Geology of the Richardson Cove and Jones Cove Quadrangles Tennessee

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GEOLOGY OF RICHARDSON COVE AND JONES COVE QUADRANGLES, TENNESSEE

By Warren Hamilton

ABSTRACT

The Richardson Cove and Jones Cove quadrangles adjoin in the foothills of the Great Smoky Mountains, Sevier and Cocke Counties, eastern Tennessee. Most of their area consists of forested and thoroughly dissected hills.

The indurated rocks are of Precambrian, Cambrian, and Ordovician age and are all of sedimentary origin. The rocks form four widely different groups, separated by reverse faults, each with miles of displacement. The Snowbird group of the late Precambrian Ocoee series underlies the southern foothills, and is an assemblage, perhaps 20,000 feet thick, dominated by a great mass of metasiltstone. The Walden Creek group, perhaps 8,000 feet thick, of the Ocoee series underlies the northern foothills, and is an assemblage of shale and sandstone with some limestone.

Lying tectonically between the Ocoee series and Ordovician rocks are the quartzite and sandstone of the Cochran formation of the Chilhowee group, about 1,000 feet thick, of Cambrian and Cambrian(?) age. The exposed Ordovician rocks consist of 2,000 feet of limestone and dolomite, overlain by about 2,000 feet of calcareous shale and sandstone.

At least three major episodes of deformation affected the rocks. The Ocoee series was metamorphosed at low grades during early(?) Paleozoic time; pelitic rocks grade from shale on the north to slate on the south. Most of the rocks have the secondary mineral assemblages of the chlorite zone, and three rough subdivisions of the zone are recognized; secondary biotite occurs in the southeastern corner of the area. The slaty cleavage was produced by shearing accompanied by recrystallization and reconstitution.

Thrust faults, axial planes of folds, and slaty cleavage all have a general south or southeast dip. The slaty cleavage strikes generally northeast, dips southeast, and is oblique in strike to the dominant eastward-trending folds of the southern half of the area showing that the cleavage is younger than this fold system. The Dunn Creek thrust fault, which separates the Snowbird and Walden Creek groups, is probably of the same age as the folding that preceded metamorphism. In late Paleozoic time a series of folds and faults, parallel to these structures formed after the metamorphism, affected the visible rocks mostly in the northern half of the area. The two major late Paleozoic faults—the English Mountain fault, along which rocks of the Chilhowee group were thrust over Ordovician rocks, and the Great Smoky fault, along which rocks of the Ocoee series were thrust over the Chilhowee group and Ordovician rocks—each have a proved minimum displacement of 7 miles. The area spans only 13 miles across the strike of the rocks, but telescoping by the several episodes of deformation has been on the order of 50 miles.

Precambrian and Paleozoic rocks are mostly mantled thinly by colluvial debris and, beneath that, by residual material produced by prolonged weathering. Thin alluvium veneers the flat-bottomed valleys, but most of the streams flow on or near bedrock. Large alluvial fans, mostly in the southeast part of the area, overlie the weathered rock, and are being eroded under present conditions; these fans probably formed during Wisconsin time, when the higher parts of the area may have been bare of timber.

No mineral deposits of present economic value are known in the area, although small quantities of iron and manganese ore have been mined in the past.

Landslides, which slipped on southeastward-dipping shears and fractures, increased construction costs of new Tennessee State Route 73 in the south part of the area. Geologic structures were not considered in locating the highway.

INTRODUCTION

The Richardson Cove and Jones Cove quadrangles ($7\frac{1}{2}$-minute) cover an area of 120 square miles in Sevier and Cocke Counties, eastern Tennessee; a small area in the southeastern corner lies in Great Smoky Mountains National Park. The quadrangles cover part of the northern foothills of the Great Smoky Mountains, extending 14 miles eastward along the strike of the rocks and 9 miles northward across it.

The two quadrangles were investigated as part of a comprehensive study of the Great Smoky Mountains by the U.S. Geological Survey, and the present report is one of several on the region. The area to the south has been studied by J. B. Hadley and Richard Goldsmith, and that to the west and southwest by P. B. King and by R. B. Neuman and W. H. Nelson (fig. 1).

The area of this report lies across the low-angle thrust faults that separate the Appalachian Valley and the Blue Ridge geologic provinces. To the north are the deformed but nonmetamorphosed Paleozoic sedimentary rocks, fossiliferous and of relatively simple stratigraphy, of the Appalachian Valley. To the south, overlying the Paleozoic rocks in great thrust sheets, are the nonfossiliferous and stratigraphically complex upper Precambrian and Lower Cambrian sedimentary rocks of the Great Smoky Mountains part of the Blue Ridge province; these rocks have been deformed several times and, within the area, record the effects of the lowest grades of regional metamorphism.

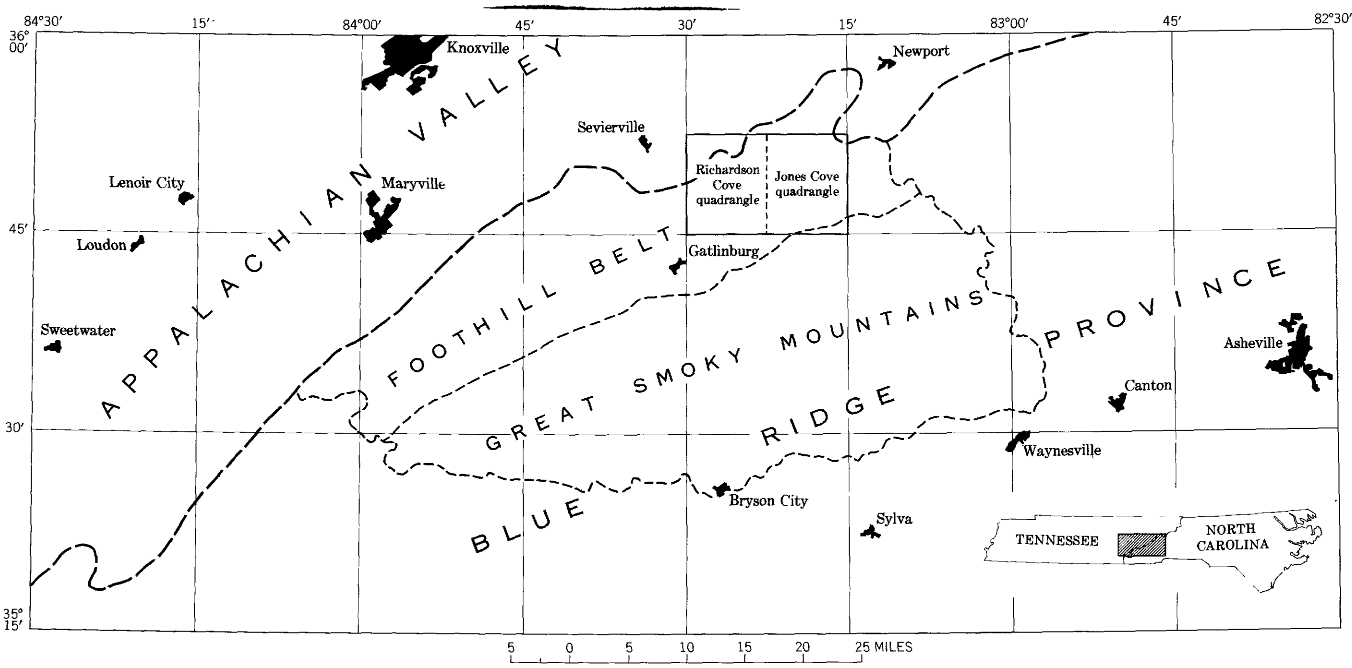

Figure 1.—Map of Great Smoky Mountains region, Tennessee and North Carolina, showing Richardson Cove and Jones Cove quadrangles.

PREVIOUS WORK

The only previous comprehensive geologic mapping in the report area was by Arthur Keith as part of the surveys of the southern Appalachians for the geologic folio series of the U.S. Geological Survey. Annual reports of the U.S. Geological Survey indicate that fieldwork was done in the Mount Guyot quadrangle, of which the report area is a part, at intervals between 1890 and 1904. A report and map of the quadrangle was submitted for publication as a folio in 1904 (U.S. Geol. Survey, 1904, p. 47), but was not issued, and is available only in open file. Early versions of Keith's mapping in the area indicate that he considered the shale and sandstone beds of the Ocoee series on the south to be continuous with and probably equivalent to the shale and sandstone of the Middle Ordovician series on the north, and the quartzite and sandstone of the Chilhowee group on English Mountain to be an outlier of the Clinch sandstone (Silurian); the fault between the Ocoee series and Chilhowee group on the south and the Ordovician on the north was not recognized (Walcott, 1891, p. 299–300; Willis, 1893, pl. 58, p. 240).

In 1898 C. R. Van Hise, seeking to resolve problems that had arisen in regard to relations between the Ocoee series and the Paleozoic rocks of the Appalachian Valley, organized a field conference in the Mount Guyot quadrangle, attended also by Keith, G. W. Stose, and Cooper Curtice (U.S. Geol. Survey, 1899, p. 39–40; Stose and Stose, 1944, p. 375). As a result of the conference, Stose was asked to map a belt along the contact of the Ocoee series and Paleozoic rocks between the towns East Fork and Cosby. Reporting on relations near East Fork, he commented (written communication, G. W. Stose to C. R. Van Hise, 1898):

> The only explanation of these abnormalities that seems probable is a flat overthrust fault from the southeast, shoving the folded slates and conglomerates of the Ocoee series over on top of the Knox. The erosion of East Fork has cut through this mantle in the embayment and exposed the Knox below the fault, with the slate and the ends of the conglomerate folds in contact with it.

These conclusions were accepted by Keith; on the final version of his Mount Guyot map the Chilhowee and Ocoee were assigned to the Lower Cambrian, and a fault was drawn between them and the Ordovician rocks to the north. The small scale of the mapping was insufficient, however, to subdivide the Ocoee series adequately so that its groups and formations as now known were largely unrecognized.

As part of a general review of the Ocoee series, a revision of the stratigraphy and structure of the present report area was proposed by Stose and Stose (1949, p. 291–298); the Walden Creek group of present usage and some adjacent rocks were reassigned to the Ordovician. This interpretation is at variance with my observations and conclusions and those of other members of this field party, as well as of G. W. Stose in his earlier work.

Preliminary observations of the Great Smoky Mountains by the field party in the report area have been published by King, Hadley, and Neuman (1952), Rodgers (1953, pl. 10), and Hadley, King, Neuman, and Goldsmith (1955). The stratigraphy of the Ocoee series was summarized by King, Hadley, Neuman, and Hamilton (1958).

PRESENT WORK

Most of the results presented here are based on my fieldwork between 1952 and 1955, although reconnaissance traverses of the western part of the report area were made by P. B. King in 1948. The Ordovician rocks in the northwestern part were mapped by R. B. Neuman in 1950, and the Ocoee series in the southeastern part, south of Tennessee State Route 73, was mapped by J. B. Hadley in 1948 and 1949.

My mapping was by traverses whose positions are suggested by the structural data shown on the map (pl. 1). The traverse net in the Richardson Cove quadrangle is more closely spaced than that in the Jones Cove quadrangle. Best exposures lie along roads, trails, and streams; exposures elsewhere are poor. Slopes are generally covered by colluvium and the rock on ridges is deeply weathered, although in places retaining original structural features. Some hilly areas, such as Webb Mountain, show little but surficial debris, from which the approximate distribution of rock types can be determined but not their structure.

Laboratory work included the study of 450 hand specimens and 100 thin sections and the chemical and spectographic analysis of 8 specimens of metapelitic rocks.

ACKNOWLEDGMENTS

Office facilities throughout the course of the fieldwork were provided by the National Park Service at the headquarters of Great Smoky Mountains National Park in Gatlinburg, and many courtesies were extended by Park Service personnel.

Field and office conferences with P. B. King, J. B. Hadley, and R. B. Neuman, other members of the field party in the Great Smoky Mountains, were invaluable, as much of the evidence for conclusions drawn about this area comes from nearby areas studied by these three geologists.

Analyses of metapelitic rocks were made by L. D. Trumbull, P. L. D. Elmore, K. E. White, S. D. Botts, and P. R. Barnett of the U.S. Geological Survey.

GEOGRAPHY

The area spans the foothill belt of the Great Smoky Mountains, the northern corners of the area reaching the Appalachian Valley province and the southeastern edge reaching the lower slopes of the main range (fig. 1). The lowest point within the area is at an altitude of about 920 feet, where the East Fork of Little Pigeon River leaves the area near its northwestern corner. The highest point, 3,200 feet, is on Buckeye Lead on the slope of the main range in the southeastern corner of the area. Peaks a few miles south of the area exceed 6,000 feet.

The foothills area is mostly timbered and much dissected, with steep slopes and narrow ridges and valley floors, and is underlain by Lower Cambrian and upper Precambrian rocks. Ridges formed of massive sandstone rise 500 to 1,500 feet above their bases; areas underlain by slate, siltstone, and thin-bedded sandstone generally have a local relief of less than 500 feet.

The Appalachian Valley area is underlain by Ordovician carbonate rocks, which form gently rolling areas with many sinkholes, and by Ordovician clastic sedimentary rocks, which form much-dissected hills.

There are no towns within the area, and the residents are mostly farmers although good farmland is nearly limited to the area of Ordovician carbonate rocks. Chief crops are corn and tobacco; foothill farming is primitive and largely confined to narrow valleys and steep hillsides, and the general standard of living is extremely low. Pulpwood and lumber are harvested in small-scale operations from the widespread forest, although nearly all of the area has been cut over at least once.

U.S. Highway 411 crosses the northwest corner of the area, and Tennessee State Route 73 crosses the southern edge. The secondary roads are paved only in small part, and many are poorly maintained.

DESCRIPTION OF ROCK UNITS

GENERAL CHARACTER AND INFERRED SEQUENCE

The indurated rocks of the quadrangles are all of sedimentary origin and are of late Precambrian, Cambrian, and Ordovician age, and have a total thickness of about 30,000 feet. The rocks belong to four groups of widely different character, deposited in diverse sedimentary environments far from their present relative positions and brought together by great thrust faults. In the southern foothills is the Snowbird group of the upper Precambrian Ocoee series; in the northern foothills, the Walden Creek group of the Ocoee series; at the north edge of the foothills, the Lower Cambrian(?) and Lower Cambrian Chilhowee group; and in the Appalachian Valley, the limestone and shale of the Ordovician series. The Snowbird group is dominated by a thick mass of metasiltstone, and the Walden Creek group is a complex assemblage of shale and sandstone. Quartzitic sandstone dominates the Chilhowee group within the area.

Formations of the Snowbird group intertongue and vary enormously in thickness, but are distinctive so that there is little confusion in mapping. In the Walden Creek group, by contrast, most of the rock types are shared by all units, units are variable along and across the strike, and the structures are complex and poorly known. Some units of the Walden Creek are characterized by distinctive rock assemblages, but others were divided arbitrarily by proportions of different rock types; these units are thus poorly defined, and the sequence and correlations given here may be in error.

The indurated rocks of the area are shown on the geologic map (pl. 1), and their general character and inferred sequence is indicated on the following table. Other formations of the Ocoee series in the Great Smoky Mountains are listed on table 1.

Indurated rocks of the Richardson Cove and Jones Cove quadrangles

Age	Series	Group	Stratigraphic unit	Member	Lithologic character	Approximate thickness (feet)
Middle Ordovician			Tellico formation		Calcareous shale and fine-grained sandstone, and impure limestone.	1,500
Middle Ordovician			Blockhouse shale		Dark fissile calcareous shale with thin beds of dark limestone.	300
Middle Ordovician			Toqua(?) sandstone member		Calcareous sandstone and shale.	1,000
			—Minor disconformity—			
Middle Ordovician			Lenoir limestone		Aphanitic gray limestone and argillaceous limestone.	100
			—Disconformity—			
Early Ordovician			Jonesboro limestone[1]		Gray limestone, some of it sandy, and dolomite.	2,000
			—Sequence broken; missing interval—			
Early Cambrian(?)			Cochran formation[2]		White quartzite and coarse-grained feldspathic sandstone; minor amounts of shaly sandstone, some of it maroon.	1,000
			—Disconformity(?)—			
Late Precambrian	Ocoee series	Walden Creek group	Sandsuck formation	Upper member	Interlaminated siltstone and fine-grained sandstone, and minor amounts of coarse-grained sandstone.	2,000
Late Precambrian	Ocoee series	Walden Creek group	Sandsuck formation	Middle member	Coarse-gained sandstone and quartz-conglomerate; and minor amounts of fine-grained rocks.	1,300
Late Precambrian	Ocoee series	Walden Creek group	Sandsuck formation	Lower member	Similar to upper member.	500
Late Precambrian	Ocoee series	Walden Creek group	Wilhite formation	Yellow Breeches member	Upper unit dominated by limestones, commonly sandy or conglomeratic. Lower unit of varied pelitic and metapelitic rocks, with sandstone and carbonate rocks.	500 1,500
Late Precambrian	Ocoee series	Walden Creek group	Wilhite formation	Dixon Mountain member	Micaceous and finely sandy siltstone and metasiltstone, often carbonate-bearing, and other clastic rocks.	1,500
Late Precambrian	Ocoee series	Walden Creek group	Shields formation	Slate of Richardson Cove	Slate and shale, with interbeds of coarse-grained sandstone.	1,000-1,500
Late Precambrian	Ocoee series	Walden Creek group	Shields formation	Conglomerate of Shields Mountain	Thick-bedded coarse-grained sandstone and quartz conglomerate, with minor amounts of finer grained rocks.	1,600
Late Precambrian	Ocoee series	Walden Creek group	Licklog formation		Siltstone and shale, with less slate, fine- to coarse-grained sandstone, and quartz-conglomerate.	300
			—Fault contact sequence uncertain—			
Late Precambrian	Ocoee series		Rocks of Webb Mountain and Big Ridge		Upper unit of coarse feldspathic sandstone, much of it in graded beds, and dark-gray slate.	3,000
Late Precambrian	Ocoee series		Rocks of Webb Mountain and Big Ridge		Lower unit of thin-bedded feldspathic sandstone and dark-gray slate.	600-1,000
Late Precambrian	Ocoee series	Snowbird group	Pigeon siltstone		Gray and greenish-gray feldspathic metasiltstone, much of it current bedded, much of it calcareous, and intercalated slate. May also overlie rocks of Webb Mountain and Big Ridge.	5,000-15,000
Late Precambrian	Ocoee series	Snowbird group	Roaring Fork sandstone		Fine- to medium-grained greenish-gray feldspathic sandstone and intercalated greenish-gray metasiltstone.	2,000
					Approximate total thickness.	30,000

[1] Only unit of Knox group of Late Cambrian and Early Ordovician age in this area.
[2] Only unit of Chilhowee group of Early Cambrian(?) and Early Cambrian age in this area.

LITHOLOGIC TERMINOLOGY

The terminology of sandstone, conglomerate, and carbonate rocks used here is that familiar to most geologists. No metamorphic rock terms will be used for these rocks, as their metamorphic character is generally far less conspicuous than their sedimentary character in outcrop and hand specimens. Grain-size designations are those of the Wentworth scale.

The terms to be used here for pelitic sedimentary rocks and their low-grade metamorphic equivalents are defined below:

Shale.—A rock composed largely of argillaceous materials or their alteration products, with fissility parallel to bedding; slaty cleavage weak or lacking.

Slate.—A reconstituted shale with a strong slaty cleavage.

Siltstone.—A rock composed largely of silt-sized clastic grains with an argillaceous groundmass; may be reconstituted, but with little if any slaty cleavage.

Metasiltstone.—A thoroughly reconstituted siltstone, generally with a well developed slaty cleavage.

Pelite.—A group name covering shale and siltstone.

Metapelite.—A group name covering slate and metasiltstone.

Many of the farmers in the area distinguished rock types with a local terminology in which the following terms are used consistently:

Flintrock.—Quartzite; vein quartz; any unusually hard rock.

Grayback.—Boulders of hard unweathered sandstone.

Sandrock.—Weathered sandstone.

Slate, slaterock—Slate, siltstone, shale.

Dirtrock, soapstonerock.—Weathered slate, siltstone, or shale.

Limestone.—Limestone, dolomite.

UPPER PRECAMBRIAN ROCKS

OCOEE SERIES

Most of the Great Smoky Mountains area is underlain by sedimentary rocks of the Ocoee series. This series is divisible lithologically, geographically, and in part tectonically, into three groups: the Walden Creek of the northern foothills, the Snowbird of the southern foothills, and the Great Smoky of the high Great Smoky Mountains to the south. One unit, probably equivalent to part of the Great Smoky group, is not assigned to a group. The Snowbird and Walden Creek groups each underlie nearly half of the Richardson Cove and Jones Cove quadrangles; the northern limit of the Great Smoky group is a short distance south of the quadrangles. The Ocoee series is revised and its groups and formations, listed on table 1, are defined and described briefly, by King, Hadley, Neuman, and Hamilton (1958). No fossils have been found in the Ocoee series.

Southeast of this map area, the Snowbird group lies conformably beneath the Great Smoky group, and lenses out between the Great Smoky group and the basement complex of older Precambrian plutonic rocks (J. B. Hadley and Richard Goldsmith, written communication). In most of the region, however, the contact between the Snowbird and Great Smoky is a thrust fault.

TABLE 1.—*Stratigraphic units of Ocoee series in Great Smoky Mountains*

[Units marked with an asterisk occur in Richardson Cove and Jones Cove quadrangles. After King, Hadley, Neuman, and Hamilton (1958, table 1)]

Age		North of and below Greenbrier fault				South of and above Greenbrier fault	
Cambrian and Cambrian(?)		Chilhowee group	*Cochran formation and higher units Disconformity?		Correlation between these sequences not established	Rocks of Murphy marble belt	Nantahala slate and higher units (Precambrian(?) and early Paleozoic (?)) Lithologic break, but probably conformable
Later Precambrian	Ocoee series	Walden Creek group[1]	*Sandsuck formation *Wilhite formation[2] {Yellow Breeches member[1], Dixon Mountain member[1]} *Shields formation[1] *Licklog formation[1] —Fault contact, sequence uncertain—			Great Smoky group	Unnamed higher strata Anakeesta formation[1] Thunderhead sandstone[1] Elkmont sandstone[1]
			Western Great Smokies	Eastern Great Smokies			
		Unclassified formations.	Cades sandstone[2]	*Rocks of Webb Mountain and Big Ridge Rich Butt[1] sandstone			
		Snowbird group	Metcalf phyllite[1] —Base not exposed—	*Pigeon siltstone[2] *Roaring Fork sandstone[1] Longarm quartzite[1] Wading Branch formation[1] —Unconformity—		Snowbird group	Roaring Fork sandstone[1] Longarm quartzite[1] Wading Branch formation[1] —Unconformity—
Earlier Precambrian				Granitic and gneissic rocks			Granitic and gneissic rocks

[1] New stratigraphic name.
[2] Old stratigraphic name, with major redefinition.

The Snowbird and Walden Creek groups are separated by major faults throughout the Great Smoky Mountains. Conformable relations, with the Snowbird the older, were suggested by Oriel (1950) for the thin sequence between the Chilhowee group and basement rocks some distance to the northeast, but the lithologic correlations are tenuous and the intervening area has not been mapped. The uppermost formation of the Walden Creek group in the present area is lithologically closely similar to the Sandsuck formation, stratigraphically beneath the Chilhowee group a few miles to the west, and is considered to be correlative with it and is so named. The Precambrian age assignment of the Walden Creek group is dependent upon this lithologic correlation, which is made across a major thrust fault.

Rocks of the Ocoee series are mostly clastic, consisting of shale, slate, siltstone, fine- to coarse-grained sandstone, and quartz-conglomerate, in variable types and proportions. Carbonate rocks are minor; no volcanic rocks or sedimentary rocks suggestive of a volcanic source are present. The Ocoee series has mostly been slightly metamorphosed, with formation of slaty cleavage and reconstitution to minerals of the muscovite-chlorite subfacies of the greenschist facies, but in the northeastern part of the area there has been only slight alteration.

SNOWBIRD GROUP

Thickest and least varied of the rocks of the area are those of the Snowbird group, which underlie most of the southern half of the area. The group name is established by King, Hadley, Neuman, and Hamilton (1958), redefining a designation by Keith; the name is derived from Snowbird Mountain, 10 miles east of the present area, near which the complete section of the following group was measured by Hadley and Goldsmith. The formations of the Snowbird group intertongue and vary greatly in thickness. In the Richardson Cove and Jones Cove quadrangles, the Pigeon siltstone alone is probably as thick as is the entire Snowbird group near Snowbird Mountain. The underlying Roaring Fork sandstone is also exposed in the quadrangles, but not the two lower formations. Another formation, designated informally "rocks of Webb Mountain and Big Ridge", overlies the Pigeon siltstone and may be equivalent to the Rich Butt sandstone.

Stratigraphic section of Snowbird group near Snowbird Mountain, Tenn. and N.C.

[Measured by J. B. Hadley and Richard Goldsmith]

	Thickness (feet)
Upper Precambrian: Ocoee series:	
Rich Butt sandstone.	
Snowbird group:	
Pigeon siltstone: greenish-gray siltstone, with minor fine-grained feldspathic sandstone and greenish-gray slate	4, 300
Roaring Fork sandstone: fine-grained feldspathic sandstone, interbedded with greenish-gray metasiltstone and minor slate	2, 700
Longarm quartzite: medium-grained feldspathic quartzite, locally arkosic, interbedded with fine-grained sandstone and metasiltstone	5, 000
Wading Branch formation: fine to very coarse feldspathic sandstone and graywacke, with lenses of phyllite and quartz-conglomerate in lower part	1, 500
Total thickness of Snowbird group	13, 500
Unconformity.	
Middle(?) Precambrian: granite and migmatite	

ROARING FORK SANDSTONE

The Roaring Fork sandstone is named for exposures 4 miles south of the area of this report (King, Hadley, Neuman, and Hamilton, 1958); within the report area, it is exposed only in the southeastern corner. It is the lowest formation of the Snowbird group exposed here, lying beneath and partly intertonguing with the Pigeon siltstone.

The Roaring Fork is made up of layers of fine- to medium-grained feldspathic sandstone, thin to thick bedded, and generally greenish gray, intercalated with greenish-gray metasiltstone layers. Both sandstone and metasiltstone are similar to those of the Pigeon siltstone, the formations being distinguished by the relative proportions of the two rock types.

PIGEON SILTSTONE

Most of the southern half of the area is underlain by metasiltstone beds, which form a sequence of great thickness and broadly uniform character.

DEFINITION

The name Pigeon slate was applied by Keith (1895) to various slate and metasiltstone beds in the foothills of the Great Smoky Mountains. The name "Pigeon" and Keith's type locality have been retained, but the formation was redefined as Pigeon siltstone with its type section exposed along the Little Pigeon River (King, 1949; King, Hadley, Neuman, and Hamilton, 1958). The formation has undergone low-grade metamorphism and has everywhere within this area a slaty cleavage and the mineralogy of the greenschist facies.

OUTCROP

Most of the siltstone of the Pigeon siltstone, where fresh, forms massive outcrops. Conspicuous bedding partings in fresh outcrops are generally a foot to many feet apart, although bedding partings are closely spaced where clastic mica is abundant. Slaty cleavage is commonly more conspicuous than bedding, and many outcrops are split into slabs by partings along cleavage a quarter of an inch to an inch apart; in many places, however, cleavage partings are several feet or many feet apart. Weathered rock is parted more closely along both bedding and cleavage; weathered chips are commonly parallel to the cleavage.

The metasiltstone of the Pigeon erodes to steep-sided round-topped hills and ridges. It forms massive outcrops and stony soils along the valleys of the larger streams. Elsewhere, it is weathered to saprolite as much as 100 feet deep (fig. 2).

LITHOLOGY

The characteristic rock of the formation is laminated metasiltstone in which dark slaty laminae alternate with light-colored silty laminae, generally thinner and less regular. Many beds in nearly all parts of the formation show small-scale crossbedding. There are many massive and faintly laminated metasiltstone beds, slate and very fine grained sandstone are common, and limestone occurs locally.

FIGURE 2.—Saprolite derived from Pigeon siltstone. The material is nearly uniform from top to bottom, and is soft and red and yellow brown. Slaty beds weather to the lighter color. Structural features are well preserved. The capping soil is about 1 foot thick. Highway cut, southeastern corner of Richardson Cove quadrangle.

The irregularly laminated metasiltstone beds have dark slaty laminae, one-hundredth to one-half inch thick, alternating with lighter colored laminae, which are commonly very finely sandy and commonly bear carbonates. Average thickness of light-colored laminae is less than that of dark, although the general range of thickness is about the same. Many of the light-colored laminae are lenticular or crossbedded, the small-scale crossbedding being shown by thin discontinuous laminae of dark material (figs. 3, 4).

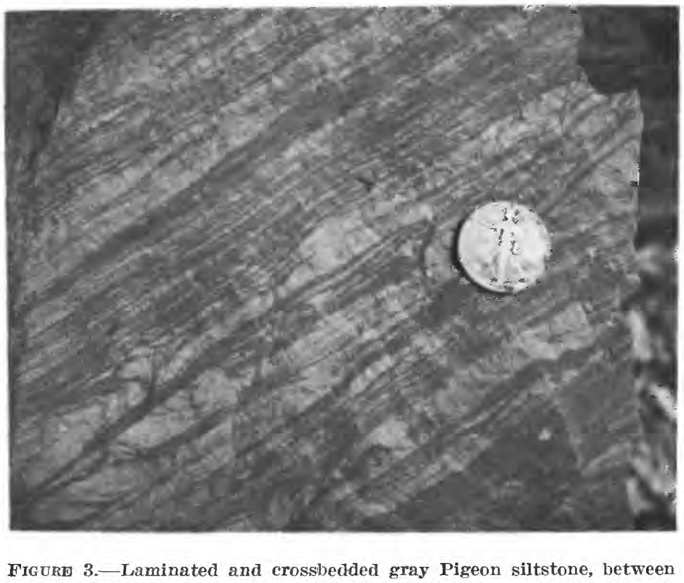

FIGURE 3.—Laminated and crossbedded gray Pigeon siltstone, between Mize and Dockery Branches. Light-colored layers are silty and calcitic fine-grained sandstone, and dark layers are slaty siltstone. Coin is 1.2 inches in diameter.

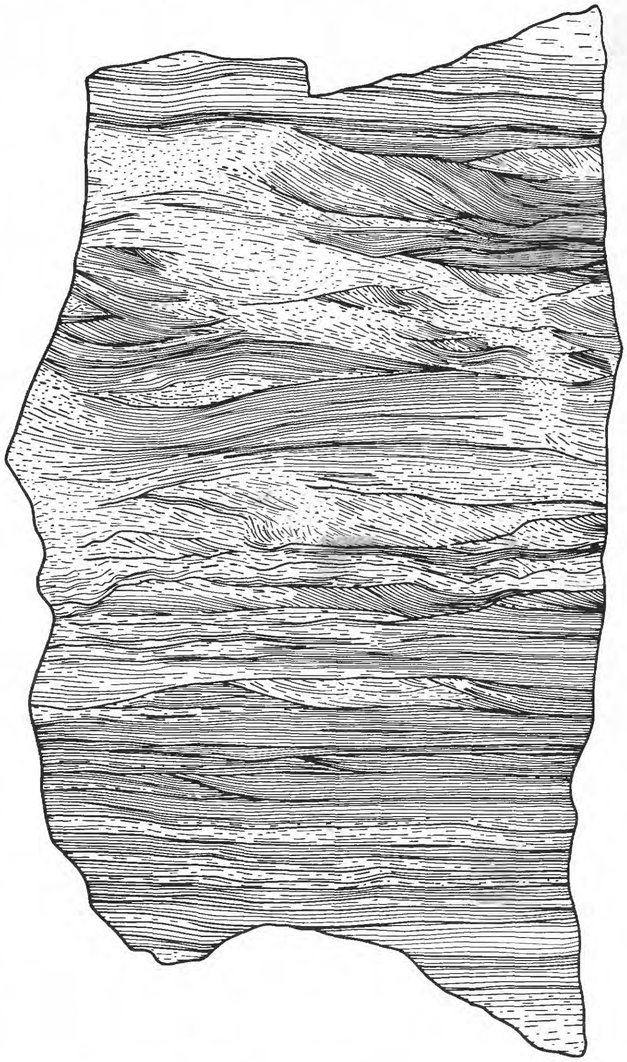

FIGURE 4.—Bedding in specimen of greenish-gray Pigeon siltstone, Grassy Branch. Drawing ½ natural size.

Crossbedded laminae have a common thickness of one-eighth to one-half inch though extending for many inches, and give way along the bedding to more regular laminae. Small-scale scour-and-fill, convolute bedding, and slump structures are locally common. The laminated rocks form units from a fraction of an inch to several hundred feet thick, interbedded throughout with thick-bedded metasiltstone. Bedding partings are spaced a few inches to a few feet apart. Carbonate-bearing laminae weather into pits (fig. 5) and the carbonate, where iron bearing, is stained brown; carbonate laminae increase in abundance irregularly northward.

FIGURE 5.—Laminated gray Pigeon siltstone near Caton Branch, showing rows of pits produced by weathering of carbonate-bearing laminae. Scale is 6 inches long.

Massive thick-bedded metasiltstone and fine-grained silty sandstone are widespread, the sandier parts being lighter colored than the silty, and show faint bedding traces on weathered surfaces but little or none on fresh surfaces. Beds are ½ to 10 feet thick and slightly lenticular; in many large road cuts, bedding surfaces can be seen to converge at angles of a few degrees. Fractures parallel to slaty cleavage are widely spaced in fresh sandy rocks, more closely spaced in rocks richer in secondary micaceous minerals. The sandy rocks weather to sandy-surfaced fragment, the metasiltstone to dull-lustered chips and fragments. The beds of massive rocks are generally separated by layers of laminated or crossbedded metasiltstone.

Laminated slate is interbedded in many parts of the Pigeon siltstone, mostly in units less than a few tens of feet thick. Cleavage partings in the slate are closer and more regular than in the metasiltstone, and cleavage surfaces are shiny in both fresh and weathered rocks.

Regularly laminated metasiltstone occurs with the other types in some areas, notably near the Dunn Creek fault in the central part of the area. Laminae of dark slaty siltstone, one twenty-fifth to one-fifth inch thick, alternate with thinner laminae of lighter and coarser metasiltstone. Conspicuous bedding partings, ½ to 3 inches apart, follow planes containing much clastic mica. Slaty cleavage partings are close, and are commonly associated with dark laminated silty slate.

Most of the sandstone is silty and very fine grained and resembles the massive metasiltstone. Fine-grained feldspathic sandstone beds, similar to those of the Roaring Fork sandstone, are most conspicuous in the southwest part of the area, as between Powdermill and Bird Creeks and between the westward projections of Tyant and Campbell Branches, where there are many sandstone units, each a few tens of feet thick, formed of 1- to 6-foot beds and long thin lenses that contain both long sweeping crossbeds and short lenticular crossbeds. The sandstone units are largely greenish gray, partly dark greenish gray, and have discontinuous lenticular laminae of darker more slaty material. The most accessible, good outcrops of these rocks are along Powdermill Creek, 1.0 to 1.1 miles north of the south margin of the area.

Coarse clastic rocks form several lenses in the metasiltstone near the southwestern corner of the area, and are best exposed where Wilson Branch crosses them. The coarse rocks contain clasts of quartz and feldspar in subequal amounts with maximum diameters of one-fourth inch and chips of slate and limestone as much as several inches long, in a dark-gray slaty micaceous matrix which makes up about half of each specimen. Feldspar clasts are mostly potassic. Both matrix and clasts are considerably sheared, the detrital grains being flattened to augen. A single road cut in similar slaty gritty sandstone is 600 feet from the western edge of the area on the west fork of Oldham Creek; quartz and feldspar augen are separated by strongly sheared anastomosing folia of the dark-gray slaty matrix, and the whole is cut by many small faults. West of this sandstone, the metapelites are conspicuously unusual: shiny purplish-gray and dark-greenish-gray slate.

Although silty and finely sandy laminae contain carbonate rocks in much of the Pigeon siltstone, discrete beds of limestone and other carbonate rocks occur only for about 700 feet along Bird Creek immediately south of the Dunn Creek fault, where carbonate rocks and metasiltstone beds are intercalated and well exposed in road cuts and in a small quarry. The carbonate rocks are intercalated and form beds that are a small fraction of an inch to a few feet thick, separated by laminae and layers of calcareous metasiltstone. Some of the carbonate rocks are silty, and some contain clasts of limestone, argillite, and quartz-feldspar sand (fig. 6). The metasiltstone beds contain well-developed crossbedding and slump structures, and many of the contacts between carbonate rocks and metasiltstone show load casting.

In the south, the dark and light laminae are greenish gray and light greenish gray, respectively; northward, the greenish rocks give way to rocks with laminae of dark and light gray, or dark gray and light greenish gray. The color change takes place gradually by intercalation in changing proportions of gray and greenish rocks; color changes along the strike as well as across it, but gray rocks are more common high in the section

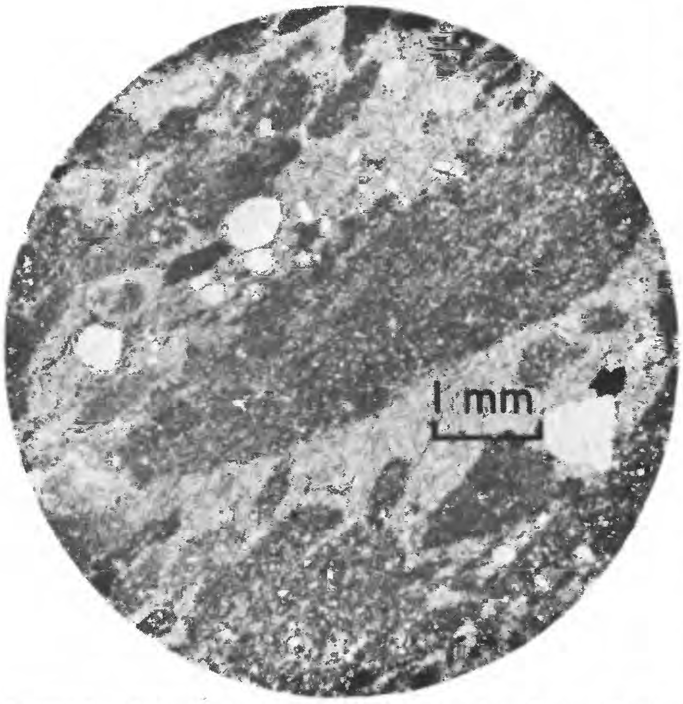

FIGURE 6.—Photomicrograph of clastic limestone from Pigeon siltstone from Bird Creek near Dunn Creek fault. Quartz sand (white) and chips of limestone (dark gray) rest in a matrix of crystalline calcite (light gray). Plane light.

than low. About three-fourths of the rocks are greenish gray. In the Richardson Cove quadrangle, the rocks are almost exclusively greenish between Tattle Branch and Webb Mountain; gray and greenish rocks are interbedded north of Webb Mountain, within a half mile of the Dunn Creek fault, and west of Tattle Branch and its projection to the south. In the Jones Cove quadrangle, the rocks are mostly greenish south of the Gatlinburg fault zone and between Webb Mountain and Big Ridge; north of Webb Mountain the rocks are mostly gray; elsewhere, gray and greenish rocks are interbedded. Most rock types are duplicated in both gray and greenish rocks, although some of the gray metasiltstone units north of Webb Mountain are richer in clastic mica, and some are more thinly and conspicuously laminated, than is common in the formation.

The metasiltstone units contain very fine sand of quartz and feldspar, the proportion of sand increasing eastward across the area. The increase continues east-southeastward beyond the area, where the formation gives way at top and base to sandstone units (J. B. Hadley and Richard Goldsmith, written communication).

STRATIGRAPHY

The lowest exposed parts of the Pigeon siltstone are in the southern corners of the area, from which the stratigraphic elevation increases irregularly northward. Total thickness of the formation in the area is on the order of 10,000 or 15,000 feet; known and possible major faults make estimates uncertain. The base of the formation, exposed in the southeastern corner of the area, is a conformable and intertonguing contact with the similar Roaring Fork sandstone. Conformably overlying the Pigeon within the area are the rocks of Webb Mountain and Big Ridge. Poorly defined stratigraphic subdivisions of the Pigeon siltstone can be made in most traverses on the basis of varying proportions of different rock types, but lateral changes prohibit extension of such subdivisions along the strike.

The Pigeon siltstone is exposed almost continuously for 4 miles across the strike in the gorge of the Little Pigeon River in large fresh stream outcrops and road cuts. The sequence of nearly vertical beds from the south edge of the area to the synclinal axis north of Laurel was measured; an overthrust fault probably is within this section, though its location is not known. Nevertheless, the section, as given below, illustrates well the character of the formation. The units are only of local significance and cannot be recognized even a mile distant along the strike.

Section of Pigeon siltstone exposed along Copeland Creek and the Little Pigeon River from south edge of Richardson Cove quadrangle to synclinal axis north of Laurel

		Thickness (feet)
Top of described section: synclinal axis north of Laurel.		
Siltstone, massive, greenish-gray, slaty; and light-greenish-gray silty fine sandstone, much of its carbonate-rich; crossbedding, scour-and-fill, and slump structures widespread; subordinate even lamination; uniform steep north dip; about one-third concealed		900
Metasiltstone, greenish-gray; mostly in thick beds faintly laminated by irregular dark and light streaks and lenses; many units of carbonate-rich interlaminated and current-bedded greenish-gray slaty siltstone and light-greenish-gray faintly sandy metasiltstone; erratic north dip in upper part, sharp folds in central part, and steep north dip in lower part		4,100
Siltstone; mostly thick-bedded; some laminated	250	
Siltstone, laminated, slaty	100	
Metasiltstone, massive, poorly exposed	400	
Siltstone; mostly thick bedded; many thin laminated units	500	
Metasiltstone, folded, poorly exposed	900	
Metasiltstone; mostly thick bedded and faintly laminated; many thin, laminated, and cross-bedded units	550	
Metasiltstone, laminated, carbonate-rich	75	
Metasiltstone, thick-bedded, faintly laminated	700	
Metasiltstone, greenish-gray; abundant cross-bedded carbonate-bearing laminae; some laminated slaty siltstone	250	
Metasiltstone, laminated	75	
Metasiltstone, thick-bedded, faintly laminated	300	

Section of Pigeon siltstone exposed along Copeland Creek and the Little Pigeon River from south edge of Richardson Cove quadrangle to synclinal axis north of Laurel—Continued

	Thickness (feet)
Metasiltstone, greenish-gray, slaty, and light-greenish-gray finely sandy metasiltstone; interlaminated and crossbedded; many light laminae contain carbonate; uniform steep north dip	250
Metasiltstone, greenish-gray, thick-bedded; uniform to faintly laminated; some very finely sandy; uniform steep north dip; about one-half concealed	1,000
Metasiltstone, greenish-gray; mostly laminated to conspicuously layered; some thick uniform beds; some crossbedding; uniform steep north dip, poorly exposed	1,400
Metasiltstone, greenish-gray; thick uniform or faintly laminated beds; uniform steep north dip; outcrops poor, and mostly weathered	850
Total thickness of Pigeon siltstone measured; no allowance made for faults	8,500

Bottom of measured section: south edge of map area, on Copeland Creek.

PETROGRAPHY

The present mineralogic character of the Pigeon siltstone is due to the reconstitution of sedimentary minerals to metamorphic assemblages of the muscovite-chlorite subfacies of the greenschist facies; sedimentary mineralogy has been obscured. Interstitial argillaceous material has been completely reconstituted to chlorite and sericite, and the clastic plagioclase is now albite. Clastic muscovite and biotite are abundant in the north, but the biotite especially was largely destroyed in the south. Along the southern edge of the Jones Cove quadrangle, J. B. Hadley has found that the formation contains secondary biotite; these rocks, which were reconstituted to assemblages of the biotite-chlorite subfacies, will not be described here. At the same time as the mineralogic reconstitution, slaty cleavage was formed by microshearing along folia spaced most closely in slaty layers. Micas and some other clastic grains are broken and bent against the cleavage folia, and in some specimens much of the detrital mica has been rotated from its bedding position into parallelism with the cleavage.

Sand- and silt-sized grains are mostly quartz and albite, with minor amounts of potash feldspar. The feldspar is generally partly altered to sericite and chlorite, the degree of alteration increasing southward. Quartz and feldspar grains are variously separated by sericite films, sutured together, or intergrown with micaceous minerals. Content of quartz and feldspar varies from a trace in the finest slate to 15 percent or so in typical slate, 50 percent in typical siltstone, and as much as 95 percent in fine-grained sandstone; adjacent microlaminae of slate and siltstone in many places differ in quartz-feldspar content by more than 50 percent. Grain size of quartz and feldspar is generally between 0.01 and 0.1 mm in slate, 0.02 and 0.2 mm in siltstone, and 0.05 and 0.3 mm fine-grained sandstone.

The fine-grained matrix of all the rocks is chlorite and sericite, making up 99 percent of some slate, and representing both reconstituted argillaceous material and altered feldspar. Grain size varies even between laminae of a single specimen, but is within the range 0.005–0.3 mm. Groundmass chlorite is colorless, or very faintly green and weakly pleochroic, and shows low birefringence under crossed nicols. (Chlorite in veins, in pseudomorphs after biotite, and in disseminated grains and clumps is generally pleochroic in green, and ultra blue under crossed nicols.) Chlorite and sericite are typically shingled, lying nearly parallel to the slaty cleavage, but the degree of schistosity varies widely, and in some specimens the minerals are felted. Sericite is generally more abundant, larger, and better oriented than is chlorite.

Clastic micas (a trace to several percent each of muscovite and biotite or pseudomorphs after biotite) occur as flakes 0.1 mm in diameter in most thin sections. The muscovite is generally deformed and partly altered to fine sericite. Recognizable clastic biotite is present only within half a mile of the Dunn Creek fault, where the biotite is red brown or yellow brown and much altered to chlorite or to interleaved chlorite and sericite. South of these biotite-bearing rocks, biotite is represented by pseudomorphs (tiny clumps of fine chlorite and sericite) similar in habit and abundance to the biotite of the northern rocks. Biotite and its pseudomorphs are generally several times as abundant as muscovite.

Zircon is a common clastic mineral, and varies from rounded grains to nearly euhedral prisms. Maximum dimension is about 0.05 mm. Apatite was seen less commonly, but the chemical analyses suggest that it may be prevalent.

Clastic tourmaline was found in about one-third of the thin sections examined, but not more than a few grains were seen in each. It is pleochroic from colorless to olive green or light bluish green, and forms rounded to nearly euhedral prisms lying parallel to the bedding. Some are partly altered to sericite.

Clastic epidote is a rare component of some thin sections. A few grains of a bright-orange clastic mineral identified tentatively as allanite were found in two slides, forming grains 0.01–0.05 mm in diameter.

Sphene and leucoxene intergrowths are seen in nearly all thin sections, and make up several percent of many. The ragged intergrowths are 0.005–0.5 mm long, dirty orange pink or brown to opaque in transmitted light, and white in reflected light. Some masses are rimmed discontinuously by very fine granular clear and colorless sphene, and similar clear sphene is disseminated as 0.001–0.01-mm anhedra in many slides. Presumably both clastic and authigenic material are present.

Magnetite(?) or ilmenite(?) occur both as clastic grains and as tiny disseminated secondary grains. Ilmenite(?) forms minute plates along the dark cleavage folia of many specimens.

Carbonate occurs in many of the coarser laminae and is most widespread in the northern rocks; commonly it is calcite, uncommonly dolomite or ankerite. The calcite is granoblastic, with replacement contacts against feldspar and less commonly against quartz. It varies widely in abundance between laminae of a specimen, or even within a lamina, but is in silty or finely sandy layers and not in slaty layers.

Pyrite is partly disseminated, but mostly is concentrated along layers parallel to bedding. It forms anhedra, cubes, and pyritohedra, with a common diameter of nearly 0.02 mm, being largest and fewest in the coarse rocks. In some specimens, many pyrite grains have irregularly augenoid shadows of wavy or chevron, fibrous quartz and less abundant fibrous chlorite; shadows parallel the cleavage.

Carbon dust is common along the cleavage folia of most of the dark rocks.

Bedding laminae in slate and metasiltstone are alternately dark and rich in metamorphosed argillaceous material, and light and rich in clastic quartz and feldspar. Adjacent laminae may contain, for example, 20 and 70 percent clastic quartz and feldspar. Laminae are as thin as 0.002 mm in some slates, but in metasiltstones are mostly thicker than 0.1 mm. The dark color of slaty laminae is due to magnetite and carbon dust, concentrated along cleavage microfolia.

Cleavage microshear folia are spaced 0.02–0.05 mm apart in the most conspicuously cleaved slates, and as widely as 1 mm in inconspicuously cleaved metasiltstones. Offsets of bedding laminae along cleavage folia are mainly on the order of 0.01 mm (fig. 7), though offsets of 0.2 mm or more are common. Folia are dark with carbon and opaque material and in thin section appear as dark lines lying between clastic grains and the clearer sericite and chlorite, which are generally shingled parallel to the cleavage. Refraction of cleavage folia is shown by many laminated specimens, the cleavage crossing slaty laminae at angles 10° to 30° closer to the direction of bedding than in silty or finely sandy laminae.

The carbonate rocks exposed along Bird Creek are light-gray silty limestone and clastic limestone, with granoblastic calcite, quartz, and feldspar. Although the calcite weathers yellow brown, which might suggest that it is an ankeritic carbonate, its identity is shown by reaction to acid and by X-ray analysis by A. J. Gude

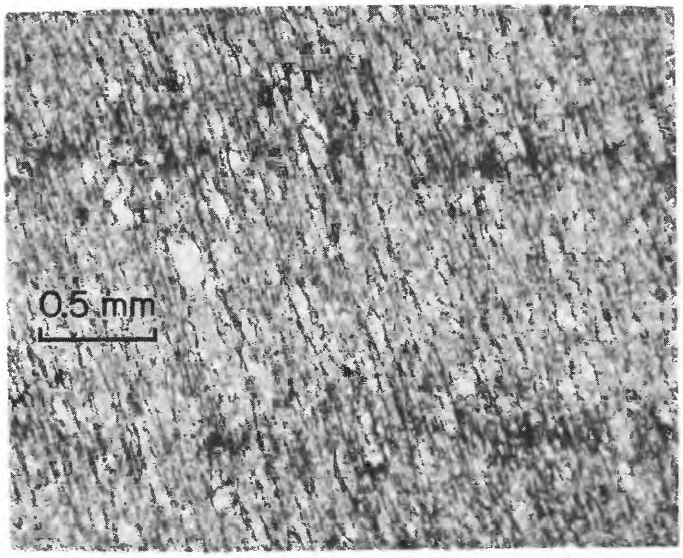

FIGURE 7.—Photomicrograph of metasiltstone with conspicuous cleavage. Bedding laminae are horizontal and are sheared along the steep and closely spaced cleavage folia. Pigeon siltstone, Dunn Creek near Youngblood Branch. Plane light.

III. Bedding is shown by varying proportions of quartz-feldspar sand and silt. The clastic limestone contains clasts of limestone and argillite from 0.05 mm to a centimeter or so long in a matrix of crystalline calcite with clastic quartz and feldspar; a photomicrograph is given in figure 6.

Veins cutting the rocks are generally thin and are most abundant parallel to the slaty cleavage. White quartz is the dominant vein material, but veins of calcite, finely crystalline chlorite, and mixtures of quartz, calcite, and chlorite are abundant. Some thin calcitic veins, parallel to cleavage and crosscutting bedding, are of calcite plus 10 or 20 percent of material—silt-sized quartz and feldspar, detrital mica(?), chlorite, sericite—like that of the host calcareous metasiltstone; the overall character of such veins is like that of the calcareous laminae of the enclosing rocks and the veins may be related to sandstone dikes.

CHEMISTRY

Chemical analyses of six specimens of slate and metasiltstone from the Pigeon siltstone are given in table 2, and ternary diagrams of some of the oxides are given in figures 8, 9, and 10. Some major oxides are similar in all specimens: SiO_2, 53–58 percent; total iron oxides, 7 or 8 percent; MgO, 2 percent. Other oxides vary widely; Al_2O_3 ranges from 14 to 21 percent, according to the amounts of feldspar, sericite, and chlorite. CaO ranges from 0.5 to more than 5 percent, but the ratio CaO/CO_2 (fig. 11) shows that CaO in excess of that in carbonate is nearly constant at about 0.5 to 1 percent. In all specimens the ratio of FeO to MgO is about 2.5:1 or 3:1 (molecular ratio 1.3:1 or 1.7:1) and the sum of Na_2O plus K_2O is 5 to 6.5 percent; the ratio of K_2O to

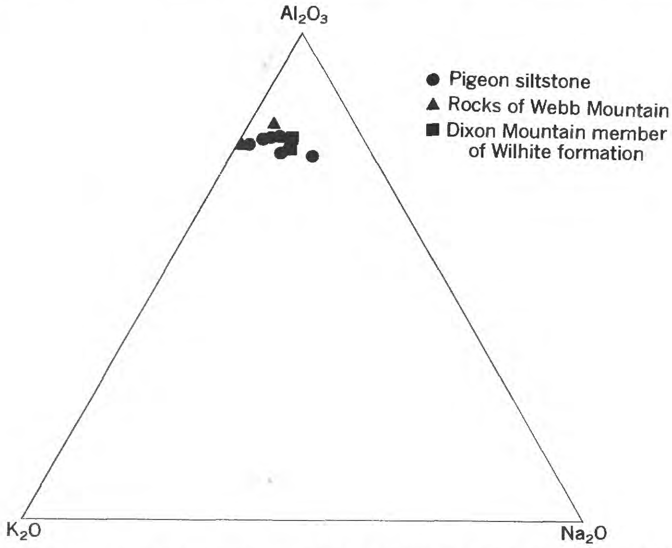

FIGURE 8.—Ternary diagram of weight percent of alumina, potash, and soda in analyses of metapelitic rocks of Ocoee series.

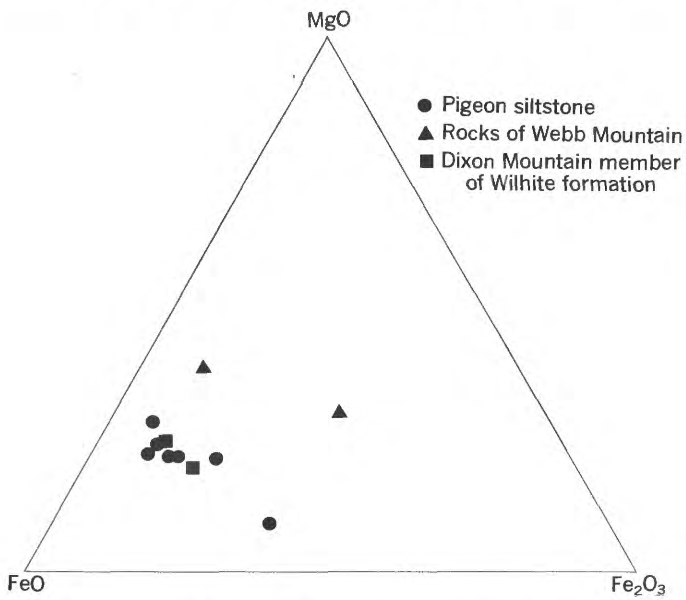

FIGURE 9.—Ternary diagram of weight percent of magnesia and iron oxides in analyses of metapelitic rocks of Ocoee series.

Na_2O is near 2:1 or 3:1 in all except specimen RC 4B (K_2O/Na_2O=8:1) and specimen JC 75–1 (K_2O/Na_2O =0.7:1). The water must be almost entirely bound in the chlorite and sericite, although in only the one standard analysis (specimen RC 299) was combined water differentiated.

All specimens contain 0.2–0.3 percent P_2O_5, indicating the presence of 0.5 percent or more of apatite, either clastic or secondary, a quantity larger than was recognized petrographically. TiO_2 is consistently about 0.8 percent.

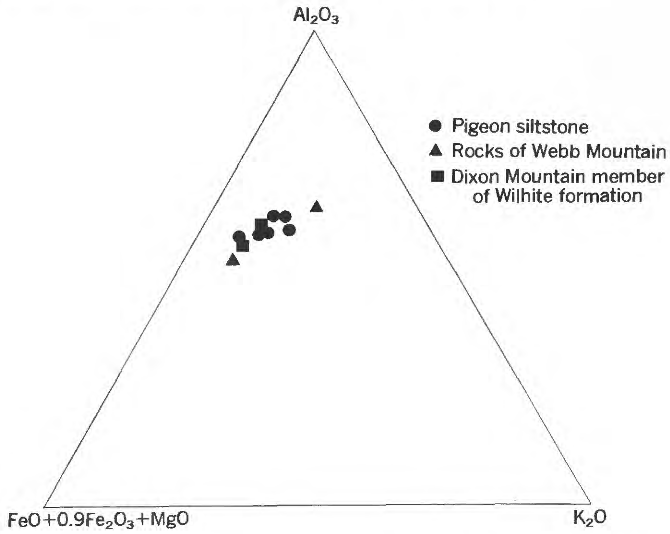

FIGURE 10.—Ternary diagram of weight percent of alumina, total iron plus magnesia, and potash, in analyses of metapelitic rocks of Ocoee series.

SEDIMENTATION

The Pigeon siltstone records a long epoch of sedimentation under almost constant conditions of source and transport. Composition of the rocks varies so little that no consistent subdivisions are recognizable in a section more than 2 miles thick. Rapid deposition is suggested by the massive and poorly bedded character of much of the formation and by its great thickness, but much of the formation is composed of laminated and crossbedded rocks that indicate transport and reworking of bottom sediments. The alternation of laminated and massive rocks indicates a corresponding irregular alternation of processes of deposition. The prevalent crossbedding suggests deposition beneath wave base, otherwise symmetrical ripple bedding would have been produced.

Small-scale crossbedding, in units ⅛ to 1 inch thick, is common in most of the formation (figs. 3 and 4); crossbeds 6 inches or more thick are present locally, for example, north of Laurel. Crossbedded units are commonly lenticular, or merge with more evenly laminated rock, and in many places contain calcite or other carbonate than do layers of any other type. Similar structures from the Cambrian of Wales are described by Kopstein (1954).

Measurements of the direction of current crossbedding, and calculations of the bearing of initial inclination crossbedding, were made. In flat-lying beds, the present bearing of current crossbedding was assumed to be the initial bearing. In tilted and vertical beds, the angle between the trend of crossbedding and the strike

TABLE 2.—*Chemical analyses of metapelitic rocks of Ocoee series.*

[Major-element analysis of specimen RC 299 by L. D. Trumbull and of all other specimens by rapid methods by P. L. D. Elmore, K. E. White, and S. D. Botts. Semiquantitative spectrographic determinations of minor elements by P. R. Barnett (specimen RC 299) and of all others by A. T. Myers; amounts are expressed as midvalues of logarithmic-third divisions.]

	Pigeon siltstone						Rocks of Webb Mountain		Dixon Mountain member of Wilhite formation	
	RC 4B	RC 22	RC 299	JC 7-1	JC 75-1	JC 80-1	JC 1B-3	JC 78A-1	RC 49	JC 16-3
	Major oxides									
SiO_2	56.4	54.6	56.28	53.2	57.1	57.7	50.4	53.3	57.7	54.4
Al_2O_3	21.0	19.5	21.36	17.4	14.5	18.9	26.1	18.9	17.7	18.6
FeO	5.6	7.1	6.04	5.6	6.2	7.0	2.7	7.5	7.5	6.0
Fe_2O_3	2.0	.9	.94	1.2	.7	1.4	3.0	1.6	1.3	1.7
MgO	2.0	2.3	2.21	2.0	2.6	2.4	2.4	5.5	2.7	1.9
CaO	.62	2.9	1.16	5.4	5.4	.50	.26	.39	1.2	3.1
Na_2O	.72	1.5	1.52	2.2	3.0	1.7	.47	1.2	2.1	2.3
K_2O	5.8	3.9	4.92	3.6	2.1	3.6	7.8	3.2	2.9	3.4
TiO_2	.68	.82	.81	.79	.82	.88	1.1	.78	.77	.86
P_2O_5	.26	.22	.24	.27	.22	.32	.23	.22	.27	.12
MnO	.06	.17	.11	.18	.20	.06	.03	.09	.12	.07
H_2O	4.2	4.0	[1] 4.19	3.5	2.7	4.2	4.7	5.2	3.9	3.8
CO_2	<0.5	1.9	.03	3.7	3.6	<.05	<.05	<.05	.88	2.5
Sum	99	100	99.81	99	99	99	99	98	99	99
	Minor elements									
B	<0.002	<0.002	0.003	<0.002	0.003	0.003	0.003	0.003	0.003	0.003
Ba	.15	.07	.07	.07	.07	.07	.15	.03	.07	.07
Be	.0003	.00015	.0007	.00015	.00015	.00015	.0003	<.0001	.00015	.00015
Ce	.015	.015	.03	.03	.015	.03	.015	.015	.015	.03
Co	.003	.003	.003	.003	.0015	.0015	.0007	.003	.003	.003
Cr	.003	.003	.007	.003	.003	.007	.007	.003	.003	.003
Cu	.007	.015	.007	.007	.007	.015	.003	.007	.015	.007
Ga	.0015	.0015	.003	.0015	.0015	.0015	.003	.0015	.0015	.0015
La	.015	.015	.015	.015	.007	.015	.015	.015	.015	.015
Li	<.02	<.02	<.02	<.02	<.02	<.02	<.02	.03	<.02	<.02
Mo	<.0005	<.0005	<.0005	<.0005	<.0005	.0007	<.0005	<.0005	.0003	<.0005
Nb	.0015	.0015	.003	.0015	.0015	.003	.003	.0015	.0015	.003
Nd	.015	.015	.015	.015	.015	.015	.015	.007	.015	.015
Ni	.007	.003	.007	.003	.003	.003	.0015	.003	.003	.007
Pb	.0015	.003	.003	.003	.003	.007	.007	.003	.003	.003
Sc	.003	.003	.003	.003	.0015	.003	.007	.0015	.003	.003
Sr	.007	.015	.015	.03	.03	.015	.003	.003	.03	.03
V	.007	.007	.015	.007	.007	.007	.015	.003	.007	.007
Y	.007	.007	.007	.007	.007	.007	.007	.003	.007	.007
Yb	.0007	.0007	.0007	.0007	.0007	.0007	.0007	.0003	.0007	.0007
Zr	.015	.015	.015	.015	.03	.03	.03	.015	.03	.03

[1] H_2O^- 0.07, H_2O^+ 4.12.

PIGEON SILTSTONE

RC 4B. Greenish-gray slate, with medium-dark to medium-light laminae; micaceous minerals are excellently oriented parallel to the cleavage, and nearly all extinguish together; appearance is of a sieve of shingled sericite and chlorite with minute (0.005–0.015 mm) quartz and feldspar in the holes; chlorite and sericite mostly 0.01–0.02 mm; contains about 24 percent quartz and feldspar, 75 percent sericite and chlorite, and 1 percent sphene, leucoxene, zircon, and allanite(?). Little Pigeon River, near Turkeypen Branch.

RC 22. Medium-dark-gray laminated slate, with 0.1–2 mm laminae; conspicuous orientation of mica parallels the cleavage, crossing the darker and more micaceous laminae at 25° from the bedding, the lighter and coarser at 35°; minutely (0.05 mm) spaced, anastomosing shears parallel the cleavage; clasts of quartz, feldspar, and microcline occur as sheared lenses parallel to the cleavage; small grains of calcite are disseminated in the slate, and larger (0.2 mm) grains pack the silty laminae; contains about 20 percent quartz and feldspar, 72 percent sericite and chlorite, 5 percent calcite, and 3 percent muscovite, pseudomorphs after biotite, sphene, leucoxene, and apatite. Mill Creek.

RC 299. Greenish-gray laminated metasiltstone; contains about 40 percent quartz and feldspar and 55 percent chlorite and sericite. Little Pigeon River near Laurel; collected by J. B. Hadley.

JC 7–1. Interlaminated dark-gray slate and siltstone, and light-gray calcareous siltstone; excellent cleavage at a high angle to bedding; cleavage folia dark, closely spaced (0.02–0.1 mm), and marked by microshears; contains sericite pseudomorphs(?), many sheared, after feldspar(?); most of initial feldspar probably now part of groundmass; groundmass well oriented parallel to cleavage, and contains much finely crushed quartz and crushed and altered feldspar; calcite content of light laminae ranges from 0 to 50 percent. For photomicrograph, see figure 22. Contains about 25 percent quartz and feldspar, 57 percent chlorite and sericite, 7 percent clastic mica, 2 percent pyrite, 8 percent calcite, 1 percent carbon dust (mostly in cleavage folia), and traces of apatite, sphene, and leucoxene. Dunn Creek.

JC 75–1. Greenish-gray slaty siltstone interlaminated with lenses of light-greenish-gray calcareous siltstone; compositions widely variable; for example, calcite makes up 80 percent of some laminae. Quartz and feldspar 0.02–0.1 mm; feldspar much altered and comminuted; chlorite and sericite 0.01–0.02 mm, well oriented parallel to cleavage; cleavage microshears 0.01–0.1 mm apart in slaty laminae, farther in calcareous laminae, with marked offsets along folia; slaty laminae contain about 15 percent quartz and feldspar, 80 percent chlorite and sericite, and 5 percent biotite, muscovite, sphene, leucoxene, zircon, and tourmaline; calcerous laminae contain about 50 percent quartz and feldspar, 26 percent chlorite and sericite, 20 percent calcite, and 4 percent biotite, muscovite, sphene, leucoxene, zircon and tourmaline. North of Webb Mountain.

JC 80–1. Medium-dark-gray siltstone, faintly laminated, with little variation in composition between laminae; quartz and feldspar mostly smaller than 0.05 mm; anastomosing dark cleavage microshear folia average 0.05 mm apart; contains about 40 percent quartz and feldspar, 53 percent chlorite and sericite, 5 percent biotite and muscovite, and 2 percent sphene, leucoxene, magnetite or ilmenite, pyrite, zircon, and apatite. Valentine Branch.

ROCKS OF WEBB MOUNTAIN

JC 1B–3. Dark-gray uniform metasiltstone; contains about 40 percent quartz and feldspar 0.02–0.3 mm in diameter; quartz rimmed, and feldspar rimmed and replaced, by sericite, and many sericite masses are probably feldspar pseudomorphs; contains about 57 percent sericite and chlorite finer than 0.01 mm, 1 percent chlorite pseudomorphs after clastic biotite, and 2 percent carbon in 0.005-mm interstitial granules. Lower division, Warden Branch, Webb Mountain.

JC 78A–1. Thinly interlaminated dark-gray slate and silty slate, with a short thin lens of sandy metasiltstone; slate contains 95 percent chlorite and sericite with an average grain size of 0.03 mm, well oriented parallel to the conspicuous cleavage, 1 percent quartz and feldspar, 3 percent clastic biotite, and 1 percent muscovite. Silty slate has 50 percent chlorite and sericite averaging 0.02 mm long, 40 percent 0.02- to 0.1-mm quartz and feldspar, and 5 percent each of clastic biotite and muscovite. Sandy metasiltstone contains 44 percent sericite and chlorite; 55 percent angular strained quartz, 0.1 to 0.6 mm in diameter; 1 percent clastic biotite; and traces of zircon, tourmaline, and magnetite or ilmenite. Quartz is slightly embayed by matrix, and feldspar much replaced by it. Upper division, northwest of Jones Gap, Webb Mountain.

DIXON MOUNTAIN MEMBER, WILHITE FORMATION

RC 49. Thinly laminated dark-gray metasiltstone; close and excellent cleavage; dull luster in hand specimen, and shows as closely spaced (about 0.2 mm) anastomosing microshears along which pyrite dust is abundant and clastic grains are offset, bent, and broken; contains about 25 percent quartz and feldspar in grains nearly 0.1 mm in diameter, and 10 percent clastic biotite, 1 percent muscovite, and a trace of zircon; dolomite in sand-sized crystals makes up 1 percent of the rock; rest of the rock is of sericite and chlorite, the former dominant; much sericite may have formed from clastic feldspar. Photomicrograph given by figure 21. Location, Dunn Creek.

JC 16–3. Gray metasiltstone; laminae of medium-dark-gray metasiltstone alternate with thinner and commonly lenticular laminae of ankeritic siltstone, and a few laminae of slate; dark laminae contain about 25 percent quartz and feldspar 0.02 to 0.2 mm in diameter and 65 percent sericite and chlorite in subequal amounts, with an average of 2 percent pyrite but as much as 15 percent in some laminae; light laminae contain 45 percent quartz and feldspar, 0.04 to 0.2 mm in diameter; slightly recrystallized, 20 percent ankerite (determined by X-ray methods by A. J. Gude III), less calcite, and about 15 percent sericite and chlorite; slaty laminae contain almost no quartz and feldspar; siltstone contains much clastic biotite and some muscovite, which give bedding fissility. Location, Long Branch at east end of Dixon Mountain.

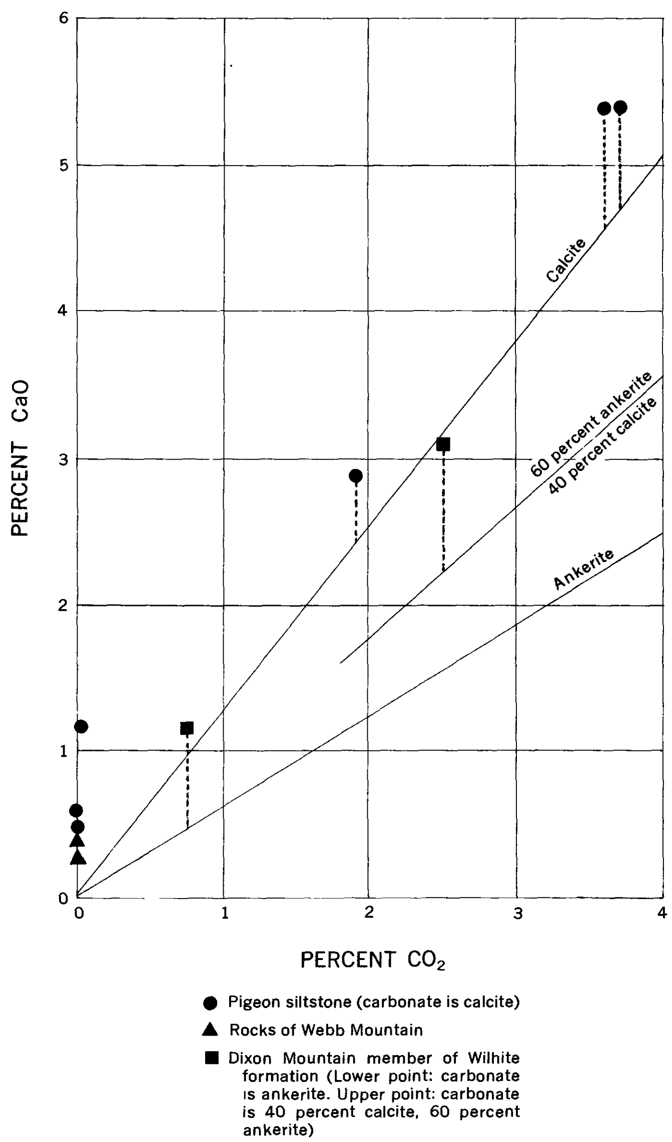

FIGURE 11.—Plot of CaO against CO_2 in analyses of metapelitic rocks of Ocoee series. Lengths of dotted lines indicate excess of CaO over that in carbonate.

was measured in the plane of major bedding, and this angle then added algebraically to the strike. These simple field measurements give directly the initial bearing of crossbedding, assuming folding by tilting about the strike; as the plunges of folds are low, the assumption is reasonable. Four to ten or more measurements were made at each of nine localities, mostly along the Little Pigeon River; about three-fourths of the observations showed an initial bearing—that is, direction of bottom currents—from the northeast quadrant, generally near the strike of the rocks. At some localities, all observations were reasonably consistent; at others, bearings were widely varied, giving all directions including that opposite to the general trend.

Convolute bedding, load casts, and scour-and-fill structures are present in many places, but are far less widespread than crossbedding. Regular graded bedding was nowhere seen.

The thick uniform mass of sediments indicates a steady supply from a source whose lithologic character changed little with progressive erosion. The evidence for bottom current action throughout the formation indicates that uplift of the source area and subsidence of the area of sedimentation were balanced with erosion and sedimentation. Incomplete weathering of the rocks of the source area is shown by the high content of clastic plagioclase and biotite. Mineralogy of the siltstone suggests a source area in which biotite schist was abundant.

Origin of much of the calcite in the rocks is in doubt. It is recrystallized and has at least in part replaced the adjoining grains, and its initial texture has been obliterated. Calcite is in the coarser silty or finely sandy layers, most conspicuously in current-bedded laminae. These features are consistent with a secondary origin of the calcite, perhaps as a byproduct of the alteration of clastic plagioclase to albite, concentrated by replacement in the most porous layers, but they are not consistent with an origin as an interstitial chemical cement. The features are also consistent with a clastic origin of the carbonate rocks; this explanation is particularly attractive for the limestone-rich section along Bird Creek, where many of the carbonate beds show clastic structures. Clastic carbonate might have formed as crystals precipitated near the site of deposition and subsequently moved as clastic grains by current action (see p. 28).

STRATIGRAPHIC RELATIONS

The Pigeon siltstone lies conformably upon and intertongues with the Roaring Fork sandstone in the southeast corner of the area. Hadley and Goldsmith found that the contact dropped westward by intertonguing in this and adjacent areas, and the Pigeon thus thickened westward.

The top of the formation within the area of this report is considered to be the conformable contact with the overlying rocks of Webb Mountain and Big Ridge; but it is perhaps possible that those rocks, whose top is not exposed, form a big lens within the Pigeon siltstone and that the Pigeon continues above the lens. This possibility is discussed at more length with the description of the Webb Mounain-Big Ridge rocks. Southeast of the area of this report, the Pigeon siltstone gives way upward through conformable intertonguing with the Rich Butt sandstone, probably itself correlative in part with the rocks of Webb Mountain and Big Ridge.

The lenticular mass of thin-bedded mixed-clastic sediments, including coarse sandstone, between Dockery and Mize Branches near the Dunn Creek fault at the center of the area, is interpreted as a fault slice of rocks of the Walden Creek group and is questionably assigned to the Licklog formation. None of the siltstone units in this lens are characteristic of the Pigeon siltstone, but it is possible that this lens is a sedimentary intercalation in the Pigeon section.

ROCKS OF WEBB MOUNTAIN AND BIG RIDGE

DEFINITION

A thick body of varied clastic sediments forms masses underlying Webb Mountain and part of Big Ridge to the east; both masses are surrounded by Pigeon siltstone. The lower (southern) contact is conformable with the underlying Pigeon; the upper (northern) contact is at least in part and probably entirely faulted, and is so shown on plate 1. The rocks probably entirely overlie the Pigeon but might be an intercalation within it. Because of the ambiguity of their relation to the Rich Butt sandstone, the rocks are not given a formal name.

The lower division of the unit is made up of varied but mostly thin-bedded clastic sediments, and is best exposed along Warden Branch (Webb Mountain) and Indian Camp Creek (Big Ridge). The upper division, of thick-bedded coarse sandstone and interbedded metapelite, is best exposed along the west fork of Jones Branch (Webb Mountain) and along Indian Camp Creek.

OUTCROP

The rocks are poorly exposed in most places. The coarse massive sandstone of the upper division underlies the high ridges of Webb Mountain and Big Ridge, but weathered material and colluvial boulders of coarse sandstone hide practically all the bedrock. The exposures along Indian Camp Creek are the result of vigorous erosion by that through-flowing stream, and the exposures on Jones Branch are out from the main ridge of Webb Mountain in a shallow valley not flooded by colluvium. Thin-bedded rocks of the lower division form low hills similar to those underlain by the Pigeon siltstone, but outcrops are few and poor.

STRATIGRAPHY AND LITHOLOGY

The unit has two conspicuous divisions. The lower is 600 to 900 feet thick on Big Ridge and about 1,000 feet thick on Webb Mountain and consists of thin-bedded sandstone, metasiltstone, and slate. The upper division is about 3,000 feet thick, and consists of slate and sandstone, the latter mostly coarse and in thick graded beds.

The lower division is dominated by fine- to medium-grained gray feldspathic sandstone, with few layers thinner than 6 inches or thicker than 2 feet. The sandstone is poorly sorted with much matrix; some beds are laminated or indefinitely layered, others massive. Coarse dirty feldspathic sandstone and arkose are present also, and are similarly thin bedded; thin beds of slate-chip conglomerate are rare. No graded beds were seen. Thinner beds of dark-gray slate and finely sandy metasiltstone alternate with the sandstone beds and dominate parts of the sequence. The metapelite beds are partly massive, partly evenly laminated; they are nowhere greenish like Pigeon siltstone, and nowhere display current bedding like the Pigeon.

The upper division consists of thick graded beds of coarse dirty feldspathic sandstone, thinner nongraded beds of medium and coarse sandstone, and dark-gray slate and metasiltstone. Sandstone and metapelite are of approximately equal amount, each dominating parts of the division. The best exposed section within the upper division is that of the west fork of Jones Branch, where the following stratigraphic section stands nearly vertical with top to the north. Of this section, about three-fourths is metapelite and one-fourth sandstone.

Section of upper part of upper division of rocks of Webb Mountain and Big Ridge along west fork of Jones Branch

	Thickness (feet)
Top of section: sharp contact with Pigeon siltstone, presumably faulted.	
Sandstone, feldspathic, graded beds 3–10 ft thick; very coarse at base of each bed, grading upward to medium-, fine-grained or very fine-grained sandstone, and that in some beds to slate or metasiltstone; each sandstone bed is either in sharp contact with the underlying bed, or separated from it by a few inches of laminated metapelite; granite pebbles as much as 1 in. in diameter occur rarely near the bases of some of the beds; average maximum grain size is about one-eighth in	400
Metapelite, thin-bedded, dark-gray, and medium-grained feldspathic sandstone; generally in beds less than 1 in. thick	200
Metapelite, dark-gray, interlaminated, and nongraded feldspathic sandstone; variously fine to coarse; several units about 50 ft thick of coarse sandstone in thick graded beds	700
Total thickness measured	1, 300
Base of described section: southern end of exposures.	

A few hundred feet of rocks, some hundreds of feet south of the north boundary of the unit, crop out in the hollow due north of Jones Gap. They consist of feldspathic sandstone, partly coarse to fine in graded beds 3 to 8 feet thick and partly medium grained in laminated platy beds; they are interbedded with dark-gray laminated metapelite. Another outcrop of a few hundred feet at the north edge of the member occurs in the hollow midway between Jones and Dockery Branches and consists of coarse- to medium-grained feldspathic sandstone, and dark-gray silty slate with thin lenses of medium-grained sandstone. Elsewhere on Webb Mountain, rocks similar to those described above are seen as loose blocks and chips and, rarely, as small outcrops. Coarse sandstone beds are the most conspicuous, but slate chips are abundant in the creep mantle.

In the Big Ridge area, east of Webb Mountain, the best outcrops are along Indian Camp Creek, and consist of thick beds of feldspathic sandstone, generally 4 to 10 feet thick, in the lower and middle parts of the upper division. Each bed is smoothly graded from coarse grained at the base to medium grained or fine grained at the top, some beds being separated by thin beds of laminated dark-gray sandy metasiltstone or slate, commonly sandy; other sandstone beds are in sharp contact. Nongraded and generally thinner sandstone, lithologically similar to the rocks of the thick graded beds, are interbedded. The coarsest sandstone beds contain a few granite pebbles as much as an inch in diameter.

Elsewhere in the upper division on Big Ridge, coarse feldspathic sandstone dominates the float and the few small outcrops. Dark-gray slate and metasiltstone are less abundant than on Webb Mountain. A single conglomerate bed was noted, with quartz pebbles about an inch in diameter in a matrix of coarse feldspathic sandstone.

PETROGRAPHY

The sandstone units are generally feldspathic and poorly sorted, and most are medium light gray, in part greenish. Most specimens have a quartz content between 40 and 80 percent; feldspar, between 10 and 40 percent; and sericite plus chlorite, between 10 and 35 percent. Clastic quartz is nearly all gray, although some of the quartz of rare specimens is slightly bluish; quartz grains are mostly strained single crystals, with a little vein quartz and fine-grained quartzite. Quartz is slightly replaced by sericite along margins and cracks, and many grains are cut by narrow zones of finely granular quartz. Feldspars are mostly white, many chalky owing to alteration; some large grains of perthite are pale pink. The ratio of potash feldspar to plagioclase increases with grain size, and plagioclase is generally in smaller grains than the quartz and potash feldspar. Most of the potash feldspar is microcline or microperthite; in some specimens, many microcline grains have ragged cores of orthoclase, partly sericitized, showing some microcline to be secondary after orthoclase. Plagioclase is albite. Feldspar is variably altered, notably to sericite. In the most altered rocks, the feldspar remains only as tiny residual islands in sericite, and such sericite formed from feldspar is generally coarser than that from argillaceous material.

Coarse sandstone units have common maximum grain sizes of 2 to 4 mm. in diameter, although quartz and potash feldspar grains as large as 1 cm. and rare granite pebbles as large as 3 cm. occur; grains are mostly subangular or subrounded. Most rocks are poorly sorted, containing quartz and feldspar of all sizes down to fine silt. The matrix is generally sericite, with variable but subordinate amounts of chlorite, near 0.01 or 0.02 mm. in average size; in some specimens much of the matrix was altered from feldspar. Quartz and feldspar are sutured together in some specimens, separated by sericitic films in others. Finely crystalline calcite makes up as much as 10 percent of some specimens, appearing either in place of or with chlorite and sericite.

The fine-grained rocks—metasiltstone and slate—are generally dark gray owing to minute granules of carbon in dark bedding laminae and along cleavage microfolia. Microfolia of some specimens also have minute plates of ilmenite(?). Most of the rocks are laminated, though less conspicuously than the pelitic rocks of the other formations; a further distinction is that cleavage of the rocks of Webb Mountain and Big Ridge is generally weak, cleavage microfolia being wider spaced, less distinct, and less sheared than is typical of nearby rocks of other formations. Further, cleavage in many places is parallel to bedding. Dark laminae, as well as being more carbonaceous than light laminae, contain more chlorite and sericite, and less and smaller clastic quartz and feldspar. Minute grains of quartz and feldspar are abundant in the groundmass of many metapelites. No calcareous metapelite units were noted.

Altered but recognizable biotite is a minor component of many sandstone beds, and constitutes as much as 5 percent of some fine-grained rocks; only chlorite pseudomorphs after biotite appear in other specimens, but recognizable biotite extends farther south than in the nearby Pigeon siltstone. Clastic muscovite occurs with the biotite in subequal amounts. Epidote is a minor clastic mineral in many specimens, and hornblende was noted in one. Zircon, tourmaline, and apatite are common minor accessory clastic minerals.

Low-grade metamorphism of the sandstone completely reconstituted the argillaceous material, mostly to chlorite and sericite, and altered much of the feldspar to sericite and all remaining plagioclase to albite, but quartz and feldspars show only slight marginal recrystallization. Cleavage is generally expressed in outcrops of the sandstone only as rough and widely spaced joints, and in thin section by weak orientation of secondary micaceous minerals. Microshearing and flattening of quartz and feldspar grains are rare.

Many of the rocks of all textural types are strewn with pyrite grains, notably cubes. Veins are mostly of quartz—white granular, sutured, or comb-structured. Quartz-chlorite veins are abundant; some are quartz veins with intergrown masses of quartz and green chlorite, with or without cores of green granular chlorite in the intergrown masses.

CHEMISTRY

Chemical analyses of the two specimens of metapelitic rocks described above are given in table 2, and various oxides are plotted on figures 8 to 11. The metasiltstone (specimen JC 1B–3) is very high in Al_2O_3 (26 percent) and K_2O (8 percent), and low in Na_2O (0.5 percent); the slate (specimen JC 78A–1) is high in MgO (5 percent). The ratio FeO to MgO is much smaller (0.6:1 to 0.8:1) than in the specimens from the Pigeon or Wilhite formations.

SEDIMENTATION

The rocks of Webb Mountain and Big Ridge record a profund change in sedimentation from that of the underlying Pigeon siltstone. The graded sandstone beds must record depositional pulses, the laying down of as much as 10 feet of sediment in a very brief time. Kuenen (1953) concluded that such graded, poorly sorted sandstone beds must have formed almost instantaneously from some sort of turbidity currents, and such a mechanism seems required to explain the rocks of this area.

The slate, metasiltstone, and nongraded sandstone record gradual rather than pulsing sedimentation; their thin bedding and diversity indicate frequently changing modes of transport and deposition. The change in character of the sediments between the lower and upper divisions of the unit might reflect a steepening of the submarine slope, permitting large turbidity currents to form and flow, or a change in the location or character of the source of sediment.

The high feldspar content probably reflects rapid erosion and deposition, which suggests in turn a nearby source area of moderate or high relief. The rocks generally have a higher ratio of potassium feldspar to plagioclase than those of the Pigeon siltstone; clastic mica and heavy mineral contents of the two formations are similar. The difference in feldspar ratios might indicate either different source rocks, or selective processes of sedimentation; the proportion of potassium feldspar to plagioclase tends to increase with grain size, showing some operation of selective sedimentation. The rocks of Webb Mountain and Big Ridge probably were derived from a terrane of plutonic rocks.

STRATIGRAPHIC RELATIONS

The Webb Mountain and Big Ridge rocks form two masses, surrounded by Pigeon siltstone and in contact with no other formation. These rocks conformably overlie the Pigeon; although the exact contact was nowhere seen, conformability is shown by the parallelism of bedding and contact.

The eastern and western contacts of both the Webb Mountain and Big Ridge blocks, and the northern contact of Big Ridge, are low-angle faults, strongly discordant to structural features both above and below. The character of the northern Webb Mountain contact is in doubt; it is slightly concordant, and might be either stratigraphic or tectonic.

The following features suggest stratigraphic concordance: (1) the well-exposed Jones Branch section is nearly vertical with top north, as is most of the Pigeon siltstone to the north; (2) in two hollows midway between Jones and Dockery Branches, rocks of the Pigeon and of Webb Mountain crop out 20 and 50 feet apart and have parallel bedding (nearly vertical) and parallel cleavage attitudes; (3) no structural features suggestive of nearby faulting were found; and (4) the contact is concordant in strike within the limits of the mapping. The following counterarguments suggest a fault contact: (1) the contact is known to be a fault in part, and the similar Big Ridge block is faulted on the north side; (2) the evidence against a fault applies equally to a possible major fault within the Pigeon siltstone to the north, though such a fault must be present if the contact along the north side of Webb Mountain is not a fault; (3) the Webb Mountain section varies in lithology and stratigraphy along the contact; (4) there is no interbedding of Webb Mountain rocks and the Pigeon (but neither is there interbedding along the southern contact, which is almost certainly sedimentary); (5) the contact is markedly discordant west of the west fork of Jones Branch; (6) the probable correlatives of the sandstone units in areas to the south are known to entirely overlie the Snowbird group. This evidence supports the tentative conclusion that the northern Webb Mountain contact is a fault; it is possible, though unlikely, that the Pigeon siltstone stratigraphically overlies, as well as underlies, the Webb

Mountain rocks which would then form a thick lens within the Pigeon.

South of the eastern part of the area, J. B. Hadley found that the Rich Butt sandstone concordantly overlies the Pigeon siltstone with slight intertonguing. Rocks of the Rich Butt are similar to those of the lower division of the Webb Mountain-Big Ridge sequence, but are dominated by the finer grained rocks, and are unlike the rocks of the upper division. The Rich Butt occurs both in sequence above the main mass of Pigeon siltstone and in fault slices related to but beneath the Greenbrier fault; the latter structural position seems required to explain also the Webb Mountain-Big Ridge structural features (pl. 1, section *E–E′*). Correlation of the Rich Butt with the lower division of the Webb Mountain-Big Ridge rocks thus seems likely, the differences being ascribed to lateral facies changes. If correlatives of the upper division of the rocks of Webb Mountain and Big Ridge were once present above the type Rich Butt, they have been removed by faulting.

Above the Greenbrier fault the basal Elkmont sandstone and medial Thunderhead sandstone of the Great Smoky group lie stratigraphically above the Snowbird group. The lower division of the rocks of Webb Mountain and Big Ridge are lithologically similar to much of the Elkmont, and the upper division to much of the lower part of the Thunderhead, and such correlations are probable.

Similar stratigraphic and structural interpretations are made by R. B. Neuman for the Cades sandstone, probably correlative with the rocks of Webb Mountain and Big Ridge and the Metcalf phyllite of the Snowbird group of the western foothills (fig. 1). In the central foothills, rocks similar to those of Webb Mountain and Big Ridge, but with coarse rocks more abundant, are correlated directly with the Elkmont and Thunderhead sandstones by P. B. King, and the thrust fault bounding the rocks is considered by King to be the main Greenbrier fault, but an interpretation of a fault beneath the Greenbrier fault would also fit King's data.

WALDEN CREEK GROUP

Most of the northern half of the report area is underlain by the Walden Creek group of the Ocoee series. It consists of widely varied clastic rocks—slate, siltstone, shale, fine to coarse sandstone, quartz conglomerate—and carbonate rocks, which are mostly in one formation. Facies changes are complex and abrupt, and most clastic rock types appear in all of the formations designated. Faults are certainly more numerous, and folds more complex, than shown on the geologic map. These variables make uncertain the differentiation and correlation of formations in the Walden Creek group. The sequence and designations given here, while consistent with known facts, must be regarded as tentative. In the unpublished Mount Guyot quadrangle, Keith applied the name Hiwassee slate to the fine-grained rocks, and Citico conglomerate to the coarse-grained rocks, of what is here called the Walden Creek group; these names have no stratigraphic significance in this area, were derived from geographic features many miles to the southwest, and are not used in this report.

All formations of the Walden Creek group are exposed between Shields Mountain and Pine Mountain in nonrepetitive order in what is considered a conformable upward sequence eastward. From oldest to youngest, they are named the Licklog, Shields, Wilhite, and Sandsuck formations. The group and formation names were defined, or redefined, by King, Hadley, Neuman, and Hamilton (1958).

LICKLOG FORMATION

Oldest, least extensive, and poorest exposed unit of the Walden Creek group is the Licklog formation, named for its largest area in and near Licklog Hollow between the Little Pigeon River and the East Fork. The formation is exposed mostly along and near the northwest edge of the Ocoee series in the Richardson Cove quadrangle. The formation is well exposed where crossed by the Little Pigeon River at the Dunn Creek fault, but elsewhere exposures are poor and the character of the formation must be judged largely by chips in the overlying soil. The formation is overlain, apparently conformably, by the conglomerate of the Shields formation, and the eastward thinning of the conglomerate suggests that the two intertongue. Lower limit of the formation in the area is everywhere a fault, and its preserved thickness is only a few hundred feet.

The Licklog formation is a sequence of siltstone and shale or slate, with some fine to coarse sandstone and quartz-pebble conglomerate. These types are diversely and thinly interbedded. Pelitic rocks are dark gray, laminated to crudely layered, and micaceous, weathering to dark-brown pencils or chips parallel to the bedding. Interbedded sandstone units resemble those of the overlying conglomerate, and coarse beds are a few inches to a few feet thick. Some of the sandstone beds have a carbonate cement, only partly calcite.

Megascopic metamorphic effects on the northern areas of the Licklog formation are limited to poor slaty cleavage, weak at best and lacking in many outcrops. Rocks next the Dunn Creek fault, by contrast, have a fair slaty cleavage. The single thin section from this locality is of a very fine grained calcareous sandstone;

the argillaceous component is entirely reconstituted, mostly to sericite 0.01–0.02 mm in diameter. Clastic biotite, though much altered, is recognizable. Pyrite crystals in the section have shadows of fibrous quartz and chlorite.

SHIELDS FORMATION

The Shields formation, named for Shields Mountain, has two members: below, thick-bedded sandstone and conglomerate, and, overlying and intertonguing with these rocks, slate and shale. These members are referred to here as conglomerate of Shields Mountain and slate of Richardson Cove.

CONGLOMERATE OF SHIELDS MOUNTAIN

DEFINITION AND OUTCROP

The high ridge of Shields Mountain is formed of thick-bedded coarse sandstone and quartz-pebbled conglomerate, best exposed in ledges, bluffs, and road cuts along Bird Creek at the east end of the mountain. The similar rocks near Short Mountain are considered to be correlative. High bluffs with bedding partings a foot to many feet apart are common on Shields Mountain, which has a larger proportion of natural outcrops than any other large area within the quadrangles. Northeast of the Little Pigeon River, by contrast, there are few outcrops. Short Mountain is mostly a dip slope with only scattered outcrops.

The sandstone and conglomerate are mostly light gray on weathered surfaces, and gray, brownish gray, or yellowish brown, on newly broken surfaces, with spongy interstitial limonite conspicuous in places. In deeply weathered areas, quartz pebbles released from the conglomerate strew the ground.

LITHOLOGY

The conglomerate member is composed largely of the following types in beds broadly uniform in composition and texture:

1. Gritty sandstone in beds mostly 2 to 8 feet thick, locally as thin as an inch or as thick as 15 feet. Individual beds are generally little varied, but may have poorly defined layers or lenses with diverse grain sizes. Matrix is sericite and fine-grained sand. The beds are neither graded nor crossbedded.

2. Similar sandstone beds enclosing pebbles widely scattered or in streaks, or enclosing poorly defined layers or lenses of quartz-pebble conglomerate, the conglomerate layers an inch to a few feet thick.

3. Quartz-pebble conglomerate in beds 3 to 10 feet thick, with little variation within a bed; many beds contain rock fragments.

4. Dark siltstone, shale, or slate in layers a fraction of an inch to tens of feet thick, separating some of the coarse beds; these fine-grained rocks are the probable source of most rock chips in the conglomerate.

STRATIGRAPHY

Shields Mountain is composed of a competent mass of conglomerate and sandstone about 1,600 feet thick. No consistent lithologic variations occur along or across Shields Mountain in the main mass of the rocks, but the mass intertongues upward and northeastward with pelitic rocks, and its distinctiveness decreases progressively east of the Little Pigeon River.

PETROGRAPHY

Maximum grain size of most standstone and conglomerate ranges from 2 to 10 mm in diameter, with extremes of 1 mm to 40 mm or so; average sizes are mostly between 1 and 5 mm. In any one bed, 5 to 75 percent of the clasts may be near the maximum size. Pebbles are mostly white or gray polycrystalline quartz derived from vein quartz and from both statically recrystallized and dynamically metamorphosed quartzite; there are scarce aplite pebbles. Quartz smaller than 5 mm in diameter is mostly of single crystals of little-strained white or gray quartz of probable plutonic origin; much of the quartz in some beds is slightly bluish. Dark shale chips, mostly a fraction of an inch but rarely several feet long, are numerous in many layers, and sand-sized clasts of shale speckle some sandstones; rarely beds contain cobbles of fine-grained sandstone or slabs of limestone (fig. 12).

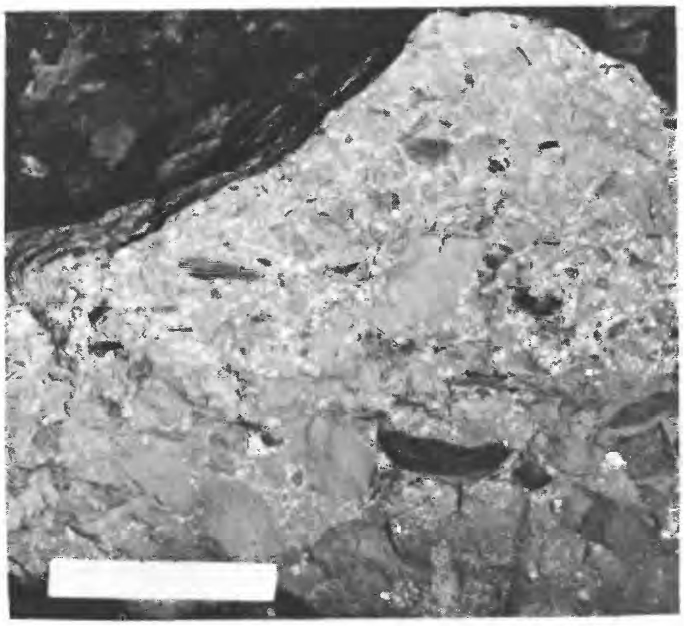

FIGURE 12.—Coarse phase of conglomerate of Shields Mountain. White pebbles are quartz, dark-gray chips are siltstone, and light-gray cobbles are impure limestone and calcareous sandstone. Matrix is coarse calcareous sandstone. Colluvial block at east end of Shields Mountain. Scale is 7 inches long. Photograph by H. E. Malde.

Feldspar commonly makes up 10 to 15 percent of the sand component of the rocks. Potassium feldspar is dominantly white to pale-orange little-altered microcline, some of it microperthitic. Plagioclase makes up one-tenth to one-half the feldspar and is faintly greenish, much altered, and replaced by sericite and carbonate. Muscovite forms a trace to 1 percent of the gritty sandstone, and zircon a trace. Leucoxene and sphene are generally present.

Matrix of the rocks is fine-grained sandstone, mainly silty, with variable amounts of greenish reconstituted argillaceous material in which sericite is dominant over chlorite. Calcite is rare in the northern areas but is an important constituent in the matrix of many specimens from the southern part of the area. In the southern outcrops, quartz margins are minutely sutured against surrounding grains and matrix. Most specimens break through clastic grains; in some, reconstituted argillaceous matter films the sand grains and protects them from fracture. The common pelitic rocks are dark siltstone with clastic mica, quartz, and feldspar as large as one-fourth mm in diameter, but shale and slate and thin beds of fine micaceous sandstone are present also.

In the sandstone and conglomerate, cleavage is shown by widely spaced joints that cross the bedding at high angles. Quartz veins, in part concentrated along the cleavage, are abundant. Slaty cleavage in the fine-grained rocks is nonexistent to fair in the northern rocks, and fair to excellent in the southern rocks, and is at a lower angle to bedding than in the interbedded sandstone.

STRATIGRAPHIC RELATIONS

The Shields Mountain mass intertongues upward and northeastward with slate; the intercalated pelitic rocks increase northeastward, and the boundaries of the member are poorly defined and the structural features complex. The member cannot be expected to have regional extent. Confusion of this lower member of the Shields formation with the middle member of the Sandsuck formation is possible as these two members are lithologically similar, but the Shields Mountain rocks give way upward to slate and downward to siltstone, whereas the middle member of the Sandsuck gives way in both directions to siltstone and fine-grained sandstone. The correlation of the rocks of Short Mountain with the closely similar rocks of Shields Mountain is reasonable, but it is conceivable that the rocks of Short Mountain do not correlate with any other part of the Walden Creek group in the area.

SLATE OF RICHARDSON COVE

DEFINITION

The upper member of the Shields formation is composed of slate and shale with lenses and tongues of coarse gritty sandstone. It is referred to Richardson Cove, which is cut in the slate, but best exposures are farther west along Middle Creek. The member lies in stratigraphic sequence above the conglomerate of Shields Mountain, and occupies a belt bordering the main mass of that member on the south.

OUTCROP

The member crops out in low hills a hundred feet or so high. Natural outcrops of the slate are rare except in stream beds, and the ground surface is commonly a mixture of soil and chips of weathered rock. Most outcrops are yellowish gray and much weathered.

LITHOLOGY

The member is unique in the area in its dominance of fine-grained silt-poor slate. Listed in order of decreasing abundance, the member consists mostly of the following four rock types:

1. Slate, laminated to obscurely bedded, with shiny slaty cleavage. Laminae are generally 0.05–0.02 inch thick, the layers alternately silty and nonsilty; silty laminae are generally the thinner, with cleavage duller and at a higher angle to bedding than in slaty laminae. The rocks are mostly medium or dark gray, although some are greenish gray. They weather to thin chips parallel to slaty cleavage, bedding-plane cleavage being inconspicuous except where clastic mica is abundant.
2. Shale, generally laminated, much of it siltier than the slate, with rough slaty cleavage.
3. Sandstone, coarse and gritty, in beds a few inches to 10 feet thick. These sandstone beds are like those of the Shields Mountain unit except that conglomerate is uncommon.
4. Sandstone, fine- or medium-grade with silty and argillaceous matrix, in laminae or layers one-fourth inch to one foot thick.

Limestone crops out along and near Bird Creek—thin beds of finely-crystalline limestone, and thick beds of limestone-conglomerate. All are calcitic, and most contain white calcite veins and anastomosing folia of chlorite and sericite.

STRATIGRAPHY

In the west, the lower half of the member contains tongues of sandstone, as much as a hundred feet thick, that are similar to the underlying rocks of Shields Mountain; they lens out eastward, where the member contains fewer and thinner sandstone beds. Sandstone beds as much as a few feet thick occur in all parts of the member. The pelitic rocks are so tightly folded that local attitudes indicate little of overall structure; the thicker sandstone tongues are more broadly folded. Estimates suggest a thickness of about 1,000 feet in the central and eastern area, and perhaps 1,500 feet farther west, the difference resulting largely from addition of sandstone.

Shale with a weak slaty cleavage is locally interbedded with slate, and there represents initially more silty layers less susceptible to the microshearing during the formation of cleavage. In the little-altered rocks of the northeastern part of the member, shale is equivalent to both the slate and the shale to the southwest.

Limestone is interbedded in slate near the Dunn Creek fault along Oldham and Bird Creeks. A single limestone-bearing unit, 100 feet thick, can account for all outcrops, and such a unit is shown on the geologic map (pl. 1). In road cuts along Bird Creek, faintly laminated finely crystalline gray limestone forms thin beds in slate, a few as much as 8 feet thick. Along Oldham Creek a quarter of a mile to the west, there is one 50-foot limestone bed, including limestone conglomerate, and many ½-inch to 1-inch limestone interlayers in slate.

STRATIGRAPHIC RELATIONS

The lower limit of the member is the intertonguing contact with the underlying rocks of Shields Mountain. Its upper limit is placed at the concordant contact with the siltstone-dominated lowest member of the Wilhite formation; this contact is gradational by changing proportions of rock types, and is not precisely definable.

The limestone beds of the Richardson Cove unit resemble those of the Wilhite formation, but as no reasonable structural explanation of such a possible correlation can be made, they are placed with the slate of Richardson Cove.

WILHITE FORMATION

The name Wilhite slate, derived from Wilhite Creek (within this area), was given by Keith (1895) to various rocks with diverse stratigraphic positions in the northern foothills in areas to the west. The name has been revised as Wilhite formation, with its type section exposed along Wilhite Creek and Long Branch (King, Hadley, Newman, and Hamilton, 1958). The formation is the most varied in the area of this report, and is subdivided into two members—Dixon Mountain below, Yellow Breeches above—and the upper member into two subdivisions. Were this area to be considered alone, the two members should be accorded formation rank, as they are distinctive assemblages of different rocks; however, such subdivisions can not be made in areas to the west, where no unit smaller than the Wilhite formation can be consistently separated.

DIXON MOUNTAIN MEMBER

DEFINITION AND OUTCROP

The Dixon Mountain member is named for Dixon Mountain, which is formed largely of rocks of the member. The member adjoins and probably overlies the slate of Richardson Cove on the east; the member occupies much of the central part of the report area, including Bearwallow Mountain, Dixon Mountain, and Chestnut Ridge, as well as smaller areas near Dockery Branch and Chavis Creek. Best exposures occur along Dunn Creek at the east end of Short Mountain, Long Branch at the east end of Dixon Mountain, and Chucky Creek at the east end of Chestnut Ridge.

The Dixon Mountain member is a sequence of clastic rocks, mainly sandy siltstone, but including coarser beds on Chestnut Ridge that are assigned to it with reservations. The unit is one of the most resistant and well exposed of the dominantly pelitic units and projects in hills with a relief as great as 700 feet.

LITHOLOGY

The typical rock of the member is micaceous and finely sandy siltstone or metasiltstone, with alternating dark- and light-gray laminae, mostly between one-twentieth and one-half an inch thick, the darker thicker than the lighter. Light-colored laminae are silty very fine grained sandstone, and the dark are slaty siltstone. Most of the rock exposed at any one locality consists of such alternating laminae but grain sizes vary from locality to locality. At most places, laminae are siltstone and fine-grained sandstone, but at many there are beds, a few inches to tens of feet thick, of laminated slate or shale. Elsewhere (for example, in the upper part of the Dixon Mountain hollow whose mouth is 0.4 mile northeast of the mouth of Valentine Branch), laminae are silty very fine grained sandstone and cleaner fine-grained or medium-grained sandstone, with many interbeds of gritty sandstone, a foot or so thick. Many of the relatively coarse laminae, sandy siltstone or very fine grained sandstone, contain abundant carbonate. In some beds, the carbonate is all calcite; in others, all ankerite or dolomite; in still others, both types occur together.

The siltstone and silty rocks of the member contain mostly regular laminae, but lenticular laminae are abundant, and cross-laminated and load-casted beds are common.

The siltstone and fine-grained sandstone contain much clastic mica and split readily along the micaceous bedding at intervals of an inch or so. In some outcrops bedding is the most conspicuous parting, in others slaty cleavage; quality of cleavage increases southward.

Medium- to coarse-grained sandstone forms beds from a quarter of an inch to a few feet thick, uncommonly more, in many areas. The sandstone is poorly sorted, and generally sparsely feldspathic, and with largest grains an eighth-inch in diameter. Some sandstone is massive; some roughly laminated by slaty folia. Most accessible of the thick-bedded sandstone beds are those along Dunn Creek, 0.6 mile east of Valentine Branch, where the massive sandstone beds, 1 to 10 feet thick, contain many chips and slabs of black shale, and are separated by equally thick interbeds of sheared black slate. A few beds of white gritty quartzite, in part crossbedded, occur along Long Branch at the southeast end of Dixon Mountain.

Carbonate rocks occur at two places near Chestnut Ridge: one along Dunn Creek, one-fourth mile south of the mouth of Chucky Creek, the other in road cuts 0.45 mile east of Howard View Church. At the first locality thin beds of buff-gray fissile dolomite are intercalated in siltstone and slate. At the second a few beds are of limestone and dolomite; the dolomite is light gray and crystalline with some calcite and scattered quartz sand. The limestone is clastic, with fragments of limestone as much as several inches long in a matrix of medium-light-gray dolomitic limestone with sparse well-rounded grains of quartz and many clumps of pyrite.

STRATIGRAPHY

The Dixon Mountain member is dominated by intricately folded siltstone and fine-grained sandstone. Thickness is probably on the order of 1,500 feet. Areal variations in the rocks do not follow any recognized consistent stratigraphic scheme.

The conformable contact between rocks defined as the Dixon Mountain member and overlying basal limestone bed of the Yellow Breeches member of the Wilhite formation is exposed in a small quarry south of the junction of Valentine Branch and Dunn Creek. The Dixon Mountain is lens- and current-laminated, gray calcitic metasiltstone; between it and normal limestone of the Yellow Breeches member is a 5-foot bed of gray silty slate that is almost phyllitic.

PETROGRAPHY

The Dixon Mountain member is dominated by slightly metamorphosed interlaminated micaceous siltstone and silty fine-grained sandstone. Quartz is more abundant than feldspar; the latter is mostly albite, with subordinate amounts of potassium feldspar. Most quartz and feldspar range from 0.02 to 0.2 mm in diameter, are angular to subrounded, and make up 25 to 75 percent of the rocks but nearly 100 percent of some laminae. Feldspar is partly sericitized, some so completely that it resembles matrix material except when viewed under highest magnification and some is partly replaced by carbonate. Quartz and feldspars are slightly recrystallized; one albite grain was seen with an untwinned rounded core rimmed by an albite-twinned anhedral shell, with one set of twins crystallographically continuous with the core.

Clastic biotite constitutes between 1 and 10 percent of the various laminae and is in thicker flakes and generally much greater abundance than muscovite; micas have a common length range of 0.1 to 0.5 mm, and are generally broken and bent by cleavage microshears. The biotite is dark yellow brown and is partly altered to sericite and chlorite, both marginally and along the cleavage. Minor accessory minerals, both clastic and secondary, resemble those of the Pigeon siltstone except that no allanite was noted.

Argillaceous material in the rocks has been largely reconstituted to sericite and chlorite in generally subequal amounts, with grain lengths between 0.005 and 0.02 mm. Slaty cleavage is marked by dark microshear folia. The strength and closeness of the folia and the degree of parallelism of the folia to sericite and chlorite define the quality of cleavage; cleavage ranges from excellent (fig. 13) to unrecognizable in thin section.

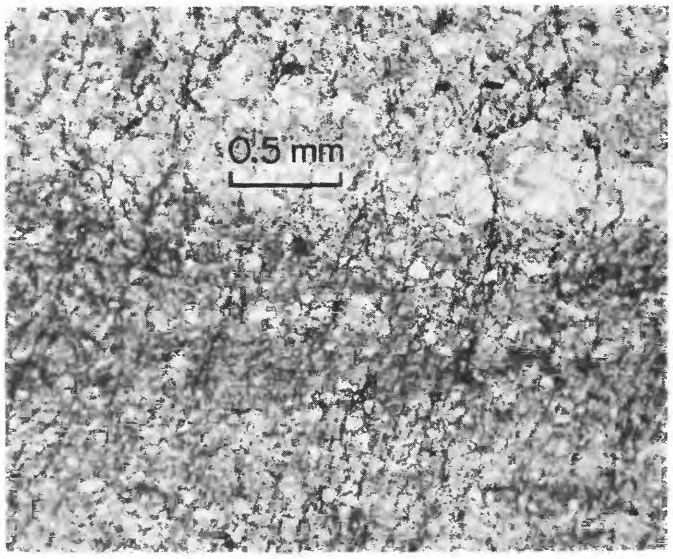

FIGURE 13.—Photomicrograph of metasiltstone with marked cleavage. Bedding laminae are horizontal and are cut, but little sheared, by steep cleavage folia. Dixon Mountain member of Wilhite formation, Dunn Creek between Short and Bearwallow Mountains. Plane light.

Microfolia are only 0.02 mm apart in the metasiltstones with most pronounced cleavage, but the degree of reconstitution in nearby rocks of widely varying cleavage quality is similar. Extremely fine-grained quartz and feldspar generally occur with the chlorite and sericite.

Many of the siltstone beds contain from 1 to 20 percent or more of carbonate, concentrated in the coarser clastic laminae. It is light gray where fresh, but weathers gray or yellow brown. All the carbonate is calcite in some specimens and some carbonate is in most specimens, but dolomite and ankerite are widespread. (The distinction between ankerite and dolomite was made by Gude using X-ray methods.) The carbonate forms anhedral grains, commonly near 0.05 mm in diameter, which have greatly replaced matrix minerals, much replaced feldspar, and slightly replaced quartz.

CHEMISTRY

Chemical analyses of two specimens of metasiltstone from the member are given in table 2, and various oxides are plotted on figures 8 to 12. The analyses are closely similar to those of rocks of the Pigeon siltstone, and the comments (p. 11) regarding the analyses of the Pigeon apply also to those of the Dixon Mountain member.

STRATIGRAPHIC RELATIONS

The contact between the Dixon Mountain and Yellow Breeches members of the Wilhite formation is drawn at the conformable but generally sharp break between the finely sandy siltstone in the upper part of the Dixon Mountain and the limestone and other rocks of the Yellow Breeches.

The Dixon Mountain member is in fault contact with the Pigeon and Sandsuck formations and in places the opposing rocks are so similar that the precise contact could not be located. Metasiltstone beds of the Dixon Mountain duplicate many bedding features of those of the Pigeon and, like them, contain carbonate; but those of the Dixon Mountain are more variable in texture, with more fine-grained sandstone, and the siltstone beds are sandier and have more clastic mica. The siltstone of the Dixon Mountain is interbedded with medium-grained sandstone and is more tightly folded than the Pigeon siltstone. Shale of the Sandsuck formation is sandier than that of the Dixon Mountain member, and contains abundant interbeds of coarse sandstone; the beds resemble strata of the Dixon Mountain in their tight folding, but differ in bedding features. On Long Branch along the north side of Dixon Mountain, the Sandsuck and Dixon Mountain are similar and much weathered; the contact on the map is placed arbitrarily. Along the lower part of Dockery Branch, the Pigeon on the south gives way to probable Dixon Mountain on the north; although outcrops are good, the rocks are so similar that a contact could not be precisely determined.

YELLOW BREECHES MEMBER

DEFINITION AND OUTCROP

Conformably above the Dixon Mountain member of the Wilhite formation is the Yellow Breeches member, named for the stream along which it is well exposed. Parts of the member are well exposed at many places, especially between Short and Bearwallow Mountains; along Dunn Creek, Wilhite Creek, and Long Branch; and along Large Branch and Chavis Creek. Westernmost outcrop area of the member in the quadrangles is a strip between Short and Bearwallow Mountains, widening northeastward toward Wilhite Creek; a wider area lies along Dunn Creek between Dixon Mountain and Chestnut Ridge, and the largest area lies east of Jones Cove.

Limestone of the Yellow Breeches member makes abundant outcrops in the valleys, but natural outcrops of other rocks are poor. The member underlies both broad valleys and moderately high ridges.

LITHOLOGY

The Yellow Breeches member is characterized by carbonate rocks, which crop out extensively 0.3 mile northeast of the mouth of Dockery Branch, on the crest of Dixon Mountain, along Dunn Creek 0.7 mile west-northwest of the mouth of Youngblood Branch, and along Large Branch. The most conspicuous are thick limestone beds, commonly sandy or conglomeratic; they are generally medium dark gray, with medium-light-gray weathered surfaces. Some are nearly pure carbonate; some contain well-rounded quartz sand that forms as much as 50 percent of the rock, the amount varying between poorly defined layers. Quartz grains project on weathered surfaces, and accentuate bedding, which may be inconspicuous on fresh surfaces. Many limestone beds contain cherty or argillaceous layers, and the limestone at one locality is nodular. Veins of white calcite are abundant.

The limestone-conglomerate units consist of subangular chips and slabs of diverse limestones and other rocks, of all sizes to a common maximum of 8 inches or a foot, and lying subparallel to bedding, in a limestone matrix which is sandy in many places (fig. 14); rock fragments average about half of the volume of the units. The fragments include gray partly sandy or conglomeratic limestone, laminated or massive dark silty limestone,

FIGURE 14.—Sandy limestone conglomerate, upper unit of Yellow Breeches member of Wilhite formation, Large Branch.

platy limestone, dolomite, dark shale, and noncalcareous sandstone. In contrast to the variety of rock fragments, the matrix limestone is homogeneous. Coarsest conglomerate seen is by Chavis Creek, 0.3 mile southwest of Holder Grove Church, where dolomitic limestone slabs as much as 5 feet long are numerous. Beds of conglomeratic sandy limestone have thicknesses of as much as several tens of feet.

Other varieties of limestone are widespread. Sandy limestone beds as thin as an inch are intercalated with other carbonate rocks. Dark platy limestone forms abundant thin interbeds in other rocks, and uniform sections as much as a few tens of feet thick (fig. 15). Thin-bedded limestone varies widely, with beds, gener-

FIGURE 15.—Platy limestone, anticlinally folded. Upper unit of Yellow Breeches member of Wilhite formation, Large Branch.

ally near an inch in thickness, of silty, sandy, and pure limestone, dolomite, and shale separated by shaly laminae.

Dolomite and ferruginous dolomite form abundant beds an inch to a few feet thick in other rocks, and along the southeastern side of Bearwallow Mountain form units as much as 250 feet thick. Some dolomite is massive, showing little internal bedding, and some is laminated. Many of the dolomite beds are slightly greenish gray on fresh surfaces or yellowish gray on weathered surfaces, in contrast to the gray limestone; many superficially resemble fine-grained quartzite. A single thin bed of dolomite conglomerate was seen. Dolomite is particularly abundant along Long Branch.

Pelitic rocks are shale and siltstone in the north, and slate and metasiltstone in the south. These rocks are medium gray to dark gray, with sparse fine sand, contain clastic mica, and are generally fissile parallel to bedding. Laminae are mostly between 0.003 and 0.2 inch thick. Small lenses and small-scale crossbedding is prominent locally. Many beds are calcitic or dolomitic, with carbonate disseminated or concentrated in a few laminae; some have laminae of nearly pure carbonate. The quality of the slaty cleavage varies, at its best giving a paper-thin fissility to slate; the various grain sizes of different laminae are expressed by differences in luster on the cleavage surfaces.

All the thick sandstone beds and most of the thin beds are medium to coarse grained; some thin-bedded sandstone is fine grained. Sandstone is argillaceous and generally feldspathic, though less so than the sandstone of the older formations. Some sandstone is quartzose, with little matrix or feldspar. Pelitic interbeds in coarse sandstone are darker than elsewhere in the area of this report.

STRATIGRAPHY

The member has two divisions: an upper unit of dominant limestone beds, commonly sandy or conglomeratic, and a lower unit of varied pelitic rocks with lesser amounts of sandstone and carbonate rocks. The lower unit is roughly 1,500 feet thick along the western part of Long Branch; it is also well exposed along Dunn Creek between Bearwallow and Dixon Mountains, where intricate folding prohibits determination of thickness. The lower unit is overlain by the upper at the northwestern end of Pine Mountain, where the upper unit is a few hundred feet thick; along Chavis Creek, the upper unit is about 500 feet thick. Total thickness of the member is thus about 2,000 feet.

Thick limestone beds dominate the upper unit, providing the basis for its distinction, and are common in the lower unit, which also contains dolomite and ankerite dolomite. Pelitic rocks dominate the lower unit and are common in the upper unit, forming sections as much as several hundred feet thick. Sandstone forms widespread thin interbeds, and for 1.5 miles eastward from Dockery Branch and on the ridge south of Large Branch, forms beds as much as 10 feet thick.

PETROGRAPHY

Little-altered pelitic rocks are gray; many metapelitic rocks are faintly greenish gray. Original argillaceous materials are now chlorite and sericite with a maximum average grain size in slates of 0.005 mm in diameter. Slaty cleavage ranges from scarcely detectable, generally in the north, to excellent; the cleavage where most conspicuous appears in thin section as closely spaced microshears paralleled by sericite and chlorite. Quartz—some bluish—is dominant over feldspar in the silt and sand fraction. Some of the feldspar is sericitized in all specimens; this alteration does not change with reconstitution of the argillaceous fraction. Clastic mica, biotite dominant over muscovite, makes up 10 percent of some laminae. The biotite is orange brown, and slightly chloritized; mica in strongly cleaved rocks is much deformed, but little altered in any other way. Zircon is the conspicuous heavy mineral, with a little tourmaline and epidote. Carbonate forms disseminated crystals, carbonate-rich laminae, and veins or microscopic veins in many pelitic rocks. Disseminated grains of calcite are anhedral, but of dolomite or ankerite may be euhedral rhombs.

Sandstone generally has less than 10 percent feldspar, hence is less feldspathic than that of older formations, has less than 15 percent matrix below sand size, and is noncalcareous. Coarse-grained sandstone contains quartz with a common maximum grain size between 1 and 3 mm, or rarely 5 mm in diameter. Fine-grained sandstone has more matrix than the coarse.

Most of the limestone is finely crystalline, with equant anhedra of medium- to dark-gray calcite 0.1–0.3 mm in diameter and scattered larger grains; grain size varies between laminae, but coarsely crystalline limestone is rare. Disseminated dolomite or ankerite is widespread, often in rhombs; textural relations commonly indicate replacement of calcite. Sandy limestone contains rounded quartz grains, generally near 1 mm in diameter (fig. 16). Quartz content may range from a trace to 50 percent of different laminae in the same specimen. Clastic feldspar is uncommon; one specimen studied has euhedral feldspar recrystallized against calcite, but calcite has more commonly replaced feldspar. Clastic biotite, zircon, and tourmaline are rare. Many sandy limestone beds contain round sand-size grains of calcite, presumably clastic, perhaps formed as primary aragonite sand. In some specimens, the larger sand grains—both quartz and calcite—are rimmed by comb-structured calcite; other specimens have many small ellipsoids of calcite, each rimmed by minutely granular pyrite. Carbon, magnetite or ilmenite, pyrite, and leucoxene form disseminated and interstitial granules, films rimming grains or parallel to cleavage or bedding, and interstitial clumps.

An unusual dolomitic limestone is illustrated by figure 17. A mosaic of 2-mm anhedra of calcite poikilitically encloses a small amount of quartz-feldspar silt, and is strewn by many euhedral rhombic shells of ferruginous dolomite. Shells are 0.5 mm long, with walls 0.03 mm thick; outside faces are straight, inside surfaces slightly irregular. Some of the calcite cores are crystallographically continuous with the calcite outside the dolomite shells, sharing both twinning and optic orientation, and in such cases, dolomite apparently grew with shell shape by replacement of calcite.

Where calcite is anhedral, dolomite, and its isomorphs, ferruginous dolomite and ankerite, are commonly euhedral. Calcite and dolomite occur together in all proportions; pure calcite limestone is common, but no pure dolomite was found. Some rocks contain interlaminated dolomite and calcite. Most carbonate-rock varieties are duplicated by both calcite and dolomite limestone, but dolomite is generally less sandy and more massive, and the coarse limestone conglomerate has no dolomitic counterparts, the dolomite conglomerate noted on an earlier page being a strikingly different rock. Manganiferous dolomite is also present.

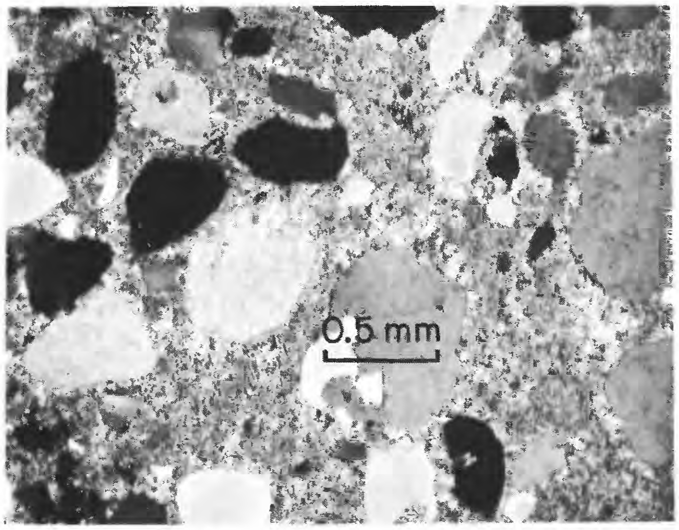

FIGURE 16.—Photomicrograph of sandy limestone of Yellow Breeches member of Wilhite formation, from Dunn Creek, near Youngblood Branch, showing quartz sand in a matrix of finely crystalline calcite. Some quartz grains are slightly replaced by calcite, and many are rimmed by calcite that is lighter and coarser than most of the groundmass. Crossed nicols.

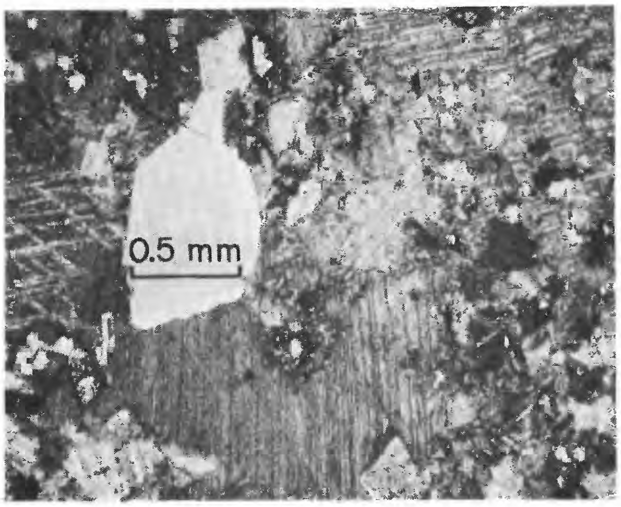

FIGURE 17.—Photomicrograph of sandy limestone of Yellow Breeches member of Wilhite formation from Dunn Creek, near Pearl Valley Church. A large grain of clastic quartz (white) lies in coarsely crystalline calcite. The euhedral rhombs above the quartz, and to the right of bottom center, are shells of ferruginous dolomite with calcite cores. Plane light.

White calcite forms abundant veins, typically with thin veins parallel to the cleavage of the rocks and thicker veins at random directions. Veins of quartz, chlorite, and calcite in various combinations, are less common.

STRATIGRAPHIC RELATIONS

The Yellow Breeches member of the Wilhite formation is unique in the Ocoee series for abundance of carbonate rocks. Structure within the member is complex, and the stratigraphy may also be more complex than the division made here into two units. It is assumed that the limestone-rich section of the upper unit at Pine Mountain correlates with the lithologically similar section along Chavis Creek and Large Branch. The apparent top of the member—the upper limit of carbonate rocks—is present only at the northwestern end of Pine Mountain, where it seems best to interpret the contact as concordant with the overlying Sandsuck formation, although this is indicated only by the crude accord of attitudes to a contact of complex configuration and possibly at the east side of the area north of Large Branch.

SANDSUCK FORMATION

DEFINITION

Beds underlying the Cochran formation on Chilhowee Mountain west of the report area in the central foothills (fig. 1) were termed the Sandsuck shale by Keith (1895), and they have since been redefined and termed the Sandsuck formation (King, Hadley, Neuman, and Hamilton, 1958). Rocks similar to the Sandsuck in its type area crop out in the north part of the report area, in a belt 2 miles wide south of English Mountain where they are faulted against the Cochran, and in a smaller area near the northeast corner where they apparently lie in sequence beneath it.

The Sandsuck formation is the highest unit of the Walden Creek group. Its rocks resemble those of the other formations of the group, and differ from overlying formations. Within the area of the present report, however, relations of the Sandsuck to the remainder of the Walden Creek group are not proved, as most of its contacts are faulted; it appears, however, to lie in sequence above the Wilhite formation in a small area at the northwest end of Pine Mountain.

OUTCROP

Most of the Sandsuck formation, being fine grained and poorly resistant, forms areas of low relief, but the coarse sandstone projects in hills as high as 700 feet. Many exposures of the formation occur in the valleys.

LITHOLOGY

The Sandsuck is composed of siltstone and fine- to coarse-grained sandstone. Interlaminated dark-gray siltstone and fine-grained sandstone is the dominant variety, laminae being mostly 0.1–0.5 inch thick but ranging from 0.01 inch to several inches. Many laminae are lenticular and current crossbedded, and a few are graded. The rocks weather into chips parallel to micaceous bedding planes. A few of the rocks contian carbonates.

Coarse-grained sandstone beds are quartzose, less commonly feldspathic or arkosic, in beds mostly 3 to 10 feet thick in some places, less than a foot thick in others. Quartz-conglomerate beds, similar to those of Shields Mountain, are widespread; some contain chips of shale or fine-grained sandstone. Many of the coarse beds are lenticular. Thin interbeds are of shale and fine-grained sandstone.

STRATIGRAPHY

Thick units of coarse sandstone occur in several places, and interpretation of the formation is based on the assumption that these are parts of a single member. On this assumption, the formation consists of lower and upper members with dominant siltstone and fine-grained sandstone, and a middle member with dominant coarse-grained sandstone. To the northwest, the lower member is about 500 feet thick, the middle member 1,300 feet. Thickness of the upper member is uncertain; about 2,000 feet of beds crop out between Mount Olive Church and the school at Sunset Gap, but if the sandstone member north of Sunset Gap is the same as that at Pine Mountain this section must be faulted. The top of the upper member, north of Rich Mountain, is not present in a section continuous from the middle member. It is assumed that the upper member is about 2,000 feet thick.

The lower and upper members are of tightly folded interlaminated siltstone and fine-grained sandstone with many interbeds of coarse sandstone. A single bed of sandy limestone was found in the lower member on Long Branch. The middle unit is of coarse sandstone and conglomerate with thin interbeds of fine-grained rocks and much variation in proportions of the diverse types. The following small section is representative of the middle member. (See facing page.)

PETROGRAPHY

The Sandsuck formation shows only trifling alteration of sedimentary minerals. The argillaceous component is chlorite, illite, and montmorillonite; meta-argillaceous sericite was not found in the several speci-

Incomplete section of middle member of Sandsuck formation, exposed in waterfall bluffs in the hollow on the northwest side of Short Mountain 0.5 mile from the east edge of the area

	Thickness Ft.	In.
Top of bluffs and of section.		
Sandstone and conglomerate in a thick massive bed, with these changes:		
Quartz-conglomerate; abundant elliptical clasts of white quartz as much as half an inch across, in coarse dirty sandstone	5	0
Sandstone; coarse, and fine conglomerate; irregular and poorly-defined lenses and layers; maximum grain size ranges from one-tenth to one-half inch	3	0
Quartz-conglomerate, as in upper part of bed	3	0
Shale and fine-grained sandstone, dark, interlaminated		2
Sandstone, medium-grained, uniform		4
Sandstone, medium grained, laminated		4
Sandstone, coarse- to medium-grained; in beds 6 in to 1 ft thick	5	0
Sandstone, coarse and gritty; contains 10 percent feldspar	3	0
Sandstone, medium-grained; partings of shale or fine-grained sandstone, 1 to 2 in apart		10
Sandstone, coarse-grained; a single massive bed, with poorly defined layers in which maximum grain size ranges from one-eighth to one-third inch	4	0
Sandstone, fine-grained, laminated; lenses out in 8 ft along bedding		0–2
Sandstone, coarse-grained; lenses out in 6 ft		0–3
Sandstone, fine-grained, laminated		½
Sandstone, medium-grained, laminated		2–4
Sandstone, very coarse; contains 20 percent feldspar		3–6
Sandstone, medium-grained, chippy		2–3
Conglomerate, massive; densely crowded with one-tenth to one-half inch quartz; feldspar, 15 percent	4	0
Sandstone, medium-grained	1	6
Sandstone, very coarse, and quartz-conglomerate, roughly layered; thin discontinuous lenses of fine sandstone	3	0
Shale		0–2
Sandstone, fine- to medium-grained		3
Sandstone, very coarse, and quartz-conglomerate, in massive bed	6	0
Total thickness of measured section		40±
Base of bluffs		

mens studied by microscope and X-rays (by Gude), although these specimens represent only the northern part of the formation. Chlorite, illite, and montmorillonite grains are mostly smaller than 0.003 mm in diameter. Feldspar is variably altered. The rocks have a weak slaty cleavage, which shows in thin section as poorly developed microshear folia without parallelism of micaceous minerals. Clastic biotite, bronzy and slightly altered, is abundant and much dominant over muscovite; other minerals include zircon, tourmaline, epidote, sphene, leucoxene, calcite, dolomite, ankerite, pyrite, and carbon.

One thin section of siltstone with graded laminae was studied; laminae are a few millimeters thick, each grading from shaly fine-grained sandstone, with a maximum grain of 0.2 mm, at the base to shaly siltstone, with a maximum grain size of 0.1 mm, at the top. The upper surfaces of shale laminae show load casting on a tiny scale.

The coarse-grained sandstone generally has 5 or 10 percent of feldspar and a maximum grain size of nearly 3 mm in diameter. Feldspathic sandstone is abundant, some with 30 percent feldspar; feldspar is mostly potassic and little altered. Quartzite is rare; quartz-conglomerate with coarse-sandstone matrix is abundant.

STRATIGRAPHIC RELATIONS

More uncertainties beset the interpretation of stratigraphy of the Sandsuck formation than of any other unit in the report area. Not only is the stratigraphy of the formation itself questionable, but its presumed concordance with other formations is inadequately shown. The lower limit is believed to be concordant with the Wilhite formation along two contacts each about a mile long; the upper limit is probably present on the north side of Rich Mountain, but the correlation of the Sandsuck on Rich Mountain with those to the south in the main mass of the formation is based on lithologic similarities. It is thus reasonable, but unproven, to place the Sandsuck formation in sequence between the rest of the Walden Creek group and the Chilhowee group.

SEDIMENTATION OF WALDEN CREEK GROUP

Most of the Walden Creek group is composed of laminated siltstone and fine-grained sandstone, coarse-grained sandstone, and quartz-conglomerate. Slate is dominant only in the unit of the Shields formation exposed at Richardson Cove, and limestone is abundant only in the Yellow Breeches member of the Wilhite formation. Most of the group thus probably formed under similar conditions of sedimentation, or rather from similar alternations of similar conditions.

Because the sandstone beds are typically feldspathic, and the fine-grained rocks contain much clastic biotite and some muscovite, the source terrane must have been rich in granitic rocks and biotitic schists or gneisses. Climate and relief of the source area were such that erosion and transport were rapid enough to prohibit more than partial chemical weathering of feldspar and biotite. The quartz-conglomerate indicates quartzite in the source terrane, and the high content of vein-quartz pebbles in many beds shows a selective concentration of material from a far greater volume of source rocks. This might be attributed either to reworking of older sedimentary rocks or to profound weathering of the rocks; but the latter possibility can be rejected because of the high content of feldspar in the Walden Creek group.

Within each formation, rocks are widely variable, interbedded in variable sequence. Reworking of sediment was probably common, along with sporadic changes in sediment supply and conditions of transport. The absence of thick-bedded siltstone and graded beds of sandstone is in marked contrast to the Pigeon siltstone and the rocks of Webb Mountain and Big Ridge; the Walden Creek group probably accumulated slowly under rapidly fluctuating conditions. Both siltstone and sandstone of the Walden Creek group are generally less feldspathic than those of the Snowbird group.

The carbonate rocks present special problems. Siltstones of several formations contain carbonate, similar to that of the Pigeon siltstone; to what extent the carbonate is of sedimentary origin, complicated by recrystallization and migration, and to what extent it is a product of metamorphism, is uncertain. The clastic structures of many of the carbonate-bearing laminae of siltstone suggests the possibility of important amounts of clastic carbonate.

Many of the limestones, especially those with quartz sand, may have originated as lime sands. Some rounded calcite grains associated with quartz of the same size and with similar secondary rims are certainly clastic; the matrix calcite—far more abundant than the obviously clastic grains—is crystalline and might have originated as cryptocrystalline sand grains. Primary aragonitic lime sand formed by chemical and biochemical precipitation from sea water has been demonstrated by Illing on the Bahaman Banks (1954). Such primary cryptocrystalline aragonite sand is nonskeletal and nonoolitic; similar lime sand perhaps formed much of the limestone in the Wilhite formation. If these limestone beds are clastic, such an origin of the carbonate is essential as the calcite is too uniform to have been derived by mechanical disintegration of older limestone and no calcareous organisms seem to have been available to supply bioclastic carbonate. Some of the carbonate in other formations might also have formed as primary lime sand.

The limestone conglomerate beds contain abundant limestone fragments in a matrix of calcite and quartz sand. These rocks are probably intraformational, formed by breakup of nearby sediments.

Some of the dolomite and ankerite are obviously of replacement origin, and perhaps most formed by alteration of calcite limestone.

Deposition of the Walden Creek group can be pictured as a slow continuing sedimentation of pelitic debris—or, infrequently, of carbonate—with irregular periods of supply and reworking of coarse sandy and pebbly material. Perhaps deposition was near sea level for much of the material.

CAMBRIAN(?) ROCKS AND CAMBRIAN SYSTEM

LOWER CAMBRIAN(?) ROCKS AND LOWER CAMBRIAN SERIES

CHILHOWEE GROUP

The Chilhowee group and its correlatives form a belt of clastic rocks—sandstone, quartzite, and shale—of similar general character along much of the length of the Appalachian system. The following type section of the Chilhowee group is on Chilhowee Mountain a short distance west of this area, where the group lies in stratigraphic order between the upper Precambrian Sandsuck formation and the Lower Cambrian Shady dolomite.

Type section of Chilhowee group on Chilhowee Mountain

[After Keith (1895) as modified by P. B. King, and R. B. Neuman (written communication)]

	Thickness (feet)
Lower Cambrian:	
Shady dolomite.	
Chilhowee group: Helenmode formation: Shale and shaly sandstone; contains *Olenellus* and other fossils	100
Lower Cambrian (?)	
Chilhowee group—continued:	
Hesse sandstone: Quartz sandstone and white quartzite	300
Murray shale: Shale, silty	500
Nebo sandstone: Quartz sandstone and quartzite	250
Nichols shale: Shale, silty, micaceous	700
Cochran formation: Sandstone, feldspathic, massive, and quartzite at top; lower part contains fine quartz conglomerate and much red arkosic shale	1, 000–1, 250
Upper Precambrian:	
Ocoee series. Walden Creek group. Sandsuck formation.	

COCHRAN FORMATION

OUTCROP

The entire Chilhowee group forms the main part of English Mountain, north of the eastern half of the report area, and also crops out immediately east of the area (fig. 18). In the Richardson Cove and Jones Cove quadrangles, only the Cochran formation is exposed. The Cochran is composed of resistant quartzite and coarse-grained sandstone and underlies the high ridges of Shell, English, and Rich Mountains along the north edge of the area; a hill south of the East Fork is capped by a small outlier of the formation.

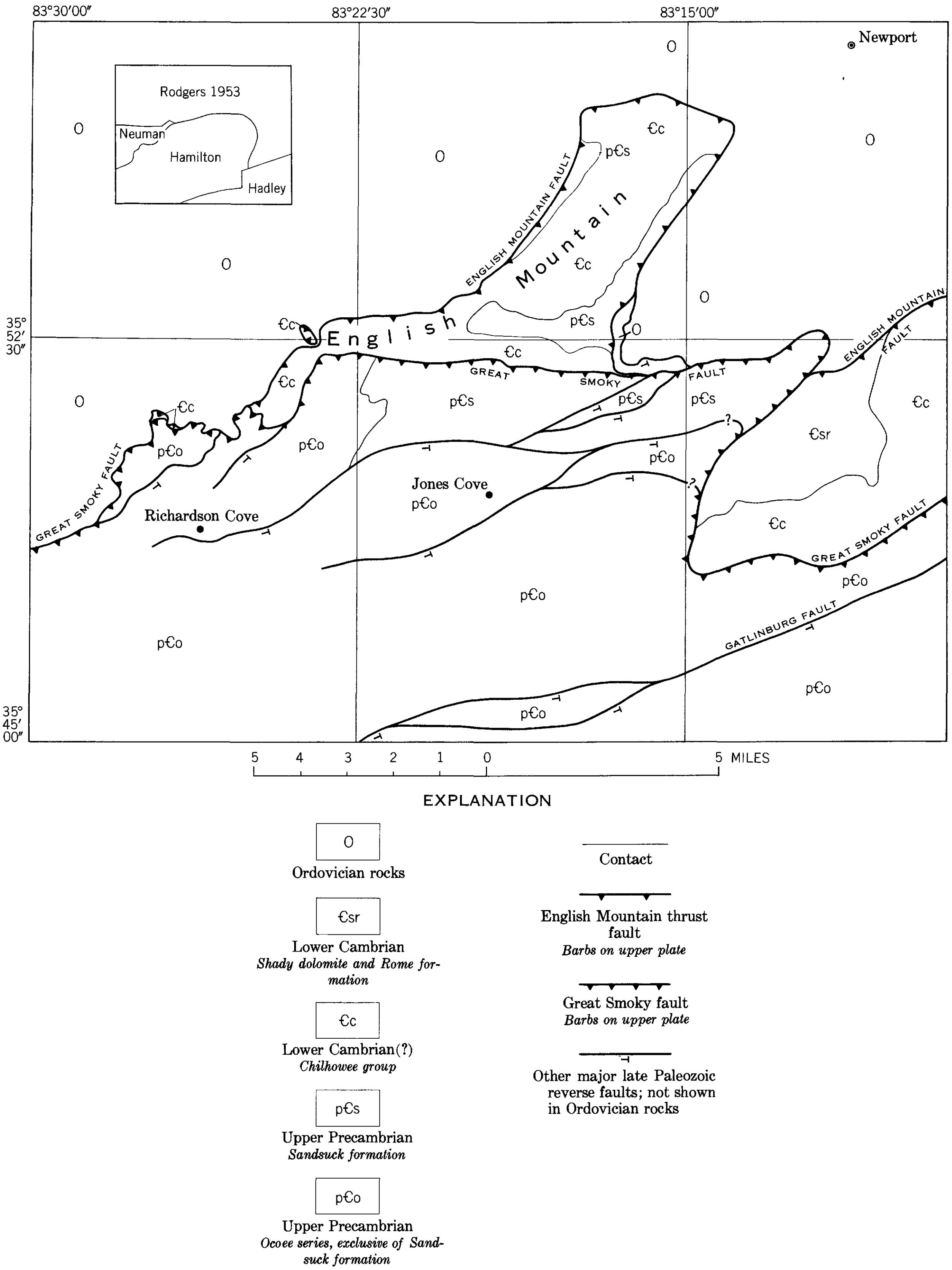

FIGURE 18.—Late Paleozoic faults of Richardson Cove (lower left) and Jones Cove (lower center) quadrangles, and area adjoining to north and east. Small inset map shows source of data.

The quartzite and sandstone weather to rounded boulders, commonly gray but shading to pinkish gray. The boulders litter the surface and hide the bedrock of many slopes.

LITHOLOGY AND STRATIGRAPHY

The Cochran formation is about 1,000 feet thick on English Mountain, immediately north of this area, where the structure is simple (John Rodgers, written communication).

The formation is mainly coarse-grained white quartzite, with much quartzose or feldspathic coarse-grained sandstone and quartz conglomerate. Fine- and medium-grained sandstone and shale are minor constituents. Most coarse-grained beds are ½ to 4 feet thick, with a few 10 feet or so thick; many are lenticular or uneven. Most beds have little or no internal bedding, although some are indefinitely layered with pebble streaks or other variations, and some are faintly crossbedded. Shale or fine-grained sandstone partings about one-half inch thick separate many beds, and there are many layers of laminated fine-grained rocks a few feet thick. Maroon shaly sandstone was found only on the spur south from Rich Mountain, 2.2 miles from the eastern edge of the area.

PETROGRAPHY

The quartzite is thoroughly recrystallized, and has little matrix material; feldspar content is generally less than 1 or 2 percent, with a maximum of 10 percent. Average grain size is commonly between 0.5 and 2 mm with poor to good sorting. Clastic grain margins have been obliterated by recrystallization. Accessory clastic minerals include traces of biotite, muscovite, zircon, and epidote. Sericite occurs as an alteration of the minor amounts of feldspar and as intergranular films. Chlorite, leucoxene, hematite, limonite, and siderite form intergranular films and interstitial masses. Of the four thin sections of quartzite studied, two are of mosaics of equigranular, little-strained quartz; one is of flattened (average about 3:2) and much-strained quartz, and one is of an equigranular mosaic with many finely crushed grain margins, showing deformation after recrystallization. Fresh fractures are generally vitreous, and grain boundaries may not be visible except in thin section. Small cavities lined with euhedra of low-quartz are numerous; in many, the crystals are rimmed by microbotryoidal iron oxide. White quartz veins are widespread. The feldspathic sandstone contains as much as 15 or even 20 percent feldspar, mostly potassic, and has more matrix than the quartz sandstone.

The quartz conglomerate beds contain abundant pebbles of white vein quartz and quartzite as much as 2 cm in diameter, with variable amounts of sandstone or quartzite matrix and sparse chips of shale or fine-grained sandstone.

The maroon (grayish-red) shaly sandstone contains 50 to 80 percent sand, mostly well-rounded quartz grains 0.2 to 2 mm in diameter with a variable amount of feldspar, in a reddish argillaceous matrix.

SEDIMENTATION

The abundance of feldspar in many beds suggests that the high quartz content of the quartzite is due to great reworking of sediment rather than to profound weathering of the source area, and a source in a plutonic terrane is likely. The sedimentary assemblage is one characteristic of a stable sedimentary environment.

AGE

Early Cambrian fossils have been found only in the highest formation of the Chilhowee group (p. 28), and considerable debate has centered on the proper age designation of the rest of the group. Current Geological Survey usage is to classify the highest formation of the Chilhowee group as Cambrian and the remainder of it as Cambrian(?), and to designate the Ocoee series as Precambrian.

MISSING INTERVAL

Overlying the Chilhowee group in this region are the Shady dolomite and Rome formation, both of Early Cambrian age. These formations are not exposed in the report area, but crop out less than a mile to the east (fig. 26) and probably underlie tectonically the Ocoee series of the eastern part of the area (pl. 1, structure sections *E–E′* and *F–F′*). The formations have been described by Rodgers (1953, p. 42–45).

ORDOVICIAN SYSTEM

Rocks of Ordovician age underlie the northern corners of the area; these rocks are part of the Appalachian Valley sequence, and are overlain tectonically by the older rocks of the foothills belt. As a part of a larger study of Ordovician rocks bordering the Great Smoky Mountains, R. B. Neuman studied those of the Richardson Cove quadrangle; most of the following description is based on Neuman's memorandum report and his 1955 paper, and on personal communications from him.

LOWER ORDOVICIAN SERIES

KNOX GROUP

JONESBORO LIMESTONE

DEFINITION

The sequence of carbonate rocks of Late Cambrian and Early Ordovician age in eastern Tennessee has long been designated the Knox group. Across the Appalachian Valley a gradual change of facies has been noted (Rodgers, 1953, p. 53–64), from predominant cherty dolomite on the northwest to predominant limestone on the southeast. Rodgers used a nomenclature for these rocks that reflects this change, applying the name Jonesboro limestone to the Lower Ordovician rocks of the eastern facies. Only the upper half of the Jonesboro has been identified in the present area.

OUTCROP

The Jonesboro weathers to a thick residuum of reddish clay, through which fresh rock projects as rounded outcrops, and its surface is dotted by sinks. Outcrops are most numerous along and near the major streams.

LITHOLOGY

The common rocks are very fine grained to aphanitic limestone, in beds ½ to 1½ feet thick. Many beds are marked by wavy anastomosing argillaceous partings subparallel to bedding; others are mottled by dolomitic limestone; others are massive. The rocks are medium light gray to dark gray on fresh surfaces and light gray where weathered. Many beds that appear massive on fresh surfaces show obvious laminae as grooves and ridges or as color changes on weathered surfaces. Small irregular nodules of dark chert are common. Sandy limestone, in layers a fraction of an inch to 5 feet thick, is conspicuous locally, with the thicker beds in places crossbedded and showing scour-and-fill structures. Intraformational limestone conglomerate, calcarenite, and rare shaly limestone are also exposed.

Dolomite is of two kinds, the one fine grained, light gray and laminated, the other coarse grained, medium or dark gray, and in thick mottled or uniform beds.

STRATIGRAPHY

About 2,000 feet of Jonesboro limestone is exposed on the northwestern limb of the Fair Garden anticline in apparent unrepeated succession. Because the rocks of this limb are all similar limestone units, and very few fossils were obtained from them, no subdivisions were made, nor could equivalents of better known sections be recognized. Thickness of subdivisions of the Knox group about 40 miles to the northeast (Oder, 1934, p. 494–496) suggest that rocks equivalent to those as old as the Chepultepec dolomite of Early Ordovician age might be present on this limb.

The total thickness of Jonesboro limestone on the southeastern limb of the Fair Garden anticline is much greater than 2,000 feet, suggesting repetition by faulting within this limb. Most of the rocks of the southeastern limb are limestone, but coarse-grained dolomite forms most of a section about 700 feet thick near Roberts School and Red Bank Church. Crossbedded sandy limestone is common in the upper 200 feet of the formation, and fine-grained dolomite is interbedded with limestone in the upper 400 feet.

Probably only the upper part of the formation is present in the Jones Cove quadrangle, where sandy limestone is abundant.

The stratigraphic position of the segments of Jonesboro limestone in the slices along the Great Smoky fault is not known.

PALEONTOLOGY

Fossils from several localities show that most of the Jonesboro limestone in this area is correlative with the Mascot dolomite of outcrop belts to the northwest, although a few fossils suggest that correlatives of the Kingsport formation are present also. Fossils identified are listed in the following table.

Fossils of Jonesboro limestone, Richardson Cove quadrangle

[Brachiopods identified by R. B. Neuman, gastropods by Ellis Yochelson, and trilobites by A. R. Palmer and W. J. Sando]

Location	Collector	Brachiopods						Gastropods			Trilobites
		Archeoscyphia sp.	*Diparelasma* sp.	*Diparelasma typicum* Ulrich and Cooper	*Finkelnburgia* sp.	*Tritoechia* sp.	*Tritoechia typica* Ulrich	*Ceratopea keithis* Ulrich	*Ceratopea subonica* Oder	*Ceratopea tennesseensis* Oder	*Isoteloides*(?) sp.
Field 0.2 mile northeast of Cedar Bluff school.	R. B. Neuman						×				
East side of road 1.31 miles southeast of Harrisburg.	do			×							
Roadside ditch 0.15 mile northwest of Cedar Bluff school.	do				×						
Floor of lane 1.18 miles southeast of Harrisburg.	do		×								×
Gullied roadway 1.45 miles northwest of Ball Cemetery.	do								×		
North bank of East Fork, between 0.4 and 0.5 mile east of bridge at Harrisburg.	James Bumgartner, W. J. Sando, and R. B. Neuman.	×				×		×	×	×	

PETROGRAPHY

Specimens were collected from a roadside quarry on East Fork 0.4 mile northwest of Cedar Bluff, where sandy limestone is dominant and cherty or dolomitic limestone is exposed in a section high in the formation. The sandy limestone beds have streaks, laminae, and layers of well-rounded and well-sorted quartz sand with an average grain size between 0.3 and 1 mm.; sand content ranges from 0 to 70 percent but is generally less than 15 percent. The sand is dispersed in finely crystalline calcite which contains varying amounts of dolomite rhombs (fig. 19).

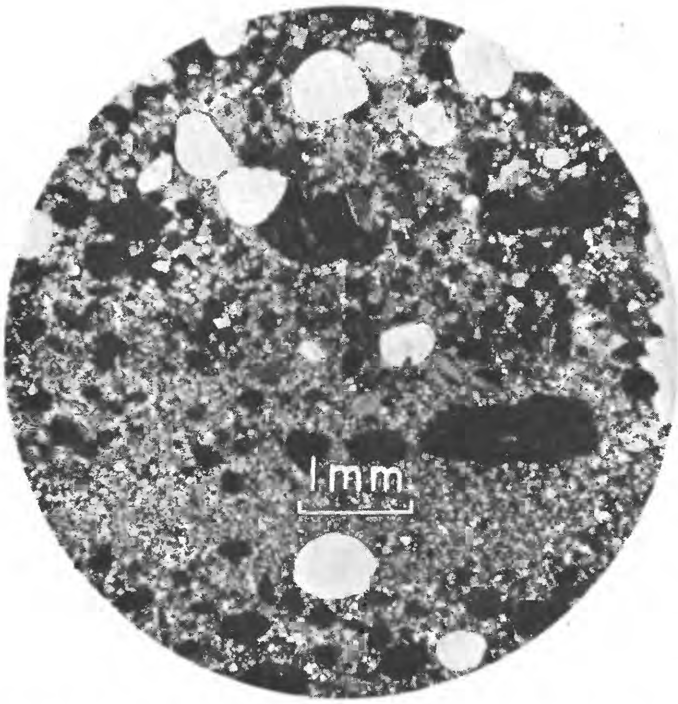

FIGURE 19.—Photomicrograph of sandy Jonesboro limestone from quarry by East Fork, 0.5 mile northwest of Cedar Bluff. Quartz sand (white) and limestone sand (dark gray) lie in matrix of finely crystalline limestone with small rhombs of dolomite. Plane light.

Quartz grains have a thin dull dark coating, which makes them appear dark when broken. Both quartzose and nonquartzose limestones contain abundant small chips of limestone (many having a clastic texture of rounded grains) in a matrix of rounded calcite grains, finely crystalline calcite, dolomite rhombs, and abundant fossil fragments.

Specimens of limestone from the small tectonic lenses along the Great Smoky fault are similar, though with less sandy limestone, and many show closely spaced shear folia of crushed calcite.

SEDIMENTATION

Terrigenous clastic material is limited to generally minor amounts of clay, silt, and sand, mostly quartz. The Jonesboro limestone and its equivalents extend the length of the Appalachian Valley and for many hundreds of miles to the west; the source area of some of the terrigenous clastic portion was far to the northwest. The formation marks a long period of slow deposition of carbonate, probably in shallow water.

Much of the calcite is probably of clastic origin, although recrystallization has obscured the original nature of the grains. Quartz sand, though separated by calcite grains, is in lenses and beds, many showing cross-bedding and scour and fill. These limestone units are not shelly, so their carbonate, like that of the Walden Creek group (p. 28), perhaps formed as primary aragonite sand.

MIDDLE ORDOVICIAN SERIES

LENOIR LIMESTONE

DEFINITION AND OUTCROP

Between the thick carbonate section of the Jonesboro limestone and the thick clastic section of the Middle Ordovician series is the thin Lenoir limestone, named by Safford and Killebrew (1876, as cited by Rodgers, 1953, p. 68) for its much thicker occurrences to the northwest. The formation is distinctive, is well exposed in many places, and forms a valuable marker between the thick sections above and below.

STRATIGRAPHY

The Lenoir limestone is everywhere a thin formation, and is no more than 100 feet thick within the report area. It is divided into the Douglas Lake, Mosheim, and argillaceous limestone members, but the first two are not present at all places. The Douglas Lake, or basal member, was recognized only in the northeastern exposures, in the Jones Cove quadrangle, where it is limestone conglomerate and gray sandy limestone. In the northwestern exposures, in the Richardson Cove quadrangle, the basal deposits of the Lenoir are generally the Mosheim member—massive nonlaminated bed of fine-grained gray limestone, that contains flecks of crystalline calcite and calcite-filled gastropod shells. Most of the Lenoir in both areas, however, is thin- to thick-bedded dark argillaceous limestone, and where the lower members are lacking this lies directly on the Jonesboro limestone. The Lenoir is separated from the Jonesboro by a regional disconformity which represents a considerable period of subaerial erosion and weathering (Bridge, 1955, p. 168).

BLOCKHOUSE SHALE

DEFINITION AND OUTCROP

The Blockhouse shale, defined by Neuman (1955, p. 148), overlies the Lenoir limestone, and consists of a thin basal limestone, called the Whitesburg limestone member by Neuman (p. 149). It is overlain by dark-gray calcareous shale. The formation supports low knobs and hills, contrasting with the lowlands of the Jonesboro limestone and with the higher hills of the more resistant rocks to the southeast.

LITHOLOGY AND STRATIGRAPHY

The basal Whitesburg limestone member (not divided from the main body of the formation on the geologic map, pl. 1) is 5 to 10 feet thick, and consists of nodular shaly gray and dark-gray fine-grained limestone with brachiopods at a few places. In the nodular limestone, flat ellipsoids of dark limestone, some of it coarsely crystalline, lie in calcareous shale. The proportion of shale increases upward in the member, which thus grades into the main body of the formation. There are a few thin beds of clastic limestone composed of rounded grains of calcite, shell fragments, and scattered quartz in a matrix of very fine grained calcite.

Calcareous shale of the main body of the Blockhouse shale is dark gray and fissile, with fragmentary graptolites in many places. Silty shale and sandstone are rare, but lenses and thin beds of dark-gray dense limestone are common in the upper part of the formation.

In this area the Blockhouse is intricately deformed, apparently thickened on the northwestern flank of the Fair Garden anticline and thinned on the southeastern flank. In the Pigeon Forge quadrangle to the west, the Blockhouse is from 150 to 400 feet thick.

PETROGRAPHY

The shale is richly calcareous and sparsely micaceous, generally laminated and thinly fissile parallel to bedding. A specimen from low in the formation on the Little Pigeon River was analyzed with X-rays by Gude, who found quartz, calcite, illite, chlorite, dolomite, and albite, listed in approximate order of abundance. In places the shale shows a faint dull-lustered secondary cleavage.

SEDIMENTATION

The Blockhouse shale was deposited (Neuman, 1955, p. 169) in a position intermediate between an area of limestone sedimentation that lay to the west and land on the east. The waters were sufficiently deep to have protected the bottom from subareal [subaerial] exposure, but no evidence was seen that suggests a maximum depth of these waters. The area of sedimentation was protected from bottom circulation, probably by submerged sills that accumulated on the shoreward side of the area of limestone sedimentation.

ROCKS QUESTIONABLY ASSIGNED TO BLOCKHOUSE SHALE

DESIGNATION AND LITHOLOGY

Lying tectonically between the Ocoee series and Chilhowee group above and the Blockhouse shale below in the northeastern corner of the area is a sheet of rocks classed tentatively with the Blockhouse. These rocks are mixtures in all proportions of clay, silt, fine feldspathic sand, fragments of calcareous organisms, and calcite; the clastic rocks are richly calcareous; the limestone, sandy or argillaceous; and diverse varieties are sharply interbedded. The shale beds are laminated to layered, mostly sandy and with micaceous partings; they are medium to dark gray, and weather brownish gray. Some of the sandstone contains granules and cobbles of limestone; some of the limestone is shelly, and R. B. Neuman found graptolites in sandstone. According to Neuman (written communication), these rocks resemble the Toqua sandstone member of the Blockhouse shale, and should be correlated tentatively with it.

PETROGRAPHY

The sand grains are mostly smaller than 0.5 mm in diameter, and less than 0.2 mm in many specimens. They are mostly subangular quartz, unstrained but slightly replaced marginally by calcite. Potassic and sodic feldspars form 10 or 20 percent of the sand fraction, and both feldspars are much replaced by sericite and calcite. Clastic mica includes both muscovite and biotite, commonly deformed but little altered. Clastic calcite, of the same size as the quartz and feldspar sand, is partly organic debris, partly of undetermined origin. Heavy minerals include zircon and magnetite or ilmenite. Matrix calcite in average size is fine grained, ranging in different specimens from 0.005 to 0.2 mm. Argillaceous material forms an extremely fine-grained maze of clay, carbonate, and unidentified brownish material. X-ray examination by Gude of several specimens of shale indicates the presence of illite, chlorite, quartz, feldspar, calcite, and dolomite or ankerite.

SEDIMENTATION

These rocks record a period of continuous deposition of carbonate, with variable deposition of clay, silt, and fine sand. The siliceous material was derived from a crystalline terrane, and the substantial feldspar content of the sand indicates incomplete weathering on that terrane.

TELLICO FORMATION

DEFINITION AND OUTCROP

The Blockhouse shale is overlain conformably by the Tellico formation (Neuman, 1955) in the Richardson Cove quadrangle. The Tellico forms hills higher than those of Blockhouse shale, but lower than those of rocks of the Ocoee or Chilhowee.

LITHOLOGY AND STRATIGRAPHY

The thickness of the Tellico within the area is about 1,500 feet, with the top not present; the formation is nearly 5,000 feet thick a few miles to the west (Neuman, 1955, pl. 28). Tellico and Blockhouse intergrade through a thickness of about 20 feet of alternating 4- to 10-inch beds of dark shale and lighter colored finely sandy shale, the proportion of the two types changing progressively. The rocks are a monotonous sequence of gray silty and sandy calcareous shale and shaly calcareous sandstone, with sparse crinoids and bryozoa in the sandy beds; the rocks are tightly folded and are cut by many small faults.

SEDIMENTARY HISTORY

The rocks of the Great Smoky Mountains and Appalachian Valley record discontinuous sedimentation from late Precambrian time through nearly all of the Paleozoic, but the character of this sedimentation varied greatly with place and with time. The entire sequence can be considered broadly as miogeosynclinal, but the use of such a term obscures the diversity of the conditions of formation of the rocks. Complications to interpretations are given by the tectonic telescoping of the rocks, by the uncertainties as to stratigraphic relations of the rocks of the Ocoee series, and by the general decrease northwestward in the age of exposed rocks.

A general interpretation of the stratigraphic relations of the rocks of the report area is given by figure 20. The area spans only 10 miles across the strike of the rocks, but telescoping within the area by the several episodes of folding and faulting has probably been on the order of 50 miles. As is discussed on page 47, the Ocoee series may have undergone major deformation before completion of Ordovician sedimentation, so that the diagram may be much oversimplified. The Great Smoky group of the Ocoee series certainly overlies the Snowbird group (J. B. Hadley and Richard Goldsmith, written communication), but the indicated correlation between Walden Creek and Great Smoky groups is only inferred.

Oldest of the Ocoee series are the rocks of the Snowbird group, mostly siltstone beds, laid down in a local rapidly subsiding trough under conditions that changed little for long periods of time. The Walden Creek group of diverse clastic rocks and locally abundant carbonate rocks records much more variable conditions, with alternating sedimentary processes of widely different character; the assemblage probably formed on an erratically subsiding platform. The Great Smoky group is exposed south of this area and is perhaps correlative with the Walden Creek group; it is dominated by a thick section of graded beds of coarse-grained sandstone probably produced by repeated pulses of sedimentation. The Ocoee series is known only in a strike belt from east-central Tennessee and adjacent North Carolina southwest into Georgia; it overlies a Precambrian plutonic basement complex, remetamorphosed during Paleozoic time, which forms much of the Blue Ridge province and probably also much of the northwestern Piedmont. The basin of deposition of the Ocoee series was probably a local geosyncline, perhaps similar to the Cretaceous and Cenozoic basins of the Coast Ranges of California, and the sedimentary rocks of the Ocoee are similar in many ways to those of the Ventura basin. (If the sediments of the Ocoee, like those of California, underwent deformation intermittently during their sedimentation, the structural interpretations presented here are greatly oversimplified.) Although the term "eugeosyncline" has been applied (for example, by King, 1949, p. 634), there are no volcanic rocks whatever in the Ocoee series, and the term is not warranted. Data as to direction of transport of sediment were obtained within the area only for the Pigeon siltstone, and indicated bottom current generally from the northeast. Intertonguing relations and facies changes south of this area indicate that the sediment of the Snowbird group there has been transported mostly from the east or southeast, and that of the Great Smoky group from the north or northeast (Hadley and Goldsmith, written communication). Green tourmaline is a conspicuous accessory mineral in many units of the Ocoee of the area but has not been reported from the known or inferred Precambrian basement rocks of the Blue Ridge and Piedmont provinces. These directions indicate the orientations of bottom currents, but data are not complete enough to relate these to directions of source areas. However, although the Ocoee series has long been assumed to have had a source to the southeast, sources in basement rocks both to the northwest and along strike to the northeast are possible for much of the material.

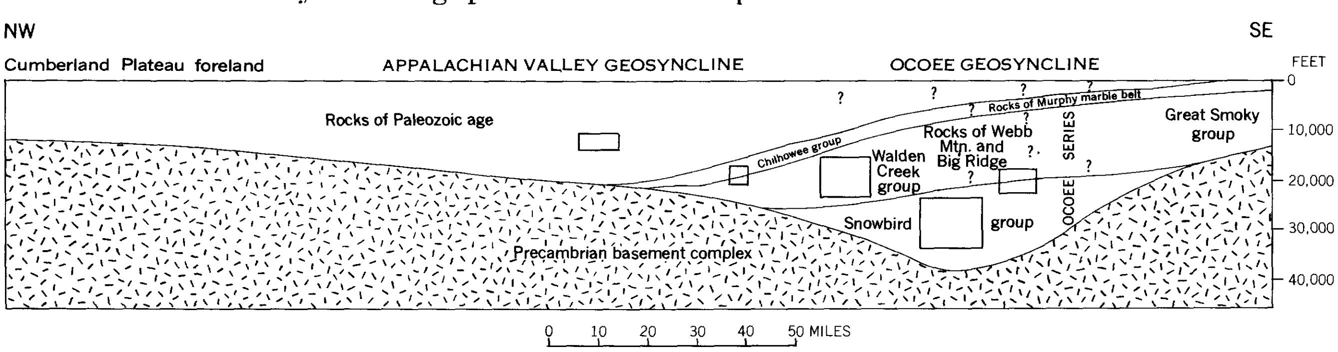

FIGURE 20.—Schematic cross section of major rock units showing possible stratigraphic relationships prior to deformation. Inferred original positions of rocks of the report area are shown by small rectangles, assuming sedimentation to have been complete before any deformation. Scales approximate; vertical exaggeration about 5 to 1.

The Chilhowee group of sandstone and shale was deposited on a stable and slowly subsiding platform, with much reworking of sediment. The group and its correlatives extends along the strike in a narrow belt from Alabama into Pennsylvania. It apparently formed in a narrow basin many hundreds of miles long. In northeastern Tennessee, where the group is thicker and its sandstone dirtier, the sediment came from the southeast (King and Ferguson, 1960).

Southeast of the Great Smoky Mountains, the rocks of the Murphy marble belt overlie the Great Smoky group, and are in some ways similar to and perhaps correlative with the rocks of the Chilhowee group and Lower Cambrian strata. If this correlation is correct, then the Great Smoky and Walden Creek groups have a similar stratigraphic position and may be different facies, products of greatly different sedimentation, of correlative but tectonically telescoped rocks. The Snowbird group might be either partly correlative with or older than the Walden Creek group, and might or might not have been deposited in the same area as the Walden Creek group. A lithologic correlation might be suggested between the Pigeon siltstone and the Dixon Mountain member of the Wilhite formation, but such a correlation would require great changes of facies between these formations and extreme changes between formations both above and below.

Overlying the Chilhowee group are the Shady dolomite and Rome formation of Early Cambrian age, the Conasauga group, of Middle and Late Cambrian age, and the Knox group of Late Cambrian and Early Ordovician age, a sequence about 7,000 feet thick, dominated by carbonate rocks; at least the clastic part of the sediment for this sequence was derived from the continental interior to the northwest (Rodgers, 1953). This early Paleozoic sequence is one of slow and stable deposition.

The Middle Ordovician sedimentary rocks form a thick wedge of clastic debris, thinning northwestward, from a maximum thickness of about 7,000 feet; source was clearly to the southeast, and uplift in that direction is indicated (Rodgers, 1953). It is perhaps significant that the several thin sections of Middle Ordovician rocks that were studied contain no tourmaline.

Younger rocks—Upper Ordovician to Pennsylvanian—are not exposed in the report area but are exposed to the northwest in the Appalachian Valley. They form a rather thin sequence of widely varied exposures with many discontinuities; the source terrane was to the southeast (Rodgers, 1953). Erratic deposition on a generally stable platform is indicated.

Rapid sedimentation in the Great Smoky Mountains and Appalachian Valley was largely limited to the Ocoee and Middle Ordovician series; sediments of the latter were derived from the southeast, and of the former from the north and east. The sediments of the Lower Cambrian and upper Precambrian (?) Chilhowee group and of the post-Middle Ordovician strata were deposited more slowly. They came from the southeast, and the remaining Cambrian and Lower Ordovician units came from the northwest. Nowhere in this sequence near this latitude has significant detritus from a volcanic terrane been recognized, so coarse-grained silicic rocks must have dominated the source terrane. Volcanic rocks and allied sedimentary rocks, possibly of early Paleozoic age, are widespread in the eastern Piedmont, but such rocks were not available as sources of sediment to the region of the Great Smoky Mountains and nearby Appalachian Valley.

STRUCTURAL AND METAMORPHIC GEOLOGY

GENERAL FEATURES

Rocks of the Ocoee series were thrice deformed during the Paleozoic era, and resultant structural features are complex. The first episode formed compressional features trending eastward to northeastward. The second, during which most of the Ocoee was slightly metamorphosed, resulted in a cleavage striking northeast. The third episode created structural features parallel to those of the first. The first and second episodes probably occurred during early Paleozoic time, and the third during late Paleozoic. The major structural features are indicated on the geologic map and cross sections (pl. 1).

Nearly all the structural features are compressional. Thrusting and overturning were relatively northwestward, and faults, axial planes of folds, and cleavage generally dip to the southeast. The rocks of the Snowbird group in the southern half of the area were deformed during the first and second episodes, and the Ordovician rocks, in the northern corners of the area, during the third episode. Rocks of the Walden Creek group, and possibly also of the Chilhowee group, lying between the Snowbird group and Ordovician rocks, were deformed variously during all three episodes and geologists are uncertain of the relative ages of many of the structural features in the Walden Creek and Chilhowee groups.

The Snowbird group forms a complex synclinorium with, in general, a low plunge toward N. 70° E. The structure of the Walden Creek group is also broadly synclinorial, plunging toward N. 60° E.; this northern synclinorium is truncated obliquely on the south, and separated from the synclinorium of the Snowbird group, by the eastward-trending Dunn Creek fault. The Dunn Creek fault and the structures of the two synclinoria were the result of the first episode of deformation. The effects of low-grade regional metamorphism were superimposed on these synclines during the second episode. Isograds trend generally eastward, but the slaty cleavage strikes generally northeastward. During the third episode of deformation, the Ocoee series and Chilhowee group were thrust relatively northwestward over Ordovician rocks on the far-travelled thrust sheets above the Great Smoky and English Mountain faults; the Ordovician rocks were folded and faulted, and new folds and faults were added to the older structural features.

METAMORPHISM

Low-grade metamorphism affected most of the Ocoee series at some time between the major episodes of nonmetamorphic deformation. As the metamorphism provides the evidence by which the two other episodes are differentiated, it will be discussed first.

GRADE

The rocks on the north—the Ordovician sequence, the Chilhowee group, and part of the Walden Creek group—were not metamorphosed, and contain illite and montmorillonite. They have, however, been variously altered, as they contain chlorite, their feldspar has been altered, their limestone dolomitized, and their quartz sandstone recrystallized. Southward, the rocks show progressively increasing low-grade regional metamorphism for they are nearly all within the chlorite zone or muscovite-chlorite subfacies of the greenschist facies. Rocks in the southeastern corner of the area extend into the biotite zone or biotite-chlorite subfacies. Within the area of the muscovite-chlorite subfacies, definitive assemblages of chlorite-muscovite, chlorite-calcite, and dolomite-quartz (Turner, 1948, p. 96) were stable; the metamorphic progression cannot be defined on the appearance of new minerals alone, and combined textural and mineralogic criteria must be used. The zones of progressive metamorphism, determined by the character of initially pelitic rocks, are listed on table 3 and are shown on an isograd map (fig. 21). Of the metapelitic rocks, none are coarser grained than slate or very fine grained phyllite.

Subzones within the chlorite zone have been defined for only a few areas, necessarily also on combined mineralogic and textural grounds. Turner (1938, p. 162–163, and 1948, p. 38) defined these subdivisions in chlorite-zone greenschists produced from graywackes in South Island, New Zealand:

Subzone 1. Clastic texture remains; matrix reconstituted.
Subzone 2. Semischists, grain size reduced by shearing.
Subzone 3. Fine-grained schists. Clastic texture gone: reconstitution almost complete; incipient segregation layering.
Subzone 4. Coarse-grained schists; segregation layering highly developed.

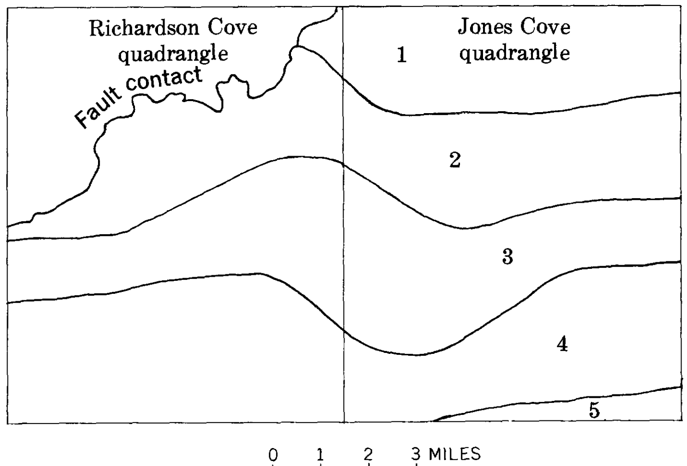

FIGURE 21.—Metamorphic zones in pelitic rocks of the Richardson Cove and Jones Cove quadrangles. Zones 2, 3, and 4 belong to the chlorite zone. Explanation: Zone 1, Shale, nonmetamorphosed, with illite, montmorillonite, and chlorite. 2, Slaty shale, with sericite and chlorite. 3, Slate, with recognizable clastic biotite. 4, Slate, with clastic biotite completely altered. 5, Slate, with metamorphic biotite.

TABLE 3.—*Subzones of progressive metamorphism of the Ocoee series, determined by the character of initially pelitic rocks.*

Nonmetamorphosed rocks:
1. Shale. Rocks contain montmorillonite, illite, and chlorite, and have no slaty cleavage.

Chlorite-zone rocks:
2. Slaty-shale. Argillaceous matrix reconstituted, mostly to chlorite and sericite. Erratic slaty cleavage.
3. Slate. Reconstituted micaceous minerals oriented paralled to conspicuous slaty cleavage. Clastic biotite altered but partly recognizable.
4. Slate. As in 3, but clastic biotite completely reconstituted to chlorite and other minerals.

Biotite-zone rocks:
5. Slate, with metamorphic biotite.

Coarseness of reconstituted minerals in rocks of the chlorite zone varies greatly from region to region; even near the biotite isograd, metashale of the present area is only slate, whereas chlorite-zone rocks in areas such as the New Zealand example just cited include gneiss and coarse schist. Similarly, rocks that are relatively fine grained in their metamorphic recrystallization characterize rocks of all grades of much of the Great Smoky Mountains. Many variables must influence such contrasts—time, temperature, shear, pressure, composition, volatiles—but it is apparent that mineralogic grade alone is an incomplete index of degree of metamorphism. Coarseness of metamorphic minerals and the extent of shear and segregation layering should also be considered.

Grain size of reconstituted micaceous minerals increases only slightly southward, and in few specimens is the average grain size of sericite more than 0.02 mm. Conversely, the size of silt and sand grains in the pelitic rocks decreases irregularly southward, owing to shearing. Clastic potassic feldspar is virtually lacking in the southern rocks, having been almost completely altered to sericite. Clastic plagioclase is almost everywhere albite, even in shale in the northern part of the area; to what extent this indicates reconstitution from more calcic plagioclase is conjectural.

Metamorphic effects are much less apparent in the sandstone (fig. 22) than in the pelitic rocks. Most of

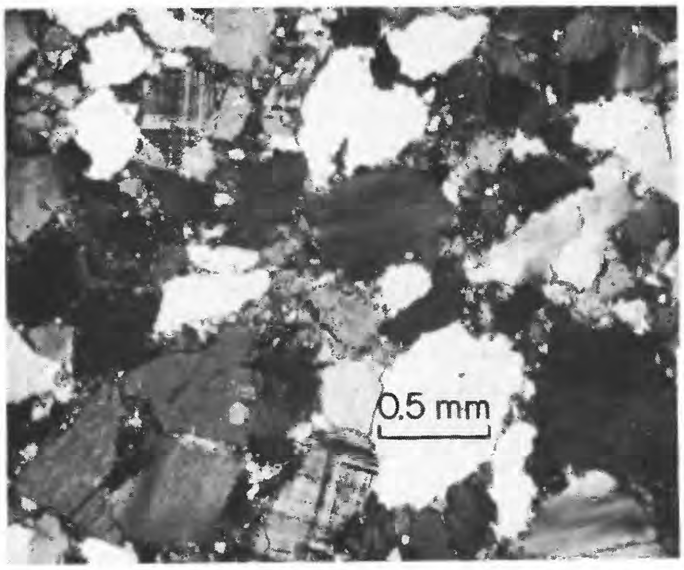

FIGURE 22.—Photomicrograph of recrystallized feldspathic sandstone, with grains sutured together but not sheared. Upper unit, rocks of Webb Mountain, north of Jones Gap. Crossed nicols.

the metasandstone would be classified within Turner's chlorite subzone 1, and only a few in subzone 2; shearing effects are evident only in isolated specimens (fig. 23), and increase only irregularly southward. Reconstitution of matrix minerals accompanies that of the argillaceous rocks, but the zones (table 3) defined for the pelitic rocks are not usable. Feldspars are partly altered in all sandstone units, mostly to sericite, the degree of this alteration increasing slightly and irregularly southward.

CLEAVAGE

Metamorphism of the rocks is most easily seen in slaty cleavage. Distinct cleavage is characteristic of pelitic rocks of the southern half of the area, and a less distinct cleavage of the rocks in the north. Cleavage is shown on the outcrop by parting planes a fraction of an inch (fig. 24) to many inches or feet apart. Cleavage surfaces are dull in sandy and silty rocks, and shiny in meta-argillaceous rocks.

In thin section, cleavage in metapelitic rocks appears as closely spaced microscopic shear folia, along which clastic grains are bent, broken, and offset (figs. 7, 13). Offsets on individual folia, a few hundredths of a milli-

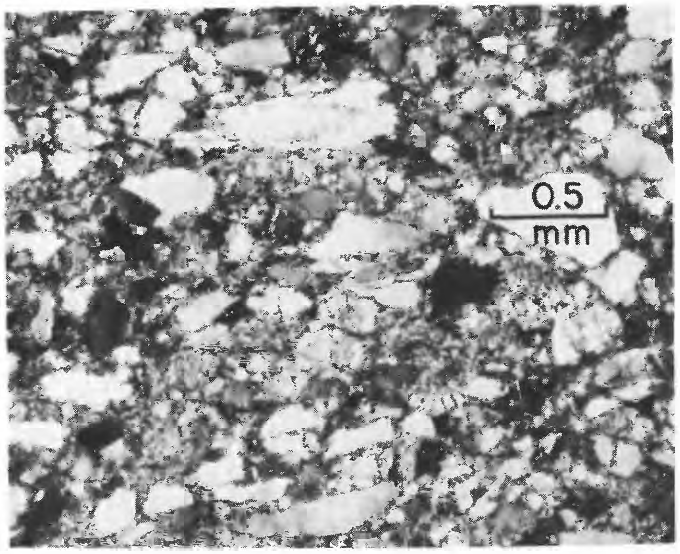

FIGURE 23.—Photomicrograph of sheared and recrystallized feldspathic sandstone, showing great flattening of sand grains. Upper unit, rocks of Big Ridge, Indian Camp Creek. Crossed nicols.

FIGURE 24.—Slaty cleavage in laminated Pigeon siltstone near Caton Branch. Cleavage dips steeply, and bedding gently, to the left (south); the smooth face is parallel to the cleavage.

meter apart, are commonly on the order of 0.01 mm, but in many places are as much as a millimeter or more, and larger offsets are obvious in outcrops. In rare outcrops of thin-bedded well-cleaved metasiltstone, shears rhythmically offset the bedding to produce pseudoripples. That the cleavage is a shear phenomenon is indicated also by its refraction with rock composition, the angle between cleavage and bedding being smallest in beds of initially high clay content, largest in massive sandstone, and intermediate in metasiltstone; this is true both for microscopic laminae and for beds many feet thick. Where slate and coarse sandstone are interbedded and dip gently south, the dip of cleavage may change 50° from one rock to the other. Cleavage microfolia are generally parallel to orientation of secondary micaceous minerals, and many microfolia are filmed by opaque dust. Clastic micas have in many specimens been rotated and sheared to parallel the slaty cleavage. The pervasiveness of shear parallel to the cleavage increases irregularly southward, and is presumably a function of the temperature and pressure of the shearing process.

Commonly, the strike of bedding and cleavage are within 60° of each other, yet bedding and cleavage planes are not parallel, cleavage in cross-strike outcrops invariably indicates the relative position of the axial plane, and hence of the direction of top of bed. In cross section, cleavage fans out from the axial planes, but is on the same side of bedding as are the axial planes; in strike, cleavage and axial planes diverge systematically. The cleavage strikes generally near N. 45° or 60° E., and dips moderately southeast. Statistical distribution of slaty cleavage in rocks south of the Dunn Creek fault—an area that includes most of the distinctly cleaved rocks—is shown on equal-area plots (fig. 25, *A* and *B*.). The minor late folding in the central part of the Jones Cove quadrangle is reflected by a weak and discontinuous girdle, showing rotation of cleavage about fold axes plunging gently southwestward, but the compactness of the distribution of cleavage poles shows that such deformation of the cleavage was of minor importance.

Axial planes of folds of bedding strike near N. 80° E. (fig. 25, *C* and *D*), and the divergence between strikes of cleavage and axial planes of these folds is obvious both on these diagrams and on the geologic map (pl. 1); locally, the strikes are at right angles. Divergence in strike of cleavage and axial planes is a regional feature, and has been studied over a large area to the south by Hadley and Goldsmith.

Although the cleavage planes are approximately axial to the folds in cross section, divergence in strike of cleavage and axial planes shows that folds and cleavage could not have developed simultaneously. Cleavage is thus a feature superimposed on the folds of the south half of the area. The cleavage resulted from pervasive microshearing and mineralogical reconstitution, essentially without further folding, superimposed on a differently oriented system of overturned folds. That the cleavage planes are on the same side of bedding as are the axial planes of the folds must indicate a mechanical control of the cleavage by shearing characteristics of the rocks.

Similar relations presumably apply to rocks north of the Dunn Creek fault, although only in part of them is cleavage distinct so that the presumption cannot be adequately tested statistically. In the north, cleavage is best developed in the finest grained rocks, the shiny slate; in these rocks bedding is mostly so intricately contorted and obscured by cleavage that spot bedding attitudes mean little, and axial planes cannot be determined. Much of the deformation of the slate is of shear-fold type and might have accompanied the development of cleavage and new minerals. The northern rocks are also complicated by abundant structural features formed after the formation of the cleavage planes.

The Great Smoky fault, the major low-angle reverse fault along which rocks of the Ocoee series were thrust relatively northward over Ordovician rocks and the Chilhowee group, is in part a metamorphic discontinuity: along it, slate and slightly metamorphosed shale of the Ocoee are brought in contact with Ordovician shale. Further, the slaty cleavage is deformed by structural features related to the Great Smoky fault. These relations are more marked in the central and western foothills, where windows through the Great Smoky fault show nonmetamorphosed Ordovician rocks tectonically beneath phyllite of the Ocoee. The Great Smoky fault and its associated faults are younger than the metamorphism of the rocks.

Metamorphism of the Ocoee was thus intermediate between two times of folding and faulting. Structural features formed before and after metamorphism are easily differentiated in most of the rocks with a strong slaty cleavage because they have been little deformed since metamorphism. In the northern outcrop of the Ocoee, where structural features that preceded and followed metamorphism are widespread, cleavage is poor or lacking, so that many features cannot be confidently assigned an age relative to that of the metamorphism. A further complication is that a weak cleavage, though generally unaccompanied by important reconstitution,

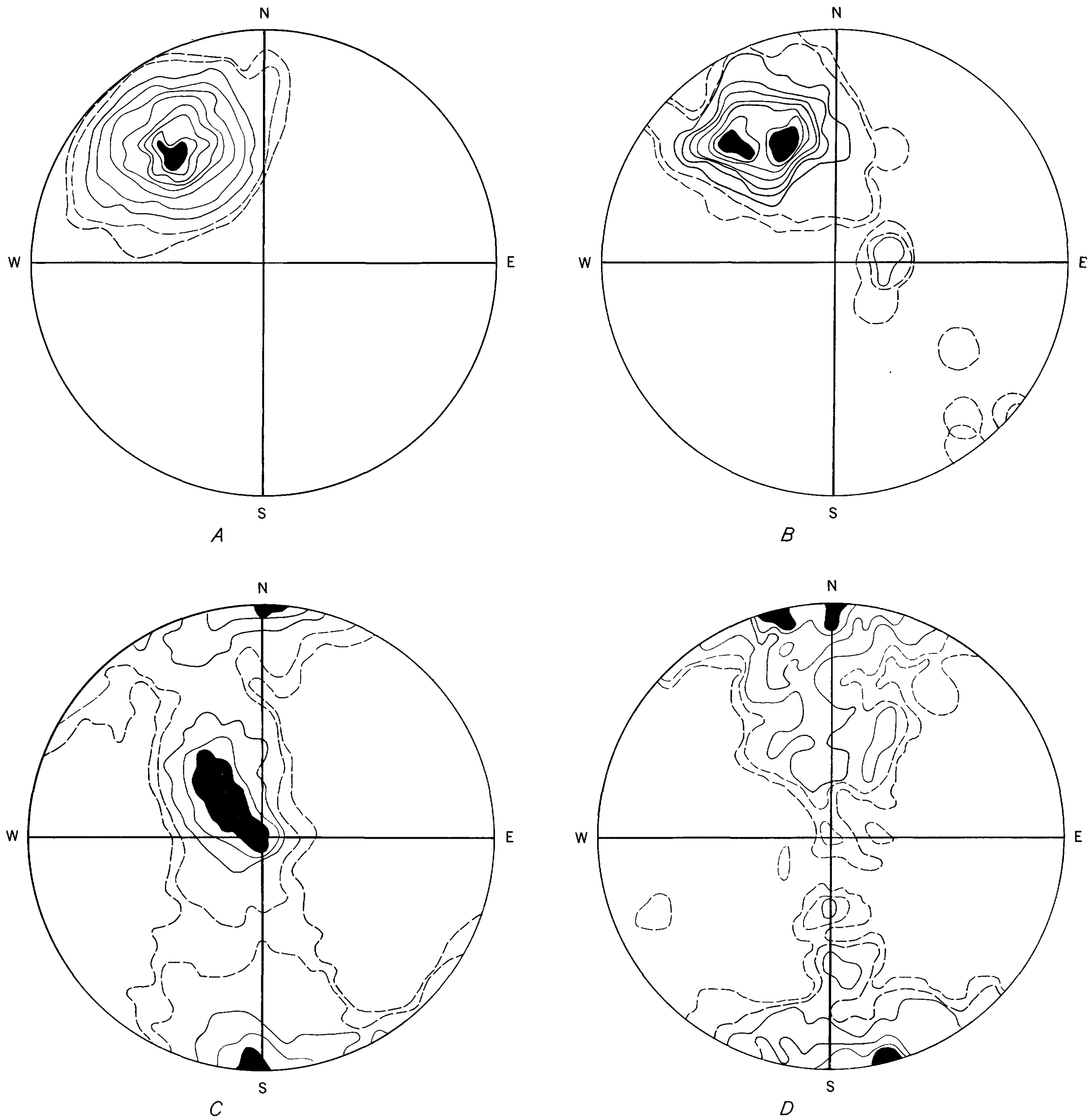

FIGURE 25.—Lower-hemisphere projection of poles of slaty cleavage and of bedding in rocks south of Dunn Creek fault. Equal-area net: solid-contour interval, 2 percent; dashed contours at ½ and 1 percent. The area inside the highest contour of each diagram is black. *A*, Cleavage, Richardson Cove quadrangle; 455 measurements. *B*, Cleavage, Jones Cove quadrangle; 133 measurements. *C*, Bedding, Richardson Cove quadrange; 867 measurements. *D*, Bedding, Jones Cove quadrangle; 226 measurements.

was developed in some of the northern rocks synchronously with the late deformation; north of the slate isograd (between zones 2 and 3, fig. 21), the relative age of the cleavage observed in many places is in doubt.

PREMETAMORPHISM STRUCTURAL FEATURES

Most of the major structural features within the Ocoee series of the south half of the area, and many in the north half, were formed before the metamorphism. The slaty cleavage that formed during metamorphism was superimposed on the deformed rocks and was itself a little deformed by later metamorphism. Two older complex synclinoria, one of rocks of the Snowbird group and one of rocks of the Walden Creek group, were brought together by the Dunn Creek fault, which also preceded metamorphism. General strike of structural features south of the Dunn Creek fault is subparallel to it, whereas that of the north is oblique. The southern synclinorium plunges eastward, the northern east-northeastward; rocks on both sides of the Dunn Creek fault are younger irregularly eastward.

Both synclinoria are complicated by many reverse faults of small to very large displacement. The geologic map and cross section (pl. 1) are believed to give the simplest reasonable interpretation consistent with the outcrop data recorded; structural features are certainly more complex than shown, and if the stratigraphic correlations are wrong the actual structural features may differ widely from those represented.

FOLDS SOUTH OF DUNN CREEK FAULT

In the Pigeon siltstone, northward-dipping limbs of folds are mostly nearly vertical, bedding being steep or overturned to the north. Upright limbs mostly dip gently south, some are horizontal, and some actually dip gently north. Limbs of most folds meet with large acute angles. Scores of folds are exposed in road cuts and nearly all are sharp, with radii of curvature of less than a few feet. Folds with major changes of dip and large radii of curvature occur only in thick-bedded metasiltstone. There are some open rolling folds, with limbs meeting at obtuse angles. Flank lengths of the sharp folds are a few feet to several thousand feet, the size varying with massiveness of the rocks; fold limbs mostly have similar dips regardless of the size of the folds (fig. 25, *C* and *D*). This relation shows that many folds disappear by intersection with opposite folds, rather than by flattening or faulting. An anticline may intersect a syncline to produce a homocline; or an anticline, for example, may split into two anticlines separated by a syncline. This can be demonstrated where good exposures permit close location of fold axes as in the Mize Branch area, of which a map and cross section are given in figure 26.

Actual fold crests were not seen in other formations south of the Dunn Creek fault.

FOLDS NORTH OF DUNN CREEK FAULT

Superimposed on the synclinorium of the Walden Creek group are folds that vary with the rock varieties. In the southern part of the belt, the rocks have good slaty cleavage, and most folds are older than or contemporaneous with the cleavage. In the northern part, cleavage is lacking and structural sequences are uncertain, although it is obvious that much of the deformation accompanied the postmetamorphism movement on the Great Smoky fault.

The northern siltstone units are generally thinner bedded than those of the Pigeon, and folds are generally both tight and small in siltstone and shale. Folds are best exposed along Long Branch north of Dixon Mountain (fig. 27) and also east of the mountain, and along Yellow Breeches Creek from west to southwest of Sunset Gap. These folds have limbs from an inch or less to tens of feet broad. Most have radii of curvature of several feet or less, but there are many open rolling folds in the Sandsuck formation along Yellow Breeches Creek, for example.

Slate is tightly contorted, and spot bedding attitudes indicate little about the general dip. Interbedded sandstone, by contrast, shows little folding. Similar relations occur wherever competent sandstone is separated by pelitic or metapelitic units in highly deformed areas—as on the west side of Yellow Breeches Creek, 1.6 miles air line from its mouth, where thick beds of coarse sandstone have a moderate southward dip, whereas intercalated platy fine-grained sandstone and shale are tightly folded and overturned to the north. Folds in the thick-bedded sandstone, conglomerate, and limestone are larger, and in general more gentle, than those in the thin-bedded rocks.

General plunge of folds is gently east-northeastward, but many folds plunge west, and some plunge steeply in other directions. Steeply plunging folds are well exposed, for example, in the bed of the Little Pigeon River for 1,000 feet southeast from Dixon Branch.

DUNN CREEK FAULT

The Dunn Creek fault bisects the area and separates the Snowbird and Walden Creek groups, not only in this area, but perhaps far to the east and west also; it was formed before the area was metamorphosed and displacement along it may be many miles. This reverse fault dips steeply to moderately southward throughout most of its length, but in the east, it flattens to a gentle dip.

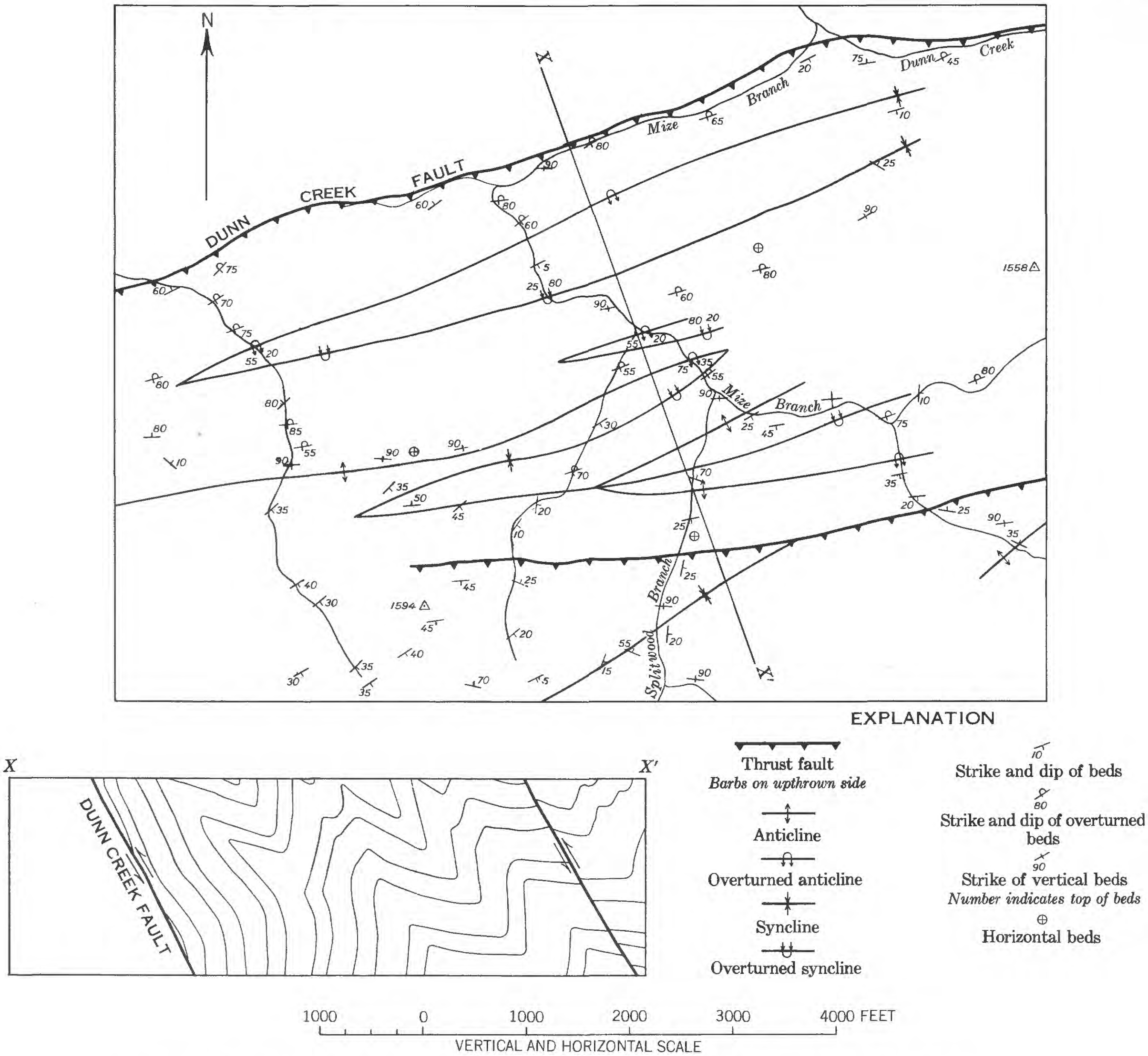

FIGURE 26.—Map and section of intersection of fold axes in Pigeon siltstone of Mize Branch area.

The fault surface is nowhere exposed; its trace across hills shows its general dip to be between about 40° and 70° S. On Bird Creek, exposures on opposite sides of the fault are only a few yards apart, and the dip is 55°. At Indian Camp Creek, it can be delimited within 15 feet, and its dip must be between 25° and 35°. Cleavage and bedding are parallel to each other and to the fault, and the slate on the north side is lineated with downdip crinkles. Within the covered zone of 15 feet, which must contain the fault, are several small outcrops of dark fine-grained sandstone, veined by calcite and quartz.

The Dunn Creek fault follows a straight valley in the eastern part of the Richardson Cove quadrangle, and is marked by an irregular fault-line scarp, due to the resistance of the Pigeon siltstone, along part of its length elsewhere.

The Dunn Creek fault is parallel to the premetamorphism folds and oblique to the slaty cleavage. The cleavage is not rotated or otherwise affected near the fault and is probably younger than the fault. The only aberrant cleavage seen near the fault is near the eastern edge of the area, and is probably related to younger deformation on faults of the Great Smoky system,

FIGURE 27.—Tightly folded shale of lower member of Sandsuck formation from a road cut, Long Branch at southwest end of Pine Mountain. View toward east-northeast, nearly along fold axes; folds are overturned to the north (left). Several lines along the bedding have been added for emphasis.

which crop out a short distance to the northeast and probably underlie this part of the area at shallow depth. The Dunn Creek fault also is presumably folded here.

The Dunn Creek fault has apparently been offset by several other faults, probably reverse faults dipping more steeply southward.

FAULTS SOUTH OF DUNN CREEK FAULT

The Snowbird group contains complex premetamorphism faults, simpler postmetamorphism faults, and faults of undetermined age. Faults bounding contrasting formations are easily traced, but few faults can be drawn with confidence in the thick and broadly uniform Pigeon siltstone.

The rocks of Webb Mountain and Big Ridge are thrust over Pigeon siltstone on the low-angle Webb Mountain reverse fault. The fault sharply truncates structures both above and below at the west end of Webb Mountain and at both ends and the north side of Big Ridge. The reasons for inferring a fault along the north side of Webb Mountain were given on page 17. The fault is not traceable beyond the limits of the sandstone blocks, where Pigeon is brought against Pigeon. Southwest of Webb Mountain, the Pigeon-against-Pigeon fault is inferred to separate rocks with aberrant northward strikes, west of Emerts Cove, from the eastward-striking rocks to the east. The attitude of the fault bounding the east end of Webb Mountain is unknown, but it is inferred to be the northwestward-dipping emergence of the same fault that underlies the sandstone block. Between Webb Mountain and Big Ridge, the Webb Mountain fault is drawn arbitrarily. Cleavage is not rotated or otherwise apparently affected by the fault, so it probably predates the metamorphism; the faults do cut folds in the Pigeon siltstone, as at the west end of Webb Mountain.

The Webb Mountain fault is presumably cut by, and upthrown on the south side of, the several faults of the Gatlinburg fault zone. South of the Gatlinburg faults and just south of the margin of the area, a low-angle premetamorphism thrust fault, mapped by J. B. Hadley, brings Rich Butt sandstone over rocks of the Snowbird group, and it is reasonable to identify this thrust with the Webb Mountain-Big Ridge faults, as is done on plate 1.

The Snag Mountain fault in the southeastern part of the area is an important moderately dipping reverse fault, offset by faults of the Gatlinburg system, and described by Hadley and Goldsmith (written communication). As the Roaring Fork sandstone above the Snag Mountain fault south of the north branch of the Gatlinburg fault does not appear north of it, the Snag Mountain fault is presumed to be hidden beneath the Webb Mountain fault.

Other faults that were formed before the metamorphism are entirely within the Pigeon siltstone. The positions of the few shown on the geologic map are inferred to account for divergences of bedding attitudes not explainable by folding. None rotate cleavage, and none are known to offset the crudely defined metamorphic isograds.

FAULTS NORTH OF DUNN CREEK FAULT

Only a few of the northern faults can confidently be assigned an age preceding metamorphism, as most of the faults either certainly or possibly postdate metamorphism.

Immediately north of the Dunn Creek fault, between the Little Pigeon River and Dunn Creek, the conglomerate of the Shields formation is brought against other rocks of the Walden Creek group by two reverse faults that dip gently to moderately southward. The eastern fault forms the Short Mountain block, and concordantly underlies the conglomerate, and the western fault cuts through the conglomerate. The faults are truncated by the Dunn Creek fault, hence also were formed before the metamorphism.

POSTMETAMORPHISM STRUCTURAL FEATURES

In late Paleozoic time, after the metamorphism of most of the Ocoee series, and much later than the formation of the structures just described, the region was again deformed. The Ocoee series and Chilhowee group were thrust relatively northward over the Paleozoic rocks along overthrust faults with many miles of displacement. Rocks of the northern half of the area were much deformed. but the Ocoee of the southern half of the area was little disrupted except for the formation of the high-angle faults of the Gatlinburg system near the southern edge of the Jones Cove quadrangle.

GREAT SMOKY FAULT

Across the north part of the area is the Great Smoky fault, an overthrust that marks the northern limit of rocks of the Ocoee older than the Sandsuck formation. It dips southward at angles that vary from horizontal to steep. Immediately east of the area, on the north side of a large reentrant (fig. 18) and also on the north sides of windows in quadrangles to the southwest, the fault has gentle to moderate northward dips. Most of this structural relief is probably a result of broad folding of the fault, some perhaps is due to an initially undulating surface.

Within the area, the Ordovician rocks against the fault are almost everywhere the Middle Ordovician clastic rocks. At many places, small tectonic lenses of shattered and contorted Jonesboro limestone intervene between the Ocoee and Middle Ordovician series. Such lenses are commonly a few tens of feet thick and a few hundred feet long. In a few places many small slivers of limestone and of clastic rocks are intercalated, as near East Fork. The small area of Jonesboro limestone surrounded by rocks of the Cochran formation at the northeastern end of Shell Mountain can be explained either as a window through the English Mountain fault sheet, or as a slice on the Great Smoky fault; the former interpretation is suggested on the geologic map (pl. 1).

A small klippe of the conglomerate of Shields Mountain lies close in front of the Great Smoky fault just east of the Little Pigeon River.

In most of the eastern half of the area, the Great Smoky fault brings the Ocoee series and Chilhowee group together and lies near the southern base of Shell, English, and Rich Mountains. The fault is oblique to attitudes both above and below it, and crosscuts major structural features of the Ocoee. It is difficult to locate the fault along much of this part of its course because of the quartzite colluvium shed across it by the Cochran formation. Further, the Sandsuck formation against the fault in parts of the Jones Cove quadrangle contains much sandstone similar to the nonquartzitic sandstone of the adjacent Cochran formation. This part of the fault is nowhere exposed, but is assumed to have a gentle to moderate southward dip.

The only place where the Great Smoky fault is well exposed within the area is at East Fork, where each of the separate fault surfaces bounding tectonic blocks and contorted slices of the conglomerate of Shields Mountain, Jonesboro limestone, and Tellico formation is marked by a few inches of gouge. Exposures of the fault elsewhere to the southwest have a gouge zone commonly only a few feet or less thick, although a zone of great folding and faulting related to the faulting may extend for hundreds of feet from the fault. During formation of the Great Smoky fault, the overriding rocks of the Ocoee were intensely deformed only near the fault, and much of the sheet apparently rode as a little-yielding mass. Many of the structural features of the Ordovician rocks are truncated by the faulting, but other features obviously were formed at approximately the time of thrusting. The Chilhowee was probably deformed mostly at this time also.

Minimum displacement on the Great Smoky fault is 7 miles, the distance across the strike from the trace of the fault in the Jones Cove quadrangle to the south side of the reentrant immediately east of the area (fig. 18).

ENGLISH MOUNTAIN FAULT

The synclinal sheet of rocks of the Chilhowee group and Sandsuck formation of English Mountain overrides Ordovician rocks on the English Mountain fault. Only the southern end of the sheet is within the area, where it forms Shell, English, and Rich Mountains. The structural features of the Chilhowee group within the report area are confused, but the rocks appear to have an overall gentle southward dip. An anticlinal axis lies north of Rich Mountain, a fraction of a mile north of the edge of the area, and probably enters the report area across English Mountain. North of the anticline is the broad and simple spoon-shaped syncline of the main mass of English Mountain.

Immediately east of the report area, the Chilhowee group and the Shady dolomite and Rome formation of Early Cambrian age lie in a fault block between Ordovician rocks and the Great Smoky thrust sheet. If the relations shown by Rodgers (1953, pl. 10) are correct, the Great Smoky sheet overrode and truncated the block, and this interpretation is used on figure 18. This block is probably part of the English Mountain thrust sheet.

A small klippe of Cochran formation lies in front of the English Mountain fault at the north end of Shell Mountain and this and the trace of the fault within the area show that the English Mountain fault dips gently. The fault is poorly exposed in a road cut 1.35 miles west of the eastern edge of the quadrangle, and at that point dips 45° SW. The flaplike block of English Mountain, north of the area, is preserved because the fault beneath it lay there deeper than elsewhere along the strike, preserving that part of the thrust sheet from removal by erosion.

A weak slaty cleavage, exposed locally in otherwise nonmetamorphosed shale near the Great Smoky and

English Mountain faults, was presumably formed at the time of the faulting. The most conspicuous of such cleavage noted is within a bluff on the south side of Bogard Creek, 0.25 mile north of the Jones Cove quadrangle near its eastern edge, where calcareous Ordovician shale was altered to shiny slate.

Minimum displacement on the English Mountain fault is 7 miles, the distance across the strike from the north end of English Mountain to the part of the English Mountain fault extending eastward beyond the area.

RELATIONS OF GREAT SMOKY AND ENGLISH MOUNTAIN FAULTS

Throughout the length of the foothills belt of the Great Smoky Mountains, the Chilhowee group—with or without the Sandsuck formation, Shady dolomite, and Rome formation—appears only in blocks bounded by major faults and intercalated tectonically between the Ocoee series and Ordovician rocks. Minimum displacement of Ocoee over Chilhowee is 7 miles, and of Chilhowee over Ordovician another 7; the Chilhowee group rocks now exposed could not have overlain directly the Ocoee rocks present. Beneath the Chilhowee group is the Sandsuck formation, certainly present in this area only north of the Great Smoky fault; the rocks designated as Sandsuck south of the fault are lithologically similar to these northern rocks and to the rocks of the type area of the Sandsuck some miles to the west, but the lithologic correlation can be questioned and the conclusion presented here that the Chilhowee rests in stratigraphic order on the Ocoee series may be incorrect.

The Great Smoky thrust sheet overrides and truncates the English Mountain sheet in the east, and the trace of the English Mountain fault is presumably beneath the Great Smoky sheet in the west. Keith (1927) introduced the name Great Smoky overthrust, applying it to the "Blue Ridge . . . border fault", which extends "for 300 miles across Tennessee and into Virginia", and forms "ten windows . . . in the Great Smoky Mountains" (p. 154). It is now known that this "overthrust" is a composite of many faults, including the Great Smoky and English Mountain of this paper, so Keith's usage is far too broad. Whichever of the separate faults here termed Great Smoky and English Mountain has the northernmost trace has since been termed the Great Smoky fault (Wilson, 1935; Neuman, 1951; Hadley, King, Neuman, and Goldsmith, 1955), a confusion due to the lack of recognition of the truncation of the Chilhowee block by the Ocoee block.

Apparently the best alternative is to apply the name Great Smoky to the fault bounding the far-travelled rocks of the Great Smoky Mountains, the Ocoee series, against the rocks of the Appalachian Valley. This is the fault bounding the windows of Ordovician rocks southwest of this area, and in part the "Great Smoky fault" of P. B. King (written communication) and R. B. Neuman (written communication) but in part instead their "Miller Cove fault". In the areas studied by King and Neuman, the inconclusive field data can be interpreted to show either that—as they conclude—the Miller Cove fault branches upward from the Great Smoky fault, the Chilhowee group forming a slice at the front of the "Great Smoky" sheet, or that the Chilhowee sheet is overridden and truncated at the south by the Miller Cove fault, but only the latter interpretation agrees with the data available in and east of the present area (fig. 18).

STRUCTURAL FEATURES NORTH OF GREAT SMOKY AND ENGLISH MOUNTAIN FAULTS

The Ordovician rocks of the northern part of the area are folded and faulted, and many are truncated by the Great Smoky and English Mountain faults. Northwest of the Great Smoky fault in the Richardson Cove quadrangle, the Ordovician rocks are arched into the Fair Garden anticline, with a faulted gently dipping south limb and a simple nearly vertical north limb. The Jonesboro limestone is several times thicker on the south limb than on the north limb, and also thicker than that known elsewhere; one or several reverse faults dipping more steeply than the bedding probably duplicate the section here, although the faults were not recognized in the field.

The conspicuous Lenoir limestone and the basal nodular limestone of the Blockhouse shale almost everywhere separate Jonesboro limestone from the main body of the Blockhouse in the Richardson Cove quadrangle, and by mapping these distinctive beds, Neuman demonstrated the deformation of the Ordovician rocks near the Great Smoky fault.

In the Jones Cove quadrangle, the structure of the Ordovician rocks is complex and poorly exposed. The Toqua(?) sandstone member forms an intermediate thrust slice several hundred feet thick between the Blockhouse shale and a variety of rocks above the Great Smoky and English Mountain faults. A smaller slice of Jonesboro limestone lies at the base of this slice near the southwestern corner of the Ordovician outcrop area.

STRUCTURAL FEATURES BETWEEN GATLINBURG AND GREAT SMOKY FAULTS

Many structural features in the northern half of the area were probably formed during the same episode of deformation that formed the Great Smoky fault.

On the western side of the Little Pigeon River north of the mouth of Bird Creek, two major shear zones are exposed—the northern 100 feet thick, the southern 150 feet. Each is composed of gouge, blocks, and lenses of sandstone and greatly sheared siltstone, bounded by anastomosing faults with an average dip of 50° SE. Adjacent rocks are sliced by many lesser faults. The two major shear zones are believed to lie on the trace of a fault trending from Shields Mountain across Sand Mountain and along Licklog Hollow, which brings conglomerate of the Shields formation over the Licklog formation. However, other interpretations could be made.

Small gouge zones are abundant in the Ocoee series near the Great Smoky fault in the western third of the area. Thus, 10 faults with various attitudes cut conglomerate of the Shields formation in a road cut, 600 feet long, on Bird Creek, where there are also lesser shears along bedding planes. These structural features in this road cut, the longest continuous exposure near the Great Smoky fault, may well typify the lower part of the Great Smoky sheet.

In Harbin Hollow, between the East Fork and the Little Pigeon River, abundant small faults are exposed, mostly lying near the bedding of intercalated sandstone and shale; the sandstone was sheared into lenses, around which flowed the shale. Much deformation near the Great Smoky fault is evident in Licklog Hollow, where the lower part of sandstone and shale were greatly sheared and crumpled, and the shale was thrust into chevron folds. A vertical normal fault along the south side of the lower part of Wilhite Creek is exposed in a quarry, where 2 to 4 feet of gouge separate sheared and contorted rocks of the opposed formations. On structures related to the Great Smoky fault, slaty cleavage is truncated and deformed (fig. 28), and the Great

FIGURE 28.—Block of slate, with folded slaty cleavage, between blocks of sandstone. Faults emphasized with lines. Bird Creek near Little Pigeon River.

Smoky fault has cut out metamorphic isograds in the western part of the area. Small gouge zones are abundant throughout the report area, generally a few inches thick and dipping south or southeast. They developed after metamorphism of the rocks, and may be presumed to be due to disruption during travel of the Great Smoky thrust sheet.

Most faults of these sorts cannot be traced away from their rare exposures. Some probably have displacements of only a few feet, others far more.

Faults in the northern half of the Jones Cove quadrangle, south of the Great Smoky fault, are drawn to account for distribution of rocks of the Walden Creek group. None of the structural features are exposed. Interpretations of structure and stratigraphy are interwoven with the concurrent hazard of circular reasoning: structural features are deduced from assumed stratigraphic correlations, and those inferred structural features are then considered to support the assumed stratigraphy. The variously anastomosing faults between the Dunn Creek and Great Smoky faults in the eastern part of the area are inferred similarly, and no significance can be attached to details of the faults as drawn. Most of the faults are assumed to be southward-dipping reverse faults. The conclusions are uncertain, and no two geologists would arrive at the same interpretations from the data available.

The Dunn Creek fault is offset from north of Chestnut Ridge to north of Webb Mountain. A lens of Walden Creek(?) rocks, tentatively assigned to the Dixon Mountain member of the Wilhite formation, lies along the offsetting fault, flanked on both sides by Pigeon siltstone, and was presumably carried up from below the Dunn Creek fault on a steeper fault. Such a fault explains the known distribution of rock types at the southwest end of Chestnut Ridge, and also the offset of the Dunn Creek fault. Projected northeastward, the same fault accounts for otherwise puzzling distributions of formations of the Walden Creek group.

Slaty cleavage is folded on a large scale in a few areas, notably near the eastern part of the Dunn Creek fault where cleavage is deformed by open folds with axes plunging gently southwestward. Folds younger than the cleavage are well exposed in road cuts along Dunn Creek for half a mile above the mouth of Youngblood Branch, and are presumably related to the nearness of the reentrant of the Great Smoky fault immediately east of the area (fig. 18).

GATLINBURG FAULT SYSTEM

Across the southern margin of the eastern half of the area are several high-angle branches of the post-metamorphism Gatlinburg fault system, which is more widely exposed south and southwest of the report area (J. B. Hadley and Richard Goldsmith, written communication; P. B. King, written communication). Vertical displacement of the southern branch of the Gatlinburg fault, as determined by its offset of the Snag Branch fault, is about 2,000 feet. Displacement of the northern branch is about a mile, if interpretations of the Big Ridge and Webb Mountain structural features are approximately correct. Hadley has found that faults of the system deform slaty cleavage, and produce slickensided shear surfaces and narrow gouge zones.

PROBLEMS OF STRUCTURE AND METAMORPHISM

Besides the uncertainty of character and location of the faults that postdate metamorphism, there are many other problems. One is the relative importance of folding that preceded and folding that followed metamorphism, particularly of the Walden group. Attitudes of the two generations of structural features are the same; where metamorphism did not intervene between the episodes, there is no basis for distinguishing the resultant features.

The isograds of metamorphism are vaguely located. They are based either on crude field criteria—quality of slaty cleavage—or on compositional features that can be determined only in the laboratory. The late structural features must offset the isograds, but meager control does not demonstrate any offsets except those produced by the Great Smoky fault. Some of the slaty cleavage north of the Dunn Creek fault may have developed synchronously with the Great Smoky fault, although no superposition of metamorphic structural features suggests that this occurred on a large scale.

CRUSTAL SHORTENING

The rocks now telescoped in a belt only 13 miles wide were spread over a belt at least 50 miles wide before deformation.

The relations shown by figure 18 show that the Great Smoky and English Mountain faults each have displacements of more than 7 miles, and a few miles southwest of this area windows prove a minimum of 9 miles for the Great Smoky alone (P. B. King, written communication; R. B. Neuman, written communication; fault nomenclature that of the present paper). Displacement on the Dunn Creek fault must be great to explain its apparent regional separation of the Snowbird and Walden Creek groups—perhaps 5 miles or more and a similar minimum amount is required by the Webb Mountain-Big Ridge thrust sheet. The Snag Branch fault has a horizontal displacement of 2 miles or more, and 3 miles additional is a reasonable minimum for the other reverse faults of the quadrangles. Unfolded, ignoring faults, the rocks of the area would flatten out into a belt about 20 miles wide, so folding accounts for another 7 miles of shortening. The total figure of 38 miles of shortening is probably too small, as the Great Smoky and English Mountain fault sheets may have moved many miles more than their exposed proven minima. A little over half of this minimum shortening was accomplished by the postmetamorphism structural features.

The structural features of the area thus record shortening by a factor of about four; as basement Precambrian rocks do not appear, post metamorphism deformation of the type exposed is probably here limited to the sedimentary cover of upper Precambrian and Paleozoic rocks. Similar, though perhaps generally lesser, shortening affected the entire Appalachian Valley without bringing basement rocks to the surface.

Basement rocks form much of the Blue Ridge province, however, and appear in premetamorphism thrust sheets in the Great Smoky Mountains (J. B. Hadley and Richard Goldsmith, written communication), and in postmetamorphism sheets in northeastern Tennessee; indeed, if Keith was correct in his interpretation of the "Grandfather Mountain window", the entire Blue Ridge may be allocthonous. Clearly, more than simple compression is represented here: some process whereby relatively thin upper layers of a belt initially several hundred miles wide were peeled from the deeper basement and shingled and folded to perhaps half of that width.

AGES OF STRUCTURAL FEATURES

Structural features of the area are of at least two ages, separated by an episode of metamorphism. The Great Smoky and English Mountain faults were formed after metamorphism of the region and cut rocks as young as Middle Ordovician. A few miles to the west-southwest of this area, Mississippian rocks are cut by structural features closely related to the Great Smoky fault (Neuman, 1951), indicating an age not earlier than Late Mississippian for the general structural features of which the Great Smoky and English Mountain faults are parts.

Fifty miles to the northwest, near the Cumberland Plateau, Lower Pennsylvanian rocks lie conformably or discomformably on Upper Mississippian and have been folded and faulted with them. It is generally assumed that the deformation in the southeastern part of the Appalachian Valley—for example, in the present area—is also post-Pennsylvanian. In northeastern Alabama, on strike from this area, rocks commonly assumed to be Pennsylvanian are involved in major faulting. These rocks belong to the Erin shale or to the

Talladega slate, depending on the structural relationships inferred. Actual fossil determinations indicate only, however, that these rocks "should not antedate the Middle Devonian", although the fossils are "suggestive of some of the Carboniferous forms" (David White, quoted by Smith, 1903, p. 246). However, the clastic Lower Pennsylvanian rocks of the plateau thicken southeastward, suggesting orogeny to the southeast in latest Mississippian time. The Permian rocks of northwestern West Virginia and adjacent Ohio and Pennsylvania were slightly deformed along with the underlying Pennsylvanian rocks, but this deformation need not have been synchronous with that of all parts of the Appalachian Valley. The structural belt of the Appalachian Valley is overlain unconformably by Upper Triassic rocks in eastern Pennsylvania, so compressive deformation in eastern Tennessee may be inferred to have been completed by Middle Triassic time.

Deformation of the Richardson Cove-Jones Cove area following metamorphism can thus be dated with certainty only as later than early Late Mississippian, and before Late Triassic. The commonly assumed Permian age for the deformation of the entire Appalachian Valley remains only an assumption.

Metamorphism preceded the late Paleozoic deformation of the area. From information within the area, the metamorphism might represent an early stage of the late Paleozoic faulting, with the rocks first metamorphosed and then thrust relatively northwestward, or metamorphism might have occurred during an entirely earlier episode.

The latter is more likely. The metamorphism is probably related to that of the Blue Ridge and Piedmont provinces, although many of the regional metamorphic complexities remain unknown. At Spruce Pine, N.C., radioactive minerals in pegmatites that were formed after at least some metamorphism have been dated as about 320 million years old (Eckelmann and Kulp, 1954), or Silurian or Devonian. Zircons from sillimanite schist and synorogenic granite in the part of the Piedmont in western North Carolina have been dated as about 400 million years, or probably Ordovician; the southeastward-thickening clastic sediments of the Middle Ordovician of the Appalachian Valley also indicate disturbance at about this time (Rodgers, 1953). Thus, metamorphism of the report area is best considered as of early or middle Paleozoic age.

The structures antedating metamorphism are younger than the upper Precambrian Ocoee series. Their relation to the Chilhowee group and Paleozoic rocks is not known. The structures might have formed early in an episode that culminated with the metamorphism, or during a completely earlier episode. The discordance between slaty cleavage and axial planes of folds in the report area indicates that the structures and metamorphism resulted from differently oriented forces, which suggests two separate episodes. Perhaps this older deformation, and not the metamorphism, is recorded by the Ordovician radiometric dates and the wedge of clastic sediments. King (1950, p. 661), Rodgers (1952), and others have suggested the possibility of orogeny of this time.

SURFICIAL GEOLOGY

The Precambrian and Paleozoic rocks of the area are covered by a thin mantle of colluvial debris which lies on a thicker mantle, locally a hundred feet or more, of residual material remaining after prolonged weathering. Alluvial deposits are extensive only near the southeastern corner of the area, although the flat-bottomed valleys of the area have alluvial veneers through which the streams have cut to bedrock. Topography of the area is the result of great erosion, of which the more recent part has been under a humid climate. The initial topography consequent on the structures of the area has no apparent reflection in the present landscape, which has been determined largely by resistance of the rocks to weathering and erosion.

RESIDUUM

In the warm and humid climate, weathering is rapid. The heavy plant cover and the cohesion of weathering products retard erosion, and a widespread mantle of weathered rock, little disturbed, lies on the bedrock. In the report area, this mantle is many tens of feet thick on many divides and in other areas where erosion is ineffective, is discontinuous in most valleys, and is missing along much of the gorge of the Little Pigeon River. The residual materials are oxidized and leached, and their character varies with the materials from which they formed.

Most widespread residuum is that formed on Ordovician limestone, which is largely buried by residuum. (Outcrop areas of Ordovician limestone are shown in the Jones Cove quadrangle, but not in the Richardson Cove.) The limestone is covered by brown clayey residuum, often reddish; as most of the limestone is fairly pure, contacts between limestone and residuum are sharp. Fresh limestone outcrops project through clay, which retains scarcely a trace of carbonate. No extensive cuts have been made in the residuum in this area, but similar material elsewhere in the Appalachian Valley has been found to be as much as several hundred feet thick, and to lie on extremely irregular limestone surfaces. Many sinkholes spot the limestone areas.

Shale and siltstone, and their metamorphosed equivalents, decompose to brown clay-rich material, soft enough to be dug with a shovel, yet in many places saprolite is so undisturbed that bedding and other structural features are clearly preserved (fig. 2). Such features can be seen only where saprolite has been newly exposed, as the material slumps and slides readily on artificial slopes. The transition zone between saprolite and rock may be a few inches, or many tens of feet thick. Between bedrock and saprolite, or above the bedrock where saprolite is missing, is a zone of chips and blocks of punky weathered rock in clayey matrix. Road cuts near the southern margin of the area show saprolitization of metasiltstone to depths of 100 feet, with highly irregular and indistinct boundaries between weathered and unweathered materials.

Sandstone decays less readily, breaking down instead into sandy, pebbly, or blocky colluvial debris. Although residuum forms on sandstone, it apparently has less cohesion than that from pelitic or carbonate rocks.

COLLUVIUM

On all but the gentlest slopes, residuum gives way upward to locally transported debris, mixtures of completely leached and oxidized material with rock in diverse stages of alteration. The colluvial veneer is generally thin, the notable exceptions being on some of the sandstone and quartzite mountains such as Shell, English, Rich, and Webb Mountains, where blocky colluvial debris has been shed in great quantities, completely obscuring bedrock over large areas. The colluvium supports heavy forest and underbrush, which might suggest that colluvial processes are now inactive.

However, a cloudburst dumped a foot of rain on Webb Mountain during 4 hours in August 1938, and the effects of the resulting flood were described by Moneymaker (1939). Most gullies were stripped to bedrock; new bottoms were created in the valleys of the lower slopes of the mountain, and old bottoms were in part destroyed. In some places, sheet wash was very effective. As Moneymaker emphasized, the effects of this single brief flood were far greater than those of the lesser floods of many normal years. So fast is colluvial movement in the area, however, that by 1952, when I began my fieldwork, the bedrock of the upper gullies, laid bare in 1938, was almost completely covered by colluvial debris.

Soil that forms on the colluvium is thin. The organic-rich layer is only a few inches thick on undisturbed slopes. Roots and fallen twigs bind the soil into a tough mat, and colluvial movement is probably much slower where this mat is continuous than on slopes of blocky sandstone rubble.

Colluvial slopes have an S-shaped profile, with gentle tops and bottoms and steep intermediate slopes. Colluvium grades into alluvium in many hollows and valleys. Were colluvium shown on the geologic map, bedrock would appear only as scattered tiny outcrops and as discontinuous narrow strips along streams and roads.

Cleared slopes slump and erode quickly, and much of the soil is soon lost. This has given rise to the notion that "stones grow in the ground", as each year sees the hillside fields with more and larger stones than the year before. Little or no effort is taken to prevent erosion, and in cleared areas most of the soil is in the bottoms. Hillsides are nevertheless farmed, their soils barren mixtures of decayed rock chips and leached clay-rich materials, poor in organic matter.

ALLUVIUM

Large alluvial fans descend from the high Great Smoky Mountains into the southeastern part of the area, choking the valleys and lapping unto the hills to the north; Webb Creek lies immediately against the bedrock of the northern hills for much of its course. The fans are dominated by resistant sandstone boulders from the Great Smoky group, and boulders larger than 5 feet in diameter strew the fans for 3 miles north of the south edge of the area; maximum boulder size decreases farther down the fan.

South of State Route 73, many of the streams crossing the fans are entrenched as much as 50 feet or more into the fans. At many places, several levels of fan surfaces are exposed a few tens of feet apart, but such surfaces merge complexly, and no simple age classification of the surfaces seems possible. The fans are not now generally aggrading, and are gullied and weathered. Materials of the fans are variably weathered, weathering being greater on the higher surfaces than on the lower. Nowhere are the materials thoroughly decomposed, although many sandstone boulders in the higher fans are soft and rotten.

STREAM ALLUVIUM

Occasional flat-bottomed valleys in the Ocoee series, mostly along the major streams, are floored by alluvium (fig. 29). Alluvial surfaces are 5 to 15 feet above the stream levels; and as most of the streams run on bedrock, these figures give the approximate thickness of alluvium. Above these surfaces are occasional alluvial terraces, 10 to 50 or more feet higher. As with the multiple levels of alluvial fans, no simple classification of these diverse surfaces seems applicable. Lowest lying alluvial fills are subject to periodic flooding under present conditions, and the alluvium in these active areas is silty and sandy. Much of the higher and terrace alluvium is pebbly or cobbly.

FIGURE 29.—View southward across Emerts Cove to Mount Le Conte. The broad cove has a veneer of alluvium, but the Little Pigeon River runs on or near bedrock. Foothills are underlain mostly by Pigeon siltstone, and the high Great Smoky Mountains in the background are formed largely from massive sandstone.

FIGURE 30.—Weathered gravel and metasiltstone in highway cut, 20 feet high, near Texas Creek. 1, Yellow-brown saprolite, produced from metasiltstone; 2, Red-brown weathered alluvium, with partly decayed boulders of sandstone; 3, Zoned red-yellow podzolic soil.

Floods that occur several times a year are adequate to move boulders 3 feet in diameter in much of the Little Pigeon River, but little coarse material is carried out of the river channel. Rare violent storms (p. 48) have much greater effect.

OLDER GRAVEL DEPOSITS

Materials of the alluvial fans and valley fills retain much of their depositional topography. In contrast, the older gravel deposits are deeply weathered and related only roughly to the present topography. Most extensive are thin deposits of deeply weathered and much eroded gravel, probably generally less than 20 feet thick, that discontinuously overlie the Jonesboro limestone. Cobbles of coarse sandstone and quartzite are dominant. The gravel overlies limestone in places, but is more common over limestone residuum and was apparently mostly deposited on preexisting limestone residuum. The gravel is greatly weathered, commonly with red soil profiles, but most of the cobbles are not saprolitized. The uneven topography of the gravel reflects varying erosion and slump in both weathered gravel and the underlying clay residuum.

Small isolated areas of old gravel cap low hills of the Ocoee series. They are well exposed in road cuts on State Route 73, 1.2 miles west of Dunn Creek, where weathered bouldery alluvium overlies saprolitized metasiltstone (fig. 30). The upper surface of the alluvium is rolling; the lower, irregular; and the thickness ranges from 3 to 15 feet. Most of the pebbles and boulders are coarse-grained sandstone, fewer are fine-grained sandstone, and many pebbles are slate and metasiltstone. Cobbles are greatly weathered, and are mostly soft; the matrix is brown clay. A marked red-yellow zoned podzolic soil crosses the top of the outcrop; and discontinuously overlying the red soil is a thin light-brown soil. Both of these soils are truncated by the present erosion surface and by the thin recent soil.

AGE OF SURFICIAL DEPOSITS

Some of the surficial materials are forming at the present time. Most of the alluvium, however, is now inactive, and streams have cut through it to bedrock. Most of the alluvial material, and presumably much of the colluvium, formed when coarse debris was shed by the mountains in much greater quantity than at present.

It is an obvious inference that the period of major alluviation and colluviation was a cold one, with less vegetation to impede movement of debris, and with much frost action to assist in riving and moving it. It is reasonable to suggest synchroneity of this period with Wisconsin glaciation. At its maximum extent, the Wisconsin ice sheet was only 250 miles north of the Great Smoky Mountains. Peaks of the Great Smoky Mountains have a maximum elevation of about 6,600 feet; above about 5,000 feet, the forest is spruce and fir. There is no present timberline in the Great Smoky Mountains, and extrapolation possible as to the theoretical height of timberline is extremely uncertain, but comparison with floral zones in New England suggests a theoretical present treeline for the mountains between 7,000 and 10,000 feet. During Wisconsin time, spruce grew in many parts of the southeastern coastal plain (Potzger, 1951; Frey, 1953), 5,000 feet below the present limit of the genus, or an equivalent of 6,000 feet if an allowance is made for latitude.

The peaks of the Great Smoky Mountains were undoubtedly above timberline, though by how much is conjectural. If timberline dropped as much as did the lower limit of spruce forest, then most of the main range, and perhaps much of the foothills, probably stood above timberline. Biogeographic evidence for such a major shift of Pleistocene flora was summarized by Deevey (1949, p. 1365–1375), who also refuted the claim made by some botanists that Pleistocene assemblages were little displaced from those of the present time.

The alluvial fans and terrace gravels may be correlated reasonably with Wisconsin glaciation, when frost-activated processes supplied coarse debris faster than it could be removed by stream transport. The "older gravel" is much more weathered than the alluvial fans and valley fills, and has little kinship with present topography; it may be related to some pre-Wisconsin glaciation. Like the younger Pleistocene deposits, the older gravel overlies residuum, indicating that the residuum was formed in early Pleistocene or Tertiary time.

ECONOMIC GEOLOGY

The area contains no known mineral deposits of present economic value, although minor amounts of manganese and iron were obtained in the past.

Manganese.—The small workings of the East Fork mine lie west of Dunn Creek, on the southeastern slope of Bearwallow Mountain. The workings have been idle for 40 years, and no attempt was made to supplement the descriptions of Stose and Schrader (1923), Reichert (1942), and H. S. Rankin and R. A. Laurence (written communication). Complex manganiferous carbonate forms veins and lenses near the top of a thick dolomite bed of the Wilhite formation, and both the carbonate and the overlying oxides in residual clay were mined as ore. Pyrite and quartz are widespread. Mining was done mostly in 1917–1918; the low-grade ore was sorted by hand and roasted to a grade of about 35 percent manganese. Much low-grade ore (less than 20 percent manganese) remains, but its treatment is costly and no further development is to be expected under present conditions.

Iron.—Small deposits of low-grade limonite ore were mined long ago and smelted locally, as at Pigeon Forge, several miles west of the area. The following deposits, which were used, have been identified: the neighborhood of the East Fork mine; from north of Long Branch near the east edge of the Richardson Cove quadrangle; from the crest of Rich Mountain, 400 feet west of the trail crossing north of Sunset Gap. No future production is to be expected.

Zinc.—The Ordovician limestone beds have yielded large amounts of zinc elsewhere in east Tennessee, but no ore has yet been found in this area. During the time of the present fieldwork (1952–1955), casual prospecting was being done by mining-company geologists in the Jonesboro limestone in the Richardson Cove quadrangle, and several small areas were under lease, but no drilling nor development had been done.

Phosphate.—A small phosphate prospect is exposed in a 75-foot bulldozer trench on the narrow ridge inside the meander loop of Dunn Creek at the west end of Dixon Mountain. The phosphate occurs with manganese and pyrite in lenses with a total length of 35 feet and a width of less than a few feet in dolomite; selected specimens contain as much as 35 percent P_2O_5 (R. A. Laurence, written communication, 1951). No phosphate has been produced.

ENGINEERING GEOLOGY

Quarries have been opened in many outcrops of limestone, from both the Ocoee series and Ordovician rocks, and the stone crushed and used on roads. In the southern third of the area, a few quarries for crushed stone were opened in massive metasiltstone. None of the local quarries are currently (1955) in use; crushed stone is trucked in from large quarries near Sevierville, just west of the area.

Landslide problems beset the builders of State Route 73 across the southern edge of the area. High cuts were made in the southeastern corner of the Richardson Cove quadrangle and for some miles from the margin of this area west-southwest to Gatlinburg. Slides of many sizes resulted in cuts facing south or southeast. All the slides are due to slippage in either fresh or weathered metasiltstone along planes of weakness, notably the slaty cleavage. Stable cuts have slopes of about 60° in fresh rock and 45° in weathered rock, as contrasted to the final slopes of the landslides of as little as 25°. The slides involve mostly saprolite and thoroughly weathered rock.

The biggest slide within the area is that at the east margin of the Richardson Cove quadrangle. The slide area is a semicircle extending 400 feet along the highway, and 140 feet vertically above it with an average slope of 30°. Much of the rock at the base is fresh, although cut by weathered zones; the upper areas are of saprolite. Bedding strikes west, and is nearly vertical, in most of the slide area. Slaty cleavage dips moderately to steeply to the south-southeast. Abundant anastomosing planes of parting have gentle southeast or south-southeast dips. The rocks broke variously on bedding, cleavage, and parting planes, and slid on the latter two. Most of the material of the slide came out as the cut was being made. The remaining loose debris is a slippery mixture of clay and weathered rock.

Two other slides, each larger than the one described above, and dozens of lesser slides, hampered construction of the highway in a distance of 6 miles across the next quadrangle to the south.

A lesser slide within the area is that in the gap between Lindsey and Copeland Creeks. This slide is 300 feet long along the road, and 75 feet high. The deeply weathered metasiltstone breaks on its vertical bedding, and slides on the cleavage and other southward-dipping parting. When investigated in 1955, the western half of the slide appeared to have reached stability, but the eastern half still had much debris to lose into the road, and appeared likely to increase its size eastward.

Other small slides came out of road cuts between Copeland and Webb Creeks.

The slides within the area, and those to the west-southwest outside the area, share many features. All important slides are on cuts facing south or southeast, the result of slippage on partings and slaty cleavage dipping in those directions. (These planes dip into northward-facing slopes, which are stable even in saprolite.) Every slide extends upward until its gentle slope intersects the surface of the hill, so height of the slides is governed by height and steepness of the hills. That such slides are certain to occur is obvious in any outcrops of the rocks, although natural outcrops along the road are too few to have permitted specific predictions as to which cuts would slide. No studies of the structural features were made prior to making the initial road cuts, however, nor was the intended route changed after the initial slides during construction of southward-facing cuts. Even a casual application of engineering geology to the road location would have yielded a great saving in initial costs of excavation and in continuing costs of slide clearance.

Other roads in the area either have low cuts or else are mostly in fresh rock. Slides and falls on them, though small, are a continuing nuisance, and mostly are controlled by the same structural features as are the vastly more costly slides of State Route 73.

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