvanian formations.

2. The foot wall lithology is the factor which governs the attitude of the Sequatchie Valley fault. The fault has flatter dips in shale units and steeper dips in carbonate units.

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