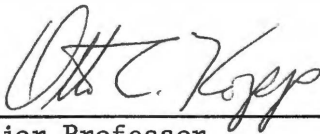


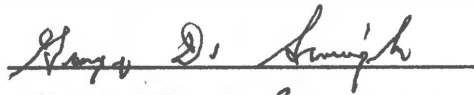
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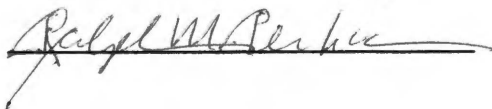
I am submitting herewith a dissertation written by Thomas Culver Sutton, entitled "Relationship Between Metamorphism and Geologic Structure Along the Great Smoky Fault System, Parksville Quadrangle, Polk and Bradley Counties, Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Geology.


Major Professor

We have read this dissertation
and recommend its acceptance:







Accepted for the Council:


Vice Chancellor for
Graduate Studies and Research

RELATIONSHIP BETWEEN METAMORPHISM AND GEOLOGIC STRUCTURE ALONG
THE GREAT SMOKY FAULT SYSTEM, PARKSVILLE QUADRANGLE,
POLK AND BRADLEY COUNTIES, TENNESSEE

A Dissertation
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

by
Thomas Culver Sutton

August 1971

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ABSTRACT

The Parksville quadrangle is structurally located at a salient in the Blue Ridge front. The Great Smoky fault divides the quadrangle such that the southeastern one-third consists of Blue Ridge rocks and northwestern two-thirds of Valley and Ridge rocks.

The Blue Ridge consists of Precambrian Ocoee and Lower Cambrian Chilhowee rocks. The Ocoee Series is represented by both the Wilhite and Sandsuck formations, although previous maps had not indicated the presence of any Wilhite rocks. A mappable unit of Wilhite containing paragonite has served to divide the Formation into an Upper and a Lower Member. All of the fine-grained Wilhite rocks possess slaty cleavage.

Valley and Ridge rocks consist of, in ascending order: Conasauga Shale, Maynardville Limestone, Knox Group carbonates, Athens Shale, and an Upper Middle Ordovician sandy calcarenite resembling the Tellico and Chota formations. They show little or no metamorphic effects. The metamorphic boundary separating the provinces is sharp and corresponds to the Great Smoky fault.

To monitor the increase in metamorphic grade within the Blue Ridge rocks, a method utilizing the sharpness of the $10 \text{ \AA}$ illite peak proved generally unsuccessful. A method was developed for comparing the relative intensities of two peaks, one for 1M and the other for 2M muscovite, which proved somewhat more successful. The ratio $I_{025(2M)}/I_{112(1M)}$ increases with increasing metamorphic grade to the southeast.

The Wilhite rocks have been metamorphosed to the quartz-albite-muscovite-chlorite subfacies; the principle assemblages are: quartz-muscovite; quartz-muscovite-chlorite; quartz-muscovite-chlorite-paragonite. The constancy of mineral assemblages suggests that the rocks are of uniform chemical composition and the simplicity of assemblages suggests the attainment of chemical equilibrium during metamorphism. Semiquantitative analyses show the atom ratio $\text{Fe/Mg} \approx 1$ which may account for the absence of chloritoid as a phase, or its absence may be due to a high f_{O_2} and P_{total} during metamorphism.

The dominant Valley and Ridge structure is a syncline, non-plunging in the north and south-plunging in the south. A low-angle thrust fault, the Cookson Creek fault, brings a flap, mainly of Knox, over the north segment of the east limb of the syncline. The Cookson Creek fault is compared to the Pulaski fault.

The Blue Ridge rocks have been tightly folded and faulted. Topographic trends generally reflect the underlying structure. A convergence of linear trends in the southwest and northeast suggest a squeezing of the structural block at either end, causing the Parksville synclinorium to doubly plunge toward the center. Local disruption of the trends suggests minor flexures which occurred later than the main period of deformation.

The tight folding and faulting was produced by compressional forces from the southeast which slightly preceded the main pulse of thermal metamorphism, previously dated at about 360 m.y. The minor flexures accompanied the emplacement of the Great Smoky thrust sheet, dated at about 225 m.y.

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CHAPTER I

INTRODUCTION

Statement of the Problem

The investigation pursued in this report involves the following problems: (1) the nature of the boundary between the Valley and Ridge Province and the Blue Ridge and Piedmont Provinces, (2) the relationship between the trend of that boundary and the structural features directly adjacent to it, (3) the relationship between the metamorphism and the structural features within the Blue Ridge-Piedmont Province, and (4) the relationship between the metamorphism in the Blue Ridge-Piedmont and Valley and Ridge Provinces.

Most geologists have assumed that most of the boundary separating the Valley and Ridge Province from the Blue Ridge or Piedmont Provinces in the Southern Appalachians is both a structural and a metamorphic discontinuity; that essentially older, metamorphosed rocks have been carried over younger, unmetamorphosed rocks by thrust faulting. This seems to be the case at known localities in Tennessee even though the boundary is very complex in some places. However, extensive mapping by Kesler (1950), in the Cartersville, Georgia mining district, failed to reveal any sign of a major overthrust. Cartersville is located at the Valley and Ridge-Piedmont boundary. A general topographic discontinuity, interpreted by Hayes (1902) as the location of a major thrust fault, is interpreted by Kesler as due to a facies change in Cambrian rocks underlying the area, with a less

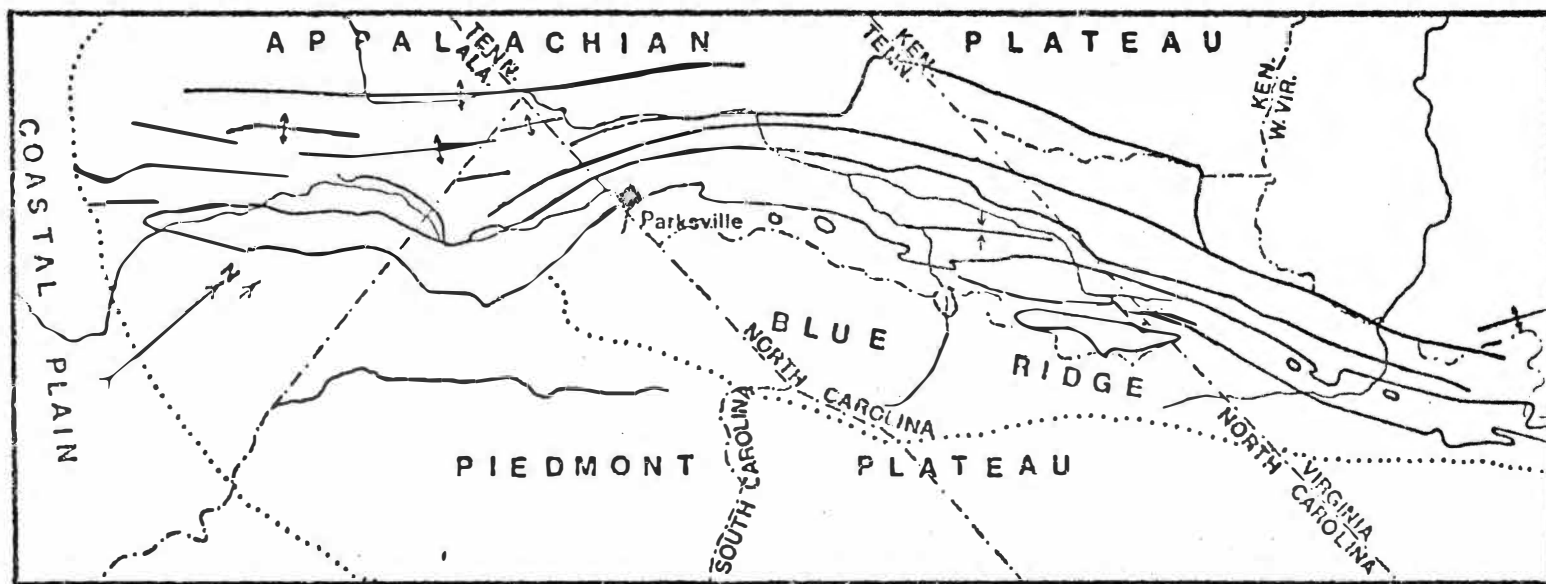
resistant carbonate facies underlying the low region on the west, and a more resistant shale facies underlying the hilly region on the east.

Neither could Kesler find a sharp metamorphic discontinuity. Metamorphic effects extend at least five miles west of the physiographic boundary of the two provinces and Kesler found that its intensity increases gradually eastward from the Valley and Ridge into the Piedmont with no abrupt increases at any point.

The correlations across the fault proposed by Kesler have not generally been accepted by Croft (1963). Whether or not Kesler's correlations are valid, of course, depends on whether or not the Cartersville fault exists. Fairley (1966) agrees with Kesler, at least in part, but realizes the problem is by no means solved.

The Cartersville Mining District is located at the apex of an embayment in the Valley and Ridge-Piedmont boundary. The Parksville quadrangle (the area of the present study) is located 65 miles almost due north of Cartersville along the physiographic front (Figure 1). At Parksville the front is a major thrust fault separating the Valley and Ridge and Blue Ridge Provinces, a sharp metamorphic boundary, and a salient complementing the Cartersville embayment.

King (1964, p. 124) states that the rocks of the Valley and Ridge Province show no metamorphic effects. However, Swingle (1962 and personal communication) describes "axial plane" cleavage as "widespread" in the central and eastern part of the Valley and Ridge between Knoxville and Bristol. It appears to be restricted to dark gray, calcareous shales and siltstones. Swingle (1966, p. 66) regards the cleavage as "... incipient slaty cleavage marking the approximate western limit of regional metamorphism which progressively increases



Explanation

— Major Thrust Fault

○ Window in Major Thrust Fault

..... Boundary of Physiographic Province

↓ Major Syncline in Valley
↑ and Ridge Province

↕ Large Anticline in Appalachian Plateau Province

Figure 1. Principal structural features of the southern Appalachians and location of the Parksville quadrangle (adapted from Rodgers, 1953, fig. 1).

in intensity through rocks of the Blue Ridge Province to the southeast." Bedding is indicated by color banding but the rocks show no fissility along the bedding planes. Furthermore, these rocks contain chlorite which, when heat treated appears to be well crystallized. Whether this well-crystallized chlorite is a product of metamorphism or whether it formed under conditions considered as submetamorphic is not certain. It should be noted that certain rocks of the Ocoee Series, in the Blue Ridge thrust sheet, exhibit no slaty cleavage and contain chlorite whose structure is destroyed when heat treated. If the former chlorite is a product of metamorphism, and the latter a product of diagenesis only, it would mean that some rocks in the Valley and Ridge are more highly metamorphosed than some in the Blue Ridge. If, however, the Ocoee chlorite is a product of weathering, the two situations cannot be compared.

Purpose and Scope of Investigation

Concentrated study of a small area was chosen to develop techniques which might be used to help solve them, especially in low-rank metamorphic rocks along the boundary separating the Valley and Ridge Province from the Blue Ridge and Piedmont Provinces. It would be advantageous to be able to monitor, precisely, very small increases in metamorphic intensity and to be able to draw isograds (or lines connecting points of equal metamorphic intensity) showing these small increases.

Such isograds could be used to locate structural features such as faults. If crustal deformation occurred after metamorphism, the

isograds should show displacement. On the other hand, if a known fault did not displace the isograds, then deformation preceded metamorphism.

Blue Ridge rocks in the Parksville quadrangle have all undergone some metamorphism but none have reached "biotite grade", i.e., the quartz-albite-biotite-subfacies and some may not have even reached the "chlorite grade", i.e., the quartz-albite-muscovite-chlorite-subfacies. It is, therefore, necessary to devise some method of defining isograds in such low-grade rocks. The grade of metamorphism in the Blue Ridge rocks of the Parksville quadrangle generally increases to the southeast. Based on textural criteria, progressive metamorphism of pelitic sedimentary rocks generally results in a gradual change from shale to slate to phyllite to mica schist (within the Parksville quadrangle, only shale and slate are found). This change is accompanied by an increase in grain size. Williams, et al. (1955, p. 174) define the textural classes as follows:

Slates. Fine-grained metamorphic rocks with perfect planar schistosity (slaty cleavage), but without segregation banding; the minerals usually cannot be determined megascopically. Products of regional metamorphism of mudstones, siltstones, and other fine-grained clastic sediments.

Phyllites. Fine-grained schistose rocks, sometimes with incipient segregation banding; schistosity surfaces have a lustrous sheen given off by mica (muscovite) and chlorite. Phyllites have the same origin as slates, but their grain size has coarsened as a result of somewhat more advanced metamorphism.

Schists. Strongly schistose, usually well-lineated rocks in which the grain is coarse enough to allow easy identification of the chief component minerals in hand specimens; minerals of micaceous habit are abundant, and their sub-parallel orientation makes the schistosity conspicuous; segregation layering is generally well developed. Products of regional metamorphism or of deep-seated dislocation metamorphism.

Attempts to define isograds on the basis of these textural changes are not precise enough because of the gradual and qualitative nature of the changes. Even if these textural changes could somehow be put on a quantitative basis, they would not necessarily be related to isograds because factors other than temperature and hydrostatic pressure are involved in producing textures. Such factors include non-hydrostatic (stress) pressure, partial pressures of such fluid phases as H₂O, CO₂, and O₂, original grain size, shape and composition, and length of time of reactions. In addition, the range of temperature of formation of slates and phyllites, through which a pelitic rock passes before becoming coarse enough to call the rock a schist, is probably not great, making it difficult to draw conclusions about the conditions of metamorphism based solely on textural criteria (Williams, et al, 1955, p. 214).

Geographic Setting

About two-thirds (the northwest part) of the Parksville quadrangle lies within the Valley and Ridge physiographic province, whereas the southeast one-third of the quadrangle is in the Blue Ridge Province (Plate I and Figure 2). The boundary between the two physiographic provinces is the Great Smoky fault which passes diagonally through the quadrangle in a northeast-southwest direction.

Maximum relief in the quadrangle is about 1,600 feet. Maximum relief in the Valley and Ridge sector is about 500 feet, the highest points being at Conasauga 1 (T.C. 2,394,000 E.; 246,000 N.), on the Tennessee Valley Divide (1,223 feet) and along other parts of the

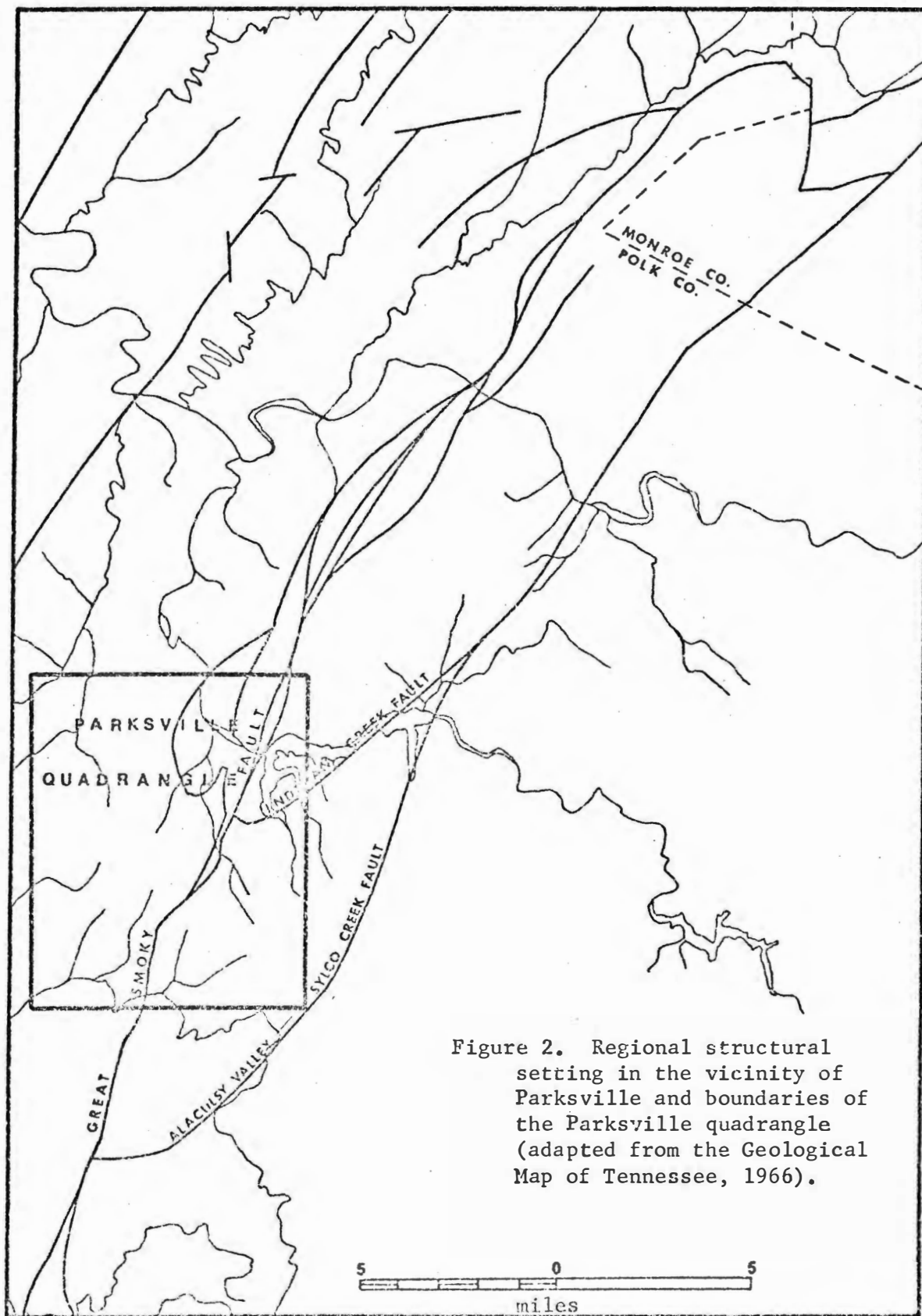


Figure 2. Regional structural setting in the vicinity of Parksville and boundaries of the Parksville quadrangle (adapted from the Geological Map of Tennessee, 1966).

two ridges designated as Sand Mountain where elevations approach 1,200 feet. The lowest elevations are in stream valleys. Examples are the Ocoee River, which drains to the north (680-700 feet), and the Conasauga River which drains the southwest corner (740-760 feet). Maximum relief in the Blue Ridge sector is about 1,500 feet, the high points being Chilhowee Mountain (2,300 feet), Sugar Loaf Mountain (1,646 feet) and a ridge in the extreme southeast corner of the quadrangle (about 1,660 feet). The lowest point is in Parksville Lake (836 feet). Elevations along the Tennessee Valley Divide range from about 1,100 to 1,500 feet.

The Tennessee Valley Divide extends west-northwest across the area, beginning at the east map boundary about one mile north of the southeast corner, to the west boundary northwest of the town of Old Fort (T.C. 2,378,000 E.; 248,000 N.). Drainage north of the divide is into the Tennessee River system while that to the south is into tributaries of the Alabama River which empties into the Gulf of Mexico at Mobile, Alabama.

The basic drainage pattern of Valley and Ridge sector is structurally controlled and basically a trellis pattern locally modified by dendritic and rectangular patterns. Drainage in the Blue Ridge sector is well developed and trellis stream courses are basically determined by the underlying structure.

Areas of comparatively high relief in the Valley and Ridge are composed of parallel ridges which owe their relief to the nearly insoluble clastic rocks and carbonate rocks carrying significant amounts of insoluble material which underlie the area. In contrast, the valleys are underlain by highly soluble carbonate rocks carrying small volumes of insoluble material or by soft, easily erodible shale.

The mountains of the Blue Ridge owe their relief to the nearly insoluble and well-indurated, fine to coarse clastics underlying them. Near the Great Smoky fault, the Ocoee argillites offer less resistance to weathering and erosion than to the southeast where they are more metamorphosed.

Transportation

The Valley and Ridge, with the exception of large parts of Sand Mountain, is largely settled land and is laced through with public roads which make access to most points relatively easy. Most of the ridge area of Sand Mountain is forested, much of it as tree farms, and lacks public rights of way. Two paved and two unpaved roads cross Sand Mountain east-west and there are a number of unpaved roads in the valley between the ridges. The Hiwassee Land Company maintains a series of private roads just south of Tennessee Valley Divide on the west ridge and north of the Divide on the east ridge. Exposures along these roads are excellent in many places.

The Blue Ridge sector lies almost entirely in the Cherokee National Forest. It is accessible by several dirt roads which are maintained by the Forest Service and are passable by passenger car. Throughout the entire area there are countless trails and logging roads blocked to motor travel by felled trees but accessible by foot. Many of the logging roads on slopes have been excavated and have good rock exposures.

Vegetation

Much of the Valley and Ridge sector has been cleared for agriculture. Vegetation cover on uncleared land consists of scrubby overgrowth such as blackberry bushes and deciduous trees such as poplar, oak, and maple. Other areas have been planted in evergreens mostly for use as pulp. Flora of the Blue Ridge is typical of the humid, warm-temperate climate of the region. Oak, maple, beech, poplar, and pine make up the trees, while the dominant shrubs are mountain laurel, rhododendron, and blackberry.

Culture

The Valley and Ridge sector is owned largely by private individuals and companies and consists of small farms, residential plots, and tree farms. The Blue Ridge sector is now mostly National Forest and is sparsely inhabited.

Map Locations by Tennessee Coordinates

Map locations are referred in the text by Tennessee coordinates. A grid was laid off dividing the area into squares 2,000 feet by 2,000 feet. Locations within a given square are referred to by the coordinates of the northwest corner of the square.

CHAPTER II

STRATIGRAPHY

Introduction

Stratigraphic units exposed in the Parksville quadrangle range in age from Late Precambrian to Middle Ordovician. In ascending order they include: Upper Precambrian Wilhite and Sandsuck Formations, Lower Cambrian Chilhowee Group, Middle Cambrian Conasauga Group, Upper Cambrian and Lower Ordovician Knox Group, and Middle Ordovician units consisting of the Athens Shale overlain by an upper Middle Ordovician calcarenite.

A number of gaps in the stratigraphic column are due to units missing by faulting or by erosion or as yet unexposed. For example, a fault contact between the Sandsuck and Wilhite Formations leaves an undetermined thickness of Sandsuck unexposed while an undetermined amount of Upper Wilhite has been removed by erosion. Several units are missing from the Paleozoic rocks also. Little and Sugar Loaf Mountains, which represent a slice along the Great Smoky fault are underlain mostly by Chilhowee Group quartzite, of Early Cambrian age, whose exact stratigraphic position within the Group is unknown. None of the other units of the Chilhowee Group are exposed. The contact between the base of the Chilhowee and the top of the Sandsuck, however, is exposed in the extreme northeast corner of the map on Bean Mountain. Other Paleozoic units which are absent include the Shady Dolomite, Rome Shale, and a portion of the Lower Conasauga Group which fit

between the top of the Chilhowee Group and the Middle Conasauga rocks. There may be other gaps in the Middle Ordovician rocks above the Knox, but their stratigraphic relations in the southeastern part of Tennessee are not completely understood so that the absence of some of the section cannot be readily recognized.

Ocoee Series

General Character

Rocks of the Ocoee Series are terrigenous, clastic sediments, with minor intercalations of carbonates, and contain no obvious volcanics or fossils. They consist of, in general, a monotonous sequence which grades laterally and vertically from one rock type to another. The total thickness of the Ocoee Series in the Great Smoky Mountains is probably at least 30,000 feet, or as great as the total thickness of Paleozoic rocks in the adjacent Valley and Ridge which range in age from Cambrian to Pennsylvanian (King, 1964, p. 15-17). Neither the base nor the top of the Ocoee sequence is visible throughout most of the outcrop area. However, on the southeast side of the Great Smoky Mountains, basal beds of the Ocoee rest unconformably upon older granites and gneisses (King, 1964, p. 15). On the northwestern edge of the mountains, the upper part of the Ocoee appears to be succeeded by basal units of the succeeding Chilhowee Group, while to the south it is succeeded by units of the Murphy Marble Belt (King, 1964, p. 15). Some geologists place the top of the Ocoee Series at the base of the Nantahala Slate (Furcron, 1953, p. 34-38; Hurst, 1955, p. 8; King, et al., 1958, p. 951), while in the past others have included the

Nantahala and even higher formations of the Murphy Marble Belt in the Ocoee (Wilmarth, 1938, p. 1529).

The U.S. Geological Survey classes the Ocoee Series as a provincial series comparable to other series of the Precambrian, such as the Keweenaw, Belt, and Grand Canyon (King, 1964, p. 17).

History of Terminology

The term Ocoee was originally applied by Safford (1869, p. 183-198) for units of "conglomerate and slate" exposed in the gorge of the Ocoee River, Polk County, Tennessee, part of which lies in the present report area. Safford recognized the Ocoee as comprising much of the Unaka Mountains between there and northeastern Tennessee. In the same region, he also recognized the overlying "Chilhowee Sandstone". Safford included the Ocoee and Chilhowee rocks together with the Knox Group of shales, dolomites, and limestones in the Potsdam Group, the name corresponding to Dana's Potsdam Period, which was the Late Cambrian Epoch in the older literature (Wilmarth, 1938, p. 1719).

Keith (1895a, 1895b, 1896, 1903, 1904, 1907a, 1907b, 1927, 1952) in a series of folios on the geology of the southern Appalachians, divided the rocks of the Unaka province into formations which he attempted to trace throughout the region. In his first folios he did not attempt to assign ages to these formations. However, as his work progressed, he finally assigned an Early Cambrian age to them (Table I) because he thought the Nantahala Slate and the Great Smoky Conglomerate were southeastern equivalents of the Chilhowee Group and that other formations in the series lay conformably beneath them.

TABLE I

COMPARISON OF CLASSIFICATIONS BY KEITH AND STOSE AND STOSE

Keith	Stose and Stose	Keith's Original Classification, Knoxville Folio (1895a)	Keith's Revised Classification, Asheville and Nantahala Folio's (1904, 1907a), and Mount Guyot, Cowee, and Murphy Quadrangles (1952)		Stose and Stose Classification (1949)	
Early Cambrian	Late Precambrian	Not Present	Murphy	Valleytown Formation	Murphy	Valleytown Formation
				Brasstown Formation		
			Marble	Tusquitee Quartzite	Marble	Big Butt Quartzite
		Not Present	Nantahala Slate: Type, Nantahala Gorge, Nantahala Quadrangle		Nantahala Slate: Includes Hazel Slate in Smoky Mountains and Pigeon Slate in places	
		Clingman Conglomerate, Hazel Slate (Part), Thunderhead Conglomerate, Cades Conglomerate:	Great Smoky Conglomerate: Type, Great Smoky Mountains, Knoxville and Mount Guyot Quadrangles		Great Smoky Quartzite:	
		Pigeon Slate (Part), Citico Conglomerate, Wilhite Slate, Sandsuck Shale:	Hiwassee Slate: Type, gorge of Hiwassee River, Murphy Quadrangle		Hurricane Graywacke	
		Pigeon Slate (Part) rest mostly not present in Knoxville Quadrangle	Snowbird Formation: Type, Snowbird Mountain, Mount Guyot Quadrangle			
Pre-cambrian		Not Present	unconformity			
			Carolina and Roan Gneisses and associated Granites:			

Keith's first stratigraphic interpretation of the Ocoee rocks was presented in the Knoxville folio (1895a). He extended these formations southwestward into Loudon quadrangle (1896) while Hayes (1895) extended them into the Cleveland quadrangle, which includes this report area. As Keith extended his mapping to the southeast, he discovered his series of units was not applicable regionally and he developed a new classification which he used in the Asheville (1904) and subsequent Natahala (1907a) folios, and Mount Guyot, Cowee, and Murphy quadrangles (1952). King (1964) has recently attempted to clarify the stratigraphic relations among the units within the Ocoee Series (Table II).

Stose and Stose (1944 and 1949) also reviewed previous work and attempted to straighten out the confusion which has arisen from misuse of formation names and errors in age determinations. They interpret the Ocoee to be of Late Precambrian age. However, they did place the Sandsuck Shale, which King (1964) interprets as the uppermost formation of the Ocoee and of Late Precambrian age, in the Lower Cambrian as the lowermost formation in the Chilhowee Group. Their proposed subdivisions are compared with Keith's in Table I (Stose and Stose, 1949, p. 273).

Keith (1949) includes the Sandsuck in the Ocoee and places the base of the Cambrian system at the base of the Cochran Conglomerate which he considers to be the lowermost formation in the Chilhowee Group.

King, et al. (1958) define the Ocoee in the Great Smoky Mountains as lying above a basement of earlier Precambrian granite and gneissic

TABLE II

SUBDIVISION OF THE OCOEE SERIES IN THE GREAT
SMOKY MOUNTAINS PROPOSED BY KING (1964)

LATE PRECAMBRIAN	Group	Formation		Formation Thickness (feet)
	Walden Creek Group	Sandsuck Formation		2,000
		Wilhite Formation	Upper Division	1,000
			Lower Division	2,500
		Shields Formation		1,500
		Licklog (?) Formation		1,500
	Unclassified	Rich Butt Sandstone (in east) and Cades Sandstone (in west)		1,500
	Great Smoky Group	Unnamed Sandstone (southwestern part of area only)		4,500
		Anakeesta Formation		3,000-4,500
		Thunderhead Sandstone		5,500-6,300
		Elkmont Sandstone		1,000-8,000
	Snowbird Group	Pigeon Siltstone		10,000
		Roaring Fork Sandstone		7,000
		Metcalf Phyllite (western part of area)		Not determined

rocks and underlying the Cochran Formation on the northwest and the Nantahala Slate to the southeast. They divided the Ocoee into three broad units (Table II) of regional extent which they designated (from oldest to youngest) the Snowbird Group, the Great Smoky Group, and the Walden Creek Group. They also recognized several formations which they could not classify as to group.

Rodgers (1953, Plate 13) compiled a map which shows all of the Ocoee south of the Hiwassee River and west of Sylco Creek fault as Sandsuck. However, much of his map was not based on his own field observations and he acknowledges the uncertainty of his information.

Ocoee Rocks of the Present Report Area

The only Ocoee rocks recognized in the area studied are the Wilhite and Sandsuck Formations of the Walden Creek Group of King (1964). According to King, the Walden Creek Group corresponds approximately to Keith's Hiwassee Slate. However, King revised the nomenclature (1964) because the type locality of the Hiwassee is outside the Great Smoky Mountains, where it was never adequately defined and because of other ambiguities. Even though the present report area is closer to the type area of the Hiwassee Slate, King's terminology from the Great Smoky Mountains will be used for the sake of clarity and continuity.

Rodgers (1953) and subsequently the Geologic Map of Tennessee, Swingle, et al. (1966) show the entire area between the Sylco Creek fault and the Great Smoky fault, as far northeast as the base of Starr, Bean, Little and Sugarloaf Mountains as underlain by the

Sandsuck Formation. However, Stose and Stose (1949) show everything approximately south of Ocoee Lake and ^{WEST} west of the Blue Ridge - Valley and Ridge boundary simply as Ocoee. They map everything north of the lake as Chilhowee in which they include the Sandsuck.

Walden Creek Group

General Features

Definition

The group name comes from exposures along Walden Creek, a western tributary of the West Fork of the Little Pigeon River which drains the southeast slope of Chilhowee Mountain and the northern foothills of the Great Smoky Mountains in Sevier County, Tennessee (King, et al., 1958). Rocks of the same character are found in the type locality of the Ocoee, exposed in the Gorge of the Ocoee River, Polk County, Tennessee.

The Walden Creek Group in the type area corresponds approximately to the Wilhite Slate, Citico Conglomerate, and Pigeon Slate as mapped by Keith (1895a) in the Knoxville quadrangle, but the stratigraphic order of the original units has been reinterpreted and changed. The term Citico Conglomerate applies to a lithologic type occurring at many levels within the unit and is, therefore, not a suitable stratigraphic term. King (1964) retained the names Wilhite and Pigeon but redefines them with respect to rocks near their type localities (Table II, p. 16).

Most of Keith's Hiwassee Slate (1904, p. 3) is approximately equivalent to King's Walden Creek Group. However, the Hiwassee was

named for a locality in Murphy quadrangle, for which no description was published, and the name has been used so confusingly elsewhere that it was abandoned in favor of the name Walden Creek (King, et al., 1958).

Lithology

The Walden Creek Group is a heterogeneous group of mostly argillaceous and silty sedimentary rocks, containing considerable amounts of conglomerate and sandstone in discontinuous lensoid masses, as well as minor amounts of quartzite, limestone, and dolomite. In all localities where Walden Creek rocks have been recognized, they have been, at least, slightly metamorphosed.

Subdivisions

King, et al. (1958) and Hamilton (1961) consider the most convincing sequence of the Walden Creek Group, in the foothills of the Great Smoky Mountains, to be that south of English Mountain in Richardson Cove and Jones Cove quadrangles. Here, the group is divided, in ascending order, into the Licklog, Shields, Wilhite, and Sandsuck Formations. This four-fold subdivision of the group is only recognized as far to the southwest as north of Tuckaleechee Cove Window. From there southwest to the Little Tennessee River, only the upper two formations (the Wilhite and Sandsuck) are recognized (King, 1964, Plate 1, and Neuman and Nelson, 1965, Plate 2). Southwest of the Little Tennessee River to the Georgia state line, the upper two formations of the group are recognized, the Wilhite on the southeast and the Sandsuck on the northwest of the Gatlinburg-Sylco Creek Fault system (Geologic Map of Tennessee, Swingle, et al., 1966).

In this report, Ocoee rocks generally south of Ocoee Lake, Parksville quadrangle, have been mapped as Wilhite while those north of the south shore of the lake are considered to be Sandsuck. The present writer has concluded that most of the Ocoee rocks south of the lake bear a striking resemblance to Sandsuck rocks in the vicinity of Chilhowee Dam on the Little Tennessee River.

Wilhite Formation

Definition

The Wilhite Formation is named for Wilhite Creek in the Richardson Cove and Jones Cove quadrangle (King, et al., 1958, p. 962). The name was adapted from the Wilhite Slate of Keith (1895a, p. 2) but with a very different interpretation of its position in the sequence and structural relations.

In the type area the unit, as presently defined, is stratigraphically underlain by the coarse-grained rocks of the Shields Formation and overlain by siltstone of the Sandsuck Formation. Here, King, et al. (1958, p. 962) and Hamilton (1961, pp. 21-26) divided it into a Lower (or Dixon Mountain) Member, of calcareous siltstone with some interbedded sandstone, and Upper (or Yellow Breeches) Member containing mainly argillaceous, silty and sandy rocks but characterized by many units of sandy and conglomeratic limestone.

In the Richardson Cove and Jones Cove quadrangles the typical lithology of the Dixon Mountain Member is described as "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" (Hamilton, 1961, p. 21). Hamilton (1961, p. 22) also describes carbonate beds containing both calcite and dolomite in the member. He estimates the thickness of this member at about 1,500 feet. King (1964) describes the Lower Member as having originally been no thicker than 2,000 feet and consisting mainly of siltstone, but including interbedded layers of quartzite, sandstone, and conglomerate in its upper part.

Hamilton (1961, p. 23-24) describes the Yellow Breeches Member as consisting primarily of medium-dark-gray limestones with medium-light-gray weathered surfaces and lying unconformably upon the Dixon Mountain Member. The limestones are commonly sandy or conglomeratic. Some sandy units contain up to 50 percent well-rounded quartz grains while the conglomeratic units consist of subangular chips and slabs of diverse limestones and other rocks. The unit also contains dolomitic units together with medium-gray to dark-gray shales and siltstones. These shales and siltstones are described as containing detrital mica and having carbonate disseminated or concentrated in a few laminae.

King (1964) estimates that there are at least 1,000 feet of the upper unit preserved and describes the lithology as consisting mainly of argillaceous shales and slates, but characterized by interbedded limestone, which forms thin to thick layers. The argillaceous rocks consist mostly of drab or dull-green laminated shale, but include some silty layers that contain fine detrital grains of quartz, feldspar, and mica, and a few thin beds of fine-grained non-calcareous sandstone.

Weak cleavage is the result of a slight metamorphism. Neuman and Nelson (1965) describe the Wilhite Formation in the southwestern end of the Smoky Mountains as consisting mostly of siltstone, argillite, and fine sandstone, locally containing beds of coarser sandstone, conglomerate, and carbonate rocks. The siltstone is mostly medium gray, but in places is greenish gray or maroon. The argillite and slate consist of up to 90 percent micaceous minerals. Conglomeratic units lie within or grade into sandstone, and both are interbedded with siltstone, argillite, and a few beds of limestone. The sandstones and conglomerates contain iron-bearing carbonate but very little micaceous material; thus Neuman and Nelson do not think most of the sandstones can be classified as graywackes. The color of the carbonate-bearing, coarse clastics on fresh surfaces is greenish gray. Upon weathering, the carbonate breaks down leaving an iron oxide residue which imparts a brownish stain to the rock surfaces.

Occurrence Within the Parksville Quadrangle

Within the Parksville quadrangle rocks of the Wilhite Formation occur in the southeastern sector, bounded roughly by the Great Smoky, Indian Creek, and Baker Creek faults.

Lithology

Siltstone and Argillite

With the exception of the Upper Member, which King (1964) describes as consisting mostly of argillaceous shales and slates, King (1964) and Hamilton (1961) describe most of the fine-grained Wilhite rocks of their report areas primarily as siltstones. Neuman

and Nelson (1965) report a significant amount of argillite, containing as much as 90 percent silt and clay-size micaceous minerals, with quartzose silt in minor amounts. This trend - a decreasing amount of siltstone and an increasing amount of argillite - seems to continue southwestward into the Parksville quadrangle. Perhaps only King's Upper Member is preserved along strike. The fine-grained Wilhite rocks in the Parksville quadrangle consist mainly of argillites and silty argillites with subordinate siltstones. The writer has been able to subdivide the argillites into four groups based in part on their general appearance, including color and sedimentary features. Most members within each group also have certain mineralogic and textural characteristics in common. The rocks of each group appear to be confined to general stratigraphic horizons.

Group 1. This group is the largest of the fine-grained clastics. About twenty thin sections were examined. These rocks are medium light-gray (N6), light-gray (N7), greenish-gray (5GY 6/1), light olive gray (5Y 6/1), and yellowish-gray (5Y 7/2). They have black, varve-like laminations which, even in hand specimen, show irregularities which represent disturbances at the sediment-water interface during deposition. The laminations are repeated over small intervals, usually on the scale of 1 mm or less. All of the samples examined display slaty cleavage not parallel to bedding. The tenacity or degree of compaction varies with mineral composition and amount of metamorphism. Relatively high amounts of quartz and increasing metamorphic intensity make for a harder and more compact rock with less closely spaced cleavage planes.

In thin sections, the dark laminae can be seen to result from carbon granules concentrated in (often discontinuous) lenses and stringers. Carbon granules are often displaced along the axial plane cleavage. The light olive-gray and yellowish-gray colors are imparted to the rock by what appears to be a golden-yellow stain, usually concentrated along bedding surfaces but often ubiquitous throughout the slide. In several cases the color tone is so deep as to be a reddish-brown. Usually the stain affects an entire area of a thin section, i.e., coarser grains and matrix alike. Often, however, the color is confined to individual grains, in which case, it is probably the color of the mineral. Where the color is due to staining, it is probably an iron oxide derived from the alteration of iron-bearing minerals. Where it is the color of the mineral, it is believed to result from oxidation of iron in the octahedral sites of chlorite. In all cases, the color masks the interference colors of minerals involved.

Tests were conducted on most of the twenty samples to determine if any trace of ankerite was still present by immersing a small quantity of each sample into hot dilute HCl. The negative results suggest that these rocks now contain no carbonates.

Sections cut perpendicular to both bedding and cleavage show an excellent bedding-cleavage relationship. In all of the sections mounted with such an orientation, the c-axes of the micas are perpendicular to the cleavage planes. Very often microshears have developed on the cleavage planes along which movement has occurred, which are recorded by the offset of bedding plane lamellae. Thin section #362 was made from a sample taken near the southeastern corner of the

quadrangle. It consists primarily of fine-grained sericite. The primary cleavage (S-2) was nearly perpendicular to bedding. A second, slip cleavage (S-3) followed which is almost parallel to bedding, resulting in micro-chevron folds or a "herring bone" texture.

X-ray diffraction patterns for sixteen of the twenty samples show peaks for quartz, muscovite, paragonite, and chlorite. Four samples contain all of the above minerals except paragonite. The presence of paragonite in most of these samples appears to have stratigraphic significance and will be discussed later.

Group 2. This lithologic type is typically pale olive (10Y 6/2), waxy in luster, soft, and is unlaminated to very faintly laminated. It is always associated with conglomerates, both as angular lithic fragments within the conglomerates and interbedded with them. Many samples appear "talcose" in surficial texture and luster, but no talc has been detected by x-ray or in thin sections. Often the basic color has been altered to dusty yellow (5Y 6/4) by iron oxide staining.

X-ray diffraction reveals that these rocks consist mainly of muscovite and quartz. Some specimens are composed almost entirely of muscovite. Peaks for chlorite and paragonite are seldom present and then only very minor.

Optically, the major mineral is very fine-grained sericite. Some sections contain angular quartz grains up to sand size and one section contains 60 to 70 percent fine silt-size grains. Minor amounts of oxidized chlorite and carbon granules may also be present. Cleavage is not obvious in hand specimens, but preferred orientation of the sericite may be observed in some thin sections.

Group 3. Argillites of this group are a dusty yellow-green (5GY 5/2). All the samples observed contain dark green specks which, in hand specimen, appear to be chlorite grains. They are usually not laminated or only faintly laminated and have a grayish-orange (10YR 7/4) weathering rind on a dry surface.

Seven thin sections were examined. Six are classified as argillites because they contain 60 to 75 percent clay-sized particles while the seventh might be best classified as a siltstone since it contains about 75 percent silt-size grains. Minerals detected by x-ray diffraction in six of the seven samples are quartz, muscovite, and chlorite. The seventh sample contains the same minerals plus a trace of paragonite. Minerals detected optically are quartz, muscovite, green chlorite, and brown oxidized chlorite.

Muscovite is present as fine-grained sericite with its c-axis preferentially oriented perpendicular to the direction of cleavage. The sericite appears to have formed through recrystallization. Present also in each section are coarser muscovite grains that are inferred to be detrital based on the ragged edges of the flakes. Sometimes it is difficult to determine whether a particular muscovite grain is recrystallized or detrital.

Chlorite is also present as fine-grained, recrystallized material woven into the matrix fabric with sericite and as coarser detrital grains. Fine-grained chlorite cannot be identified optically, but its presence is inferred from strong chlorite peaks in the x-ray patterns which cannot be accounted for solely from the larger, detrital chlorite grains. There are scattered greenish spots in the matrix

which may or may not show some pleochroism. In about half of the slides no greenish color was noted.

All of the sections examined, except one, contain coarse grains of chlorite which correspond to the green specks seen in hand specimen. The coarser grains are usually pleochroic, very green to almost colorless and have anomalous blue to brown interference colors. They usually occur in parallelogram-shaped fibrous or bladed aggregates. The long axes of the parallelograms are oriented parallel to the slaty cleavage of the rock. The fibers or blades comprising the grain are usually essentially parallel to each other, but may be oriented any way with respect to the axes of the parallelogram, being even parallel to its short axis.

Single grains not composed of blades or fibers also occur. These grains appear somewhat glassy, are bright green, and only slightly pleochroic. They are generally rectangular-shaped but with ragged edges, suggesting a detrital origin.

Group 4. Rocks of this group are medium-dark gray (N4) to medium-gray (N5) with black (N1), very thin laminations usually widely spaced. Most specimens are relatively fresh with only a very thin grayish-orange (10YR 7/4) weathering rind. They are usually smooth and compact, hard, and generally have a well-developed slaty cleavage and no fissility along bedding planes. X-ray patterns for these samples show relatively strong peaks for quartz compared with muscovite. This relatively high quartz content probably accounts for their hard, compact character.

Mineralogically, the rocks of Group 4 are somewhat varied so that some of their similarities may be mostly superficial. All eight

samples examined contain quartz, muscovite, and chlorite. In addition, the 10 Å peak of four of the samples indicates the presence of paragonite, although this is strong in only one sample. Albite, dolomite, and calcite are also present in some of the samples together with minor amounts of pyrite, leucoxene, and a dark substance thought to be carbon granules.

Individual members of this group range from coarse argillaceous siltstone to argillite. Most are siltstones or silty argillites. Varied lithologies may be displayed in a single thin section in laminations from less than 1 mm to about 1 cm thick. Laminae result mostly from changes in grain size although concentrations of carbon granules on bedding interfaces are not uncommon.

These rocks consist primarily of silt- to fine sand-size, angular quartz and feldspar grains imbedded in a clay matrix which has largely been recrystallized to sericite and fine-grained chlorite. Coarser fragments of chlorite and muscovite probably represent both detrital and recrystallized material. Most of the coarse chlorite is in fibrous aggregates which display a very pale-yellow to very pale-green color and show little or no pleochroism. These grains are probably recrystallized. Interference colors are anomalous blue. Coarser muscovite in single flakes with ragged edges is probably detrital, while that in fibrous aggregates, like the chlorite, is probably recrystallized. Some aggregates are composed of alternate layers of muscovite and chlorite, suggesting recrystallization.

Well-crystallized carbonate has replaced matrix material, usually parallel to bedding planes. Pettijohn (1957, p. 305) suggests that the carbonate in graywacke is usually ankerite resulting either

from replacement of matrix material or by diagenesis in a reducing environment. The same reasoning might apply to the carbonates in the argillaceous siltstones of this group.

Recrystallized micas in the matrix are well oriented along microshear cleavage planes which are not parallel to bedding. Some slides show bedding lamellae offset along the shear planes.

There are other rock types which cannot be assigned readily to one of the four preceding groups. One type bears special mention because its mineralogy seems out of place considering its geographic location. Sample #107 was taken near Tennessee coordinates 2,400,100 E. and 230,000 N., well within the area of rocks showing definite metamorphic effects. It is medium light-gray (N6), unlaminated, very soft, and seems fresh except for a paper-thin orange weathering rind. Instead of containing chlorite, as might be expected, it contains kaolinite and possibly montmorillonite. In thin section it appears to consist of a clay "paste" containing many angular, silt-size quartz grains. Coarse muscovite grains with ragged edges are clearly detrital but the matrix sericite is too fine grained to determine whether it is detrital or recrystallized. The matrix also contains some oxidized chlorite which is not plentiful enough to impart its color to the hand specimen.

Sandstones and Conglomerates

All gradations exist between very fine-grained argillites and conglomerates in the Wilhite Formation. Wilhite coarse clastic sediments consist of recrystallized matrix of muscovite, fine quartz, usually chlorite, and often ankerite. Imbedded in the matrix are coarser clastic particles up to several inches in diameter and ranging

in shape from angular to rounded. Coarser clastic particles may make up to 85 percent of the rock and consist of monomineralic grains, usually quartz and feldspar, as well as rock fragments.

These coarser clastic units range in thickness from a few inches to more than ten feet. In some cases the coarser rocks grade vertically into fine-grained lithologies, while in others the coarse units are interbedded with finer clastic units. Coarse clastic units occur both as lenses in finer units and as well-defined beds having sharply defined and usually undulating bedding surfaces. Since most good exposures are in road cuts and creek beds, their lateral extent cannot be determined precisely. However, the lateral extent of these units inferred from float and topographic expression indicate that individual units are discontinuous lenses that pass laterally from one lithologic type to another over distances of several tens to several hundreds of feet.

The sandstones vary not only in matrix and fragment content but also in size and abundance of detrital fragments. Virtually all the sandstones examined may be classified as feldspathic graywackes (Pettijohn, 1957). Pettijohn differentiates between graywackes and other sandstones on the basis of detrital matrix material versus void spaces which have been later filled with a cementing agent such as quartz and calcite. Graywackes have no void spaces initially but consist of sand-size fragments imbedded in a matrix which was deposited along with the coarse fragments. This matrix must make up 15 to 75 percent of the rock. Graywacke matrices generally recrystallize to mostly quartz, sericite, chlorite, and minor amounts of ankerite.

Wilhite sandstones contain up to about 80 percent ankerite. In many cases this is the main cementing agent of the rock. It would appear as though sandstones containing so high a percentage of carbonate should not be classed as graywackes. However, if ankerite formed as a result of reducing conditions in the environment and was recrystallized during diagenesis and metamorphism forming, in some cases, a coarsely crystalline mosaic, the rocks may be classed as graywackes (Pettijohn, 1957, p. 305).

A typical fresh sandstone or conglomerate consists of a green-gray (5GY 6/1) matrix enclosing detrital fragments of milky quartz and white feldspar grains. In some specimens, the quartz may be mostly blue-gray or dusty rose. In some, the dominant feldspar is pink perthite. The ratio of feldspar to quartz varies from 1:1 to 1:20. Grain shapes vary from spherical to ellipsoidal and the degree of rounding varies from angular to rounded. In general, the coarser grains are likely to be more rounded. Imbricate alignment of elongate pebbles is the usual case but they may also be suboriented to nearly random. Alignment and elongation of the pebbles is not due to metamorphism or tectonic deformation but is of erosional and depositional origin. Pebble sizes reach a maximum of about 2 1/2 cm but the usual size range is 2 mm to 1 cm. Other detrital material includes slate fragments, which vary from well-rounded pebbles to angular chips, and grains of chlorite and muscovite.

Upon weathering, both the carbonate and the feldspars are subject to rapid and thorough disintegration. The type of float produced depends on the size of the quartz grains and the degree of

cohesiveness between them. Most outcrops of sandstone or conglomerate are highly weathered and produce a sand or gravel residuum or float. Some conglomerates produce boulder and cobble-size float consisting of a honeycomb of quartz fragments apparently fused together. The void spaces have been produced by the weathering of feldspar and/or ankerite.

One unusual type of conglomerate or breccia consists of a tabular boxwork of milky quartz in a matrix of sand-sized grains. Only the weathered rock has been observed in which the sand matrix is very friable apparently due to the loss of feldspar or carbonate. Such a rock may result from the seeping of finer sand into a rubble of angular vein quartz fragments or, alternatively, the tabular quartz may represent veins of remobilized quartz "sweated" out during metamorphism and injected into fractures in the sandstone.

Detrital grains in the finer graywackes are well dispersed throughout the matrix, while in the coarser conglomerates they are close together and often in contact. Quartz grains all show undulose extinction which may vary in intensity from grain to grain. Strain shadows are often continuous across grain boundaries, indicating that the strain occurred after lithification. However, not all such strain shadows are optically continuous across grain boundaries, suggesting that some strain occurred during a previous history.

Both potassium and plagioclase feldspars are present, the diversity of types in any one sample seeming to increase with grain size. Feldspars exhibit varying degrees of alteration from virtually unaltered to near total destruction. This indicates that some alter-

ation took place prior to lithification otherwise all the feldspars would be more equally altered. Plagioclase typically shows albite and occasionally carlsbad twinning. Potassium feldspar, although usually not twinned, may show cross-hatch twinning typical of the low-temperature form, microcline. Pink feldspars in one sample were found to be perthitic. Feldspar grains also show undulose extinction but not nearly to the degree that quartz grains do.

Lithic fragments from igneous, sedimentary and possibly metamorphic rocks occur in the conglomerates, although most detrital fragments are monomineralogic. The feldspathic sandstones, however, seldom contain lithic fragments.

Muscovite occurs not only as detrital grains with ragged edges and as recrystallized sericite in the matrix but also as an alteration product of potassium feldspar grains. Chlorite, which is present in small amounts, is not evenly distributed and occurs in discreet grains within the matrix, possibly as an alteration product of detrital biotite. It is green, pleochroic, and has an anomalous Berlin blue interference color.

Sandsuck Formation

Definition

The Sandsuck Shale was named by Keith (1895a) for Sandsuck Branch southeast of Chilhowee Mountain. Keith applied the name to the shale lying stratigraphically beneath the sandstone and conglomerate which he considered to be basal Cochran Formation. However, King (1964) noted that there is actually much intertonguing between

the shale and the coarser rocks. He redefined the top of the Sandsuck as lying just below the base of the persistent beds of arkose and quartzite, which are in part maroon.

Hamilton (1961, p. 26-27) describes the Sandsuck of the Richardson Cove and Jones Cove quadrangles as siltstone and fine- to coarse-grained sandstone. "The rocks weather into chips parallel to the micaceous bedding planes. A few of the rocks contain carbonate." In thin section, the rocks show little alteration of detrital minerals such as chlorite, illite, and montmorillonite. Hamilton did not find prograde metamorphic sericite. He also reports slightly altered bronzy clastic biotite as more abundant than muscovite. Other minerals present include zircon, tourmaline, epidote, sphene, leucoxene, calcite, dolomite, ankerite, pyrite, and carbon. The fine-grained rocks have a faint slaty cleavage.

Hamilton describes the coarse-grained sandstone beds as quartzitic and occasionally feldspathic, usually containing less than 5 or 10 percent feldspar. Maximum grain size is about 3 mm in diameter. Hamilton estimates the maximum thickness of preserved section, in his report area, at about 1500 feet.

King (1964, p. 58-59) describes the Sandsuck in his report area as "olive green, or gray, non-calcareous, and largely argillaceous, but it contains numerous thin silty or sandy laminae, and much detrital mica on bedding surfaces; it weathers to hard rusty chips." The formation also contains partly feldspathic interbedded sandstone, often ankerite-rich. Based on thin section study, the argillaceous rocks are composed of 38 percent detrital material, mostly quartz, and

including muscovite, biotite, iron oxides, sphene, and plagioclase. The rest of the rock is composed of sericite and chlorite. The argillaceous minerals are concentrated along bedding planes causing a bedding plane foliation. There is no secondary cleavage. At no place in his report area are both the base and the top of the formation exposed in the same section. He estimates the thickness of one of the partial sections to be about 4,000 feet.

Neuman and Nelson (1965, p. 22-23) describe the Sandsuck as "Gray, thin bedded to fissile siltstone interbedded with feldspathic sandstone and conglomerate." They further describe these rocks as weathering to a drab-brown. "They are well-laminated fissile siltstones and fine sandstones, with conspicuous bedding surfaces at 3-10 mm intervals that are coated with large detrital mica flakes."

Occurrence Within the Parksville Quadrangle

Rocks of the Sandsuck Formation occur in the northeastern corner of the Parksville quadrangle between the south shore of Ocoee Lake and the bases of Chilhowee, Little and Sugar Loaf Mountains.

Lithology

The Sandsuck Formation in the Parksville quadrangle matches closely that of Hamilton (1961), King (1964), and Neuman and Nelson (1965). It consists of laminated siltstones in the lower part of the exposed section, grading upward into silty shales interbedded with feldspathic sandstones and conglomerates, and black, quartzose limestone. Siltstones underlie most of the peninsula between Baker Creek and Indian Creek inlets on the south side of Ocoee Lake.

Siltstone

The siltstones are generally moderate yellowish-brown (10YR 5/4) to pale olive (10Y 6/2), friable, and have a weathered appearance. Some of the rocks appear fresh except for the color while others are obviously deeply weathered. The writer did not know initially whether the freshest-appearing rocks were weathered drab brown or if this was their original color. However, later an outcrop of fresh, gray, laminated siltstone was found, well out into the peninsula, apparently the unweathered counterpart of the other rocks observed. It is probable that the drab brown or khaki colored rocks are altered from an original gray color.

The freshest rock is olive-gray (5Y 3/2) siltstone with laminations 1 to 3 mm thick of coarser siltstone or fine sandstone. The coarser layers are beginning to weather brown. There is no secondary slaty cleavage, only bedding plane fissility. Detrital mica flakes typically occur on bedding surfaces. Weathered samples have the same general appearance as the fresh, except for the color. The bedding surfaces are accentuated in the weathered rocks.

In thin section the fresh siltstone consists mainly of detrital grains in various stages of alteration. There has been obvious prograde recrystallization of the clay or micaceous constituents. Minerals present include angular quartz and feldspar grains of coarse silt-size and smaller. Feldspar is much subordinate to quartz and in various stages of alteration. Micaceous minerals include muscovite and a brown mica, probably detrital biotite or oxidized chlorite, sometimes interlaminated with green chlorite. The brown mica is pleochroic,

often has a bronze or golden cast, and its interference colors are masked by the mineral color. Grain size ranges up to 1 mm in length and 0.02 mm in width. It strongly resembles the brown pleochroic mica reported in the Wilhite Formation, subsequently identified in this study as oxidized chlorite. The size of the muscovite grains, which are mostly detrital, range from sericitic to 0.5 mm in length. Chlorite does not appear to be abundant in thin section, yet it shows up strongly in the x-ray diffraction pattern. Perhaps most or all of what appears to be weathered biotite is actually oxidized chlorite. All of the micas are oriented parallel to bedding fissility. Oxidation of iron in partially weathered ankerite is responsible for the incipient brown weathering in the coarser layers.

Shale

Silty shales interbedded with feldspathic sandstones and conglomerates are exposed along Highway 64 (T.C. 2,406,000-2,408,000 E.; 262,000 N.), and are interbedded with siltstones in exposures on the west side of Ocoee Lake at the foot of Sugar Loaf Mountain (T.C. 2,404,000 E.; 256,000-258,000 N.). These rocks are highly weathered and often sheared, the shearing presumably accompanying faulting that brings the Sandsuck into juxtaposition with the Chilhowee Formation on Little and Sugar Loaf Mountains. Bedding is seen not to be parallel with shearing. The silty shales are moderate yellowish-brown (10YR 5/4) to pale olive (10Y 6/2), very soft, and show little or no fissility other than along bedding planes.

Sandstone and conglomerate

Sandstones and conglomerates are best exposed along Highway 64 about 2,000 feet east of the Great Smoky fault (T.C. 2,404,000 E.; 262,000 N.). They are highly weathered to the same colors as the shales and siltstones described above. Indications are that they are feldspathic and ankeritic but only weathered exposures, from which these components have been removed, are available.

Limestone

A black, quartzose limestone is exposed in a lensoid body in a road cut on the north side of Highway 64, 800 feet west of the map boundary (T.C. 2,410,000 E.; 262,000 N.). It appears to be identical to exposures the writer has seen, near Servilla, Tennessee, in the Wilhite Formation and other exposures reported throughout the Wilhite Formation (Hamilton, 1961, p. 23-24; King, 1964, p. 53). This limestone is blue gray or black and fine grained, cut by numerous gash veinlets of calcite and contains frosted quartz sand grains. It lenses out along strike into a black sandy shale. In thin section it is seen to contain calcite, quartz, plagioclase, pyrite, and muscovite. Eighty percent of the rock is a mosaic of twinned, cloudy calcite. The gash veinlets are filled with similarly twinned calcite which is not clouded. Grains of quartz and feldspar are of coarse silt size and smaller, and are mostly angular. The feldspar is unaltered and displays good albite twinning. Pyrite is both euhedral and anhedral, the anhedral material concentrated along one bed which is about 40 percent pyrite. Pyrite cubes are less abundant and are scattered throughout the slide. Muscovite consists of individual grains with ragged edges, suggesting it is detrital.

Stratigraphic relations between the Wilhite and Sandsuck Formations

The Wilhite Formation in the Parksville quadrangle can be conveniently divided into two stratigraphic units: An upper unit dominated by argillites of Group 1 described previously, which is characterized by the presence of the sodium-rich mica, paragonite, and a lower unit dominated by sandstones and conglomerates interbedded with argillites, commonly belonging to Groups 2, 3 or 4, which are generally free of paragonite. The lower unit is exposed in a roughly U-shaped belt along the northern, northwestern, extreme southern, and southeastern portions of the Wilhite belt, while the upper unit underlies the central and extreme northern portions of the belt where it is in contact with the Sandsuck Formation. While intricate folding and possible thrust faulting interfere with accurate thickness calculations, it is estimated that about 3500 feet of lower unit rocks are exposed and about 1800 feet of upper unit rocks. These calculated minimums are based upon the structural interpretation represented in cross sections E-E' and F-F' (Plate II). If unexposed rocks underlying the area are added, the lower unit thickness may be increased to roughly 4,000 feet, making a total minimum thickness of 5,800 feet for the Wilhite Formation, based on the interpretation in the cross sections. How much of the section has been removed by erosion is impossible to determine.

The relationship of the Wilhite Formation to the Sandsuck Formation is not clear in the Parksville quadrangle because they are separated by the Baker Creek and Indian Creek faults (discussed in Chapter IV of this report). The problem of the stratigraphic relationship between the Sandsuck and adjoining formations, especially the Wilhite, is one which has plagued most other geologists who have

worked with these rocks. Hamilton (1961, p. 27) writes, "Not only is the stratigraphy of the formation itself questionable, but its presumed concordance with other formations is inadequately shown.... 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."

King (1964, p. 55) states that within his report area, the Wilhite and Sandsuck Formations are in fault contact, and therefore their stratigraphic relations cannot be determined. He suggests the possibility that the two sequences overlap but dismisses it as remote because of lithologic differences and the location of the Sandsuck beneath the Chilhowee Group suggests it is higher in the section. He believes, however, that the Wilhite and Sandsuck were originally deposited far apart and were later brought into juxtaposition by low-angle faulting. This leaves open the possibility that the two formations were deposited contemporaneously.

Neuman and Nelson (1965, p. 22) report: "The boundary of the Wilhite with the overlying Sandsuck Formation is not exposed in the report area where both the top of the Wilhite and the base of the Sandsuck are cut by faults."

In the Parksville quadrangle, division of Sandsuck and Wilhite Formations is based on the following criteria: gross lithologic differences (greenish-gray to gray non-feldspathic, argillaceous slates with fine dark laminations of the Wilhite contrasted with generally olive-drab, non-slaty, feldspathic, coarser-grained siltstones and conglomerates of the Sandsuck); slaty cleavage in the Wilhite versus

no slaty cleavage in the Sandsuck; recrystallized matrix and detrital material in the Wilhite versus essentially noncrystallization in the Sandsuck; and the obvious structural discontinuity separating the two units, the Indian Creek fault.

None of the preceeding criteria prove any stratigraphic succession from Wilhite to Sandsuck. However, these formations are different in lithologic character in several respects and they were probably juxtaposed after metamorphism occurred.

In the view of the present writer, based on the preceeding discussion, there are no reasons to support the view that the Sandsuck Formation stratigraphically succeeds the Wilhite. In fact, the occurrence of black, quartzose limestone in the Sandsuck, which appears identical to that found at numerous locations within the Wilhite, suggests they may be facies of each other. Until more conclusive proof is available, however, this writer believes both terms should be retained for the sake of continuity with the work done in the Great Smoky National Park, which is the most widely recognized work to date.

The location of the upper Sandsuck - lower Cochran Conglomerate contact is somewhat more secure. The Cochran is the lowermost formation of the Chilhowee Group and its base has been defined as the base of the Cambrian. Hamilton (1961), King (1964), and Newman and Nelson (1965), who mapped in the Great Smoky National Park have all found what they believe to be contacts between the Sandsuck and Cochran Formations.

Rackley (1951, p. 18 and 45) reports upper Sandsuck in contact with basal Cochran separated by about a 100 foot transition zone.

The present writer has confirmed this contact in two of the six locations named by Rackley.

Paleozoic Rocks

Chilhowee Group

General Features

Definition

The name Chilhowee Group is derived from Safford (1856, p. 152-153; 1869, p. 198-203) who applied the term "Chilhowee Sandstone" to rocks exposed on Chilhowee Mountain, the ridge between the foothills of the Great Smoky Mountains and the Valley and Ridge in Blount and Sevier Counties, Tennessee. The Chilhowee Sandstone is the middle member of Safford's Pottsdam Group, consisting of clean sands and whitish quartzose beds which contain the fossil Scolithus linearis and furoid impressions.

Keith (1895a) had included the Sandsuck Shale in the Cambrian, implying that it was the lowermost formation in the Chilhowee Group. Keith (1905, p. 3) subdivided the group, in ascending order, into the Cochran Conglomerate, Nichols Slate, Nebo Quartzite, Murray Slate and Hesse Quartzite. Keith (1903, 1907b) recognized units in northeastern Tennessee correlative with the Chilhowee Group but applied a new set of formational names because of the apparent pinching out of one of the shale layers. King and Ferguson (1960) were able to recognize all of the units of the Chilhowee Mountain area in northeast Tennessee and, also, were able to recognize one of the members of the north-

eastern Tennessee area (the Helenmode) in the Chilhowee Mountain area (Table III).

The present classification of the Chilhowee Group is basically after Keith (1895a) with modification by King (1964, p. 71) and is presented in Table III.

Occurrence Within the Parksville Quadrangle

Rackley (1951) mapped the Chilhowee Group in the Bean Mountain area. Bean Mountain, between the Hiwassee and Ocoee Rivers, and Starr Mountain, its extension north of the Hiwassee River, represent the southern continuation of Chilhowee Mountain which terminates just south of the Little Tennessee River. A distance of about twenty-three miles separates the southern end of Chilhowee Mountain and the northern end of Starr Mountain. Only a small portion of the southwestern corner of Bean Mountain extends into the extreme northeast corner of Parksville quadrangle. The southern portion of Bean Mountain is referred to on Tennessee Valley Authority topographic maps as Chilhowee, but to avoid confusion with Chilhowee Mountain to the north, the segment between the Hiwassee and Ocoee Rivers will be referred to as Bean Mountain in this report as it was in Rackley's report.

Rackley also mapped Little and Sugar Loaf Mountains, fault slices of incomplete Chilhowee sections along the Great Smoky fault, which lie completely within the Parksville quadrangle. He extended his mapping southward from Sugar Loaf Mountain to Cookson Branch (T.C. 2,402,000 E.; 250,000 N.).

On Bean Mountain proper, he recognized and mapped the Cochran Conglomerate, Nichols Shale, Nebo Quartzite and Murray Shale. No

TABLE III

FORMATIONS OF THE CHILHOWEE GROUP IN TENNESSEE AND VIRGINIA

		East-central Tennessee (Chilhowee Mountain)	Northeastern Tennessee (Johnson, Carter and Unicoi Counties)	Northern Virginia (Elkton and Harpers Ferry areas)
		Shady Dolomite (in Miller Cove)	Shady Dolomite	Tomstown Dolomite
Lower Cambrian	Chilhowee Group	Hesse Quartzite	Erwin Quartzite	Antietam
		Murray Shale		Quartzite
		Nebo Quartzite		
		Nichols Shale	Hampton Shale	Harpers Shale
		Cochran Conglomerate	Unicoi Formation (with basalt flows 1000-1500 feet below top)	Weverton Quartzite
				Loudoun Formation (with tuffaceous slate and rare flows)
Precambrian		Ocoee Series	Volcanics of Mt. Rogers area	Catoctin Greenstone Swift Run Formation
			Cranberry Granite	Injection Complex

(Adapted from King, 1949, 1964).

Hesse Quartzite or Helenmode Member were recognized. The fault slices of Little and Sugar Loaf Mountains, and the area southward along the Great Smoky fault to Cookson Creek, were mapped as Chilhowee Group undifferentiated. Rocks underlying this area consist mainly of quartzite and quartzose sandstones strongly resembling the Nebo, Hesse, and some units within the Cochran. In the absence of a more complete section, correlation could not be made with any specific unit within the Chilhowee Group (Rackley, 1951, p. 37-38).

The present writer agrees with Rackley's interpretation of Little and Sugar Loaf Mountains. South of Sugar Loaf Mountain Chilhowee quartzite crops out at the intersection of Baker Creek Road and a private road serving lake shore cabins at the base of Sugar Loaf Mountain on the shore of Ocoee Lake (T.C. 2,402,000 E.; 254,000 N.). However, the present writer disagrees with Rackley's extension of the Chilhowee Group south of Baker Creek Road. Outcrops east of this intersection for at least one mile consist of highly weathered conglomerate and interbedded pea-green shale typical of the Wilhite Formation. The conglomerate which Rackley calls Chilhowee at the intersection of Cookson Branch and the Great Smoky fault is Wilhite conglomerate and graywacke.

Further mapping, by the present writer, along the Great Smoky fault, south of the Tennessee Divide (T.C. 2,390,000-2,394,000 E.; 226,000-238,000 N.), revealed a ridge-forming quartzite and quartzitic conglomerate. It differs from typical Ocoee conglomerate in that it contains little or no "matrix" material, carbonate, feldspar, or rock fragments. The quartz grains are in contact and well cemented or

fused together, producing a float of coarse boulders. It more closely resembles the Chilhowee than the Ocoee, differing from typical Chilhowee only in being coarser grained and more conglomeratic. Jasperoid float from the ridge, found in a draw (T.C. 2,392,000 E.; 236,000 N.) was identified by G.D. Swingle (personal communication, 1969), as derived from basal Shady Dolomite. If Shady, it probably represents the last remaining remnants eroded from the ridge. However, similar jasperoidal material has been noted in some units of the Cochran Conglomerate. The ridge is tentatively mapped as Chilhowee, undifferentiated, until its stratigraphic position can be confirmed by closer investigation.

Conasauga Group

General Features

Definition

Hayes (1891, p. 143) and Walcott (1891, p. 304) used the term Conasauga to designate argillaceous shales, containing some interbedded limestone, that define a belt followed by the Conasauga River in Whitfield and Murray Counties, Georgia. Equivalent rocks were called Coosa and Flatwood shales by Smith (1890) and Knox shales by Safford (1856). Northward from the type area, carbonate beds become more persistent in units of the same age, and eventually separate formations can be recognized.

The Conasauga Group is of Middle to Late Cambrian age and includes all units between the Rome Formation and the base of the Copper Ridge Dolomite of the Knox Group. Based on faunal evidence, the Pumpkin Valley Shale, (Rodgers and Kent, 1948), Rutledge Limestone,

Rogersville Shale, and Maryville Limestone (Resser, 1938; Oder, 1934) are of Middle Cambrian age, while the Nolichucky and Maynardville Formations are Late Cambrian.

Occurrence Within the Parksville Quadrangle

Rocks of the Conasauga Group underlie the northwest portion of the Parksville quadrangle in Polk and Bradley Counties, Tennessee, which is an extension of an outcrop belt in the adjacent Cleveland quadrangle mapped and described by Swingle (1959). A narrow belt of Conasauga Shale also extends from the road cut just west of Cloud Branch, northward along Cloud Branch, intersecting the Parksville-Benton Road at the northern map boundary (T.C. 2,400,000 E.; 264,000 N. to 2,404,000 E.; 270,000 N.). Earlier, Rodgers (1953), and more recently, the Geologic Map of Tennessee, Swingle, et al. (1966) show this belt as Athens, but the outcrop on U.S. Highway 64 contains fissile shale typical of the Conasauga Group and not the splintery weathered fragments characteristic of argillaceous beds in the Athens. Moreover, the outcrop has a zone of fossils containing inarticulate brachiopods and trilobites identified as Elrathea. Highly deformed shale with lenses of limestone are exposed in the highway cut along U.S. Highway 64 a few hundred feet west of Ocoee Dam No. 1. Across the Ocoee River, in an abandoned quarry at the base of Sugar Loaf Mountain, Maynardville Limestone is exposed in contact with Copper Ridge Dolomite (T.C. 2,402,000 E.; 260,000 N.).

Although some carbonate units occur in the Conasauga, they are not persistent enough to allow subdivision of the group as is done farther to the north. Swingle (1959) divided the belt in the Cleveland

quadrangle, southeast of the Knoxville fault, into (1) a lower shale and limestone sequence which he designated the lower siltstone and shale sequence and Nolichucky Shale, undifferentiated, and (2) the overlying Maynardville Limestone. In the present report the units will simply be referred to as (1) the Conasauga Shale, for the lower unit, and (2) the Maynardville Limestone, for the upper unit.

Conasauga Shale

The lowermost Conasauga Shale in the Parksville quadrangle consists of beds of siltstone one to four inches thick interbedded with thinly laminated to laminated, silty, micaceous shale of mostly pale yellowish-brown (10YR 6/2) and similar colors. These rocks are best exposed just north of the Parksville quadrangle, in the southwest corner of the Benton quadrangle (126-NW), in a road cut along U.S. Highway 64 between U.S. Highway 411 and the west boundary of Benton quadrangle.

The thin-bedded siltstones and silty shales pass upward into shales and thin beds and lenses of argillaceous limestone. The rocks are characterized by a pale olive (10Y 6/2) micaceous, slightly silty, thinly laminated to laminated shale and a pale yellowish-brown (10YR 6/2) thinly laminated claystone. This latter type often displays faint pastels of pink, maroon, and purple. The shale generally becomes less silty toward the top of the unit. The limestone is thin- to medium-bedded, microcrystalline and sucrosic, weathering to give a blue ribboned or "straticulate" appearance. Secondary veinlets of white calcite commonly are present along fractures.

Marked topographic breaks result from the variation in resistance to weathering and erosion between the clastic and carbonate units; the more resistant clastics underlying low, knobby topography while the more soluble carbonates underlie shallow valleys. Removal of the carbonate material from the shaly limestone produces a soil containing the remaining shaly material but the soil is usually sufficiently mixed with colluvium produced from siltstones and shales that it becomes impossible to trace carbonate beds by soil type if exposures are not present or if there are no marked topographic breaks. Conasauga Shale yields a thin soil containing shale chips and is quite distinguishable from most other soils of the area.

The thickness of the Conasauga Shale in the northwest corner of the Parksville quadrangle is virtually impossible to determine because of its incompetence and probable repetition of section by faulting. Swingle (1959) very tenuously estimates the thickness of the entire unit at less than 1,000 feet and believes that the lower silty beds are thicker than the overlying shales and limestones. Since most of the section in the Parksville quadrangle consists of upper unit shales and limestones together with a small thickness of lower siltstone, the thickness is probably less than 500 feet.

Maynardville Limestone

The Maynardville Limestone closely resembles the limestone beds and lenses described for the lower Conasauga Shale unit. It is a thin-bedded, grayish-brown (5YR 3/2) sucrosic limestone. The weathering surface is dark-blue with a ribboned or "straticulate"

appearance due to shaly partings 1/8 inch to 1/2 inch thick. It is microcrystalline and commonly contains veinlets of secondary white calcite.

In the belt west of Sand Mountain, only one outcrop was observed within the Parksville quadrangle, but the contact between the Maynardville Limestone and the overlying Copper Ridge Dolomite is exposed in the extreme southeastern corner of Felker quadrangle (120-SE), just off the southwestern corner of Parksville quadrangle. The one small outcrop area, occurring within Parksville quadrangle, is located on Little Chestuee Creek, west of Sand Mountain (T.C. 2,378,000 E.; 260,000 N.). Outcrops occur in the creek, which at this point mark the contact between the Maynardville Limestone and the underlying Conasauga Shale, and extend about half way up the west slope of the adjacent ridge where the Copper Ridge Dolomite crops out. Although neither the upper nor the lower contacts of the Maynardville are visible they can be inferred within 10 or 15 feet. The lower contact controls the drainage of Chestuee Creek and is marked by the break in topography at the base of the ridge as well as a change to a soil typical of that derived from Conasauga Shale. The upper contact is inferred from the close proximity of Maynardville and Copper Ridge outcrops.

A road cut 300 feet southeast of the intersection of Ladd Spring and Old Fort Roads (T.C. 2,374,000 E.; 240,000 N.) containing carbonate rocks altered to saprolite, exposes the contact between the Maynardville and the overlying Copper Ridge Dolomite. Although the contact between the two formations cannot be precisely determined,

it is arbitrarily placed below the zone carrying heavy chert derived from the Copper Ridge. The base of the Maynardville, although not exposed, is easily determined near the intersection of Ladd Spring and Old Fort Roads by an abrupt change from a thick, red, carbonate-derived residuum to a thin, gray-brown, shaly soil. The Maynardville Limestone in the western strike belt underlies the west side of the ridge capped by the lowest Copper Ridge Dolomite.

The thickness of the Maynardville in the west belt is about 250 feet based on the width of outcrop and the average dip angle of 30°.

East of Sand Mountain the upper Maynardville Limestone - basal Knox contact is exposed in quarries located at T.C. 2,398,000 E.; 242,000 N. and 2,402,000 E.; 260,000 N. A saprolite exposed in the eastern part of the road cut exposing Conasauga Shale, located on U.S. Highway 64 (T.C. 2,400,000 E.; 264,000 N.), is also interpreted as Maynardville.

Knox Group

General Features

Definition

Safford (1869) named a Knox or Knoxville Group, consisting of the Knox Dolomite, the Knox Shales (presently the Conasauga), and the Knox Sandstone (presently the Rome), for exposures in and around Knoxville, Tennessee. The term later became restricted to the dolomite (Smith, 1890; Keith, 1895a). Presently the Knox Group extends from the top of the Maynardville Limestone to the marked disconformity separating Lower and Middle Ordovician rocks.

In compiling previous work done on the Knox, Rodgers (1953) notes that a marked change in lithology occurs from the northwestern strike belts to those in the southeast. He divides the Knox, on this basis, into a northwestern phase, which is dominantly dolomite, thick-bedded, and containing much chert which accumulates in the residual soil, and a southeastern phase consisting mainly of limestone, containing much less chert and characterized by a prominent group of sandstone beds below the middle of the group. Separation of the two phases for mapping is made at the Pulaski fault.

At the time of Rodgers' compilation, the northwestern phase of the Knox had been subdivided into the following formation (in descending order).

<u>Name</u>	<u>Map Symbol</u>	<u>Original Description</u>
Mascot Dolomite	Oma	Oder and Miller, 1945
Kingsport Formation	Ok	Oder and Miller, 1945
Longview Dolomite	Olv	Butts, 1926
Chepultepec Dolomite	Oc	Ulrich, 1911
Copper Ridge Dolomite	Cr	Ulrich, 1911

Recently, Harris (1969) questioned the subdivision of the units above the Copper Ridge and has resubdivided it as follows:

<u>Previous Classification</u>	<u>Harris' Classification, 1969</u>
Mascot Dolomite	Mascot Dolomite
Kingsport Formation	Kingsport Formation and Longview Dolomite
Longview Dolomite	
Chepultepec Dolomite	Chepultepec Dolomite

In regrouping the units he has lowered the Mascot-Kingsport contact and includes most of the original Longview with the Kingsport, except for a small section of lower Longview which he includes with the Chepultepec.

Units of the Knox in this report will be defined as follows:

<u>Name</u>	<u>Map Symbol</u>	<u>Rodgers' Equivalent (1953)</u>
Upper Knox	Oku	Mascot Dolomite Newala Kingsport Formation Formation
Middle Knox	Okm	Longview Dolomite Chepultepec Dolomite
Copper Ridge Dolomite	✶cr	Copper Ridge Dolomite

Occurrence Within the Parksville Quadrangle

Formations of the Knox Group underlie a belt approximately 1.5 miles wide running the full length of the quadrangle west of Sand Mountain and much of the area between Sand Mountain and the Great Smoky fault to the east. Outcrops are very rare except along a belt underlain by Upper Knox (Kingsport and Mascot) along the eastern and western flanks at base of Sand Mountain. Mapping the upper and lower contacts of the group, especially in the belt west of Sand Mountain, was accomplished on the basis of topographic expression and changes in residual soil type. However, distinguishing individual formations within the group is very tenuous.

Copper Ridge Dolomite

Outcrops of Copper Ridge west of Sand Mountain occur in an abandoned quarry in the extreme southeastern corner of Felker

quadrangle, just south of the intersection of Frazier Road and Chestuee Creek (T.C. 2,378,000 E.; 260,000 N.) and along the west side of the next ridge to the west (T.C. 2,380,000 E.; 258,000 N.). In the Parksville quadrangle outcrops of saprolite occur in the road cut along Ladd Spring Road (cited on page 50).

Copper Ridge of the belt west of Sand Mountain consists mainly of dolomite, but one small outcrop of limestone was observed. The dolomite is medium to thickly bedded, medium dark-gray (5YR 4/1), microcrystalline and is asphaltic on fresh fracture. It contains much dark porous cryptozoan chert in the lower third of the formation and much bedded dark nodular chert in the upper two-thirds. The contact with the Maynardville Limestone is placed below the lowermost heavy chert concentrations. Sandstone beds at the top of the formation mark the contact with the overlying Middle Knox unit. These sandstone beds are only found in a few places in the western belt; hence, much of the contact must be inferred. The Copper Ridge - Middle Knox contact also marks the Cambro-Ordovician boundary. Thickness of the Copper Ridge Dolomite in this area, based on a dip angle of 30° , is about 1,000 feet.

Between Sand Mountain and the Great Smoky fault, the Knox Group has been intensely disrupted by faulting and one cannot rely on any sequential order of the formations. There are a number of isolated outcrops of Knox Dolomite, but in most cases it cannot be determined whether these are Copper Ridge or some other formation of the Knox.

The contact between the Copper Ridge and the Maynardville is exposed at the base of the quarry wall on the south bank of the Ocoee

River 1,000 feet downstream from Ocoee Dam No. 1 (T.C. 2,404,000 E.; 260,000 N.). Limestone outcrops on the Parksville-Benton Road, 800 feet south of the northern map boundary (T.C. 2,404,000 E.; 270,000 N.), probably belong to the southeastern equivalent of the Copper Ridge. An outcrop at nearby Rymer Spring (T.C. 2,406,000 E.; 268,000 N.) consists of limestone and dolomite. Limestone and dolomite breccia correlative with Copper Ridge of the western belt is found in the foot-wall of the Great Smoky fault in many places. Outcrops in the quarry 1,000 feet downstream from Ocoee Dam No. 1 contain straticulate Maynardville Limestone overlain by Copper Ridge or its southeastern phase equivalent.

An old quarry located on the northern map boundary 300 feet east of the Ocoee River contains medium-gray (N5) fine- to coarse-grained limestone which weathers to light-gray (N7). A minor amount is oolitic. It contains a moderate amount of chert, mostly in the form of porcelanous disc-shaped nodules of a grayish red-purple color (5RP 4/2). Upon weathering, the rock leaves an insoluble residue of dark yellowish orange (10YR 6/6) clay-like material on the surface. This limestone and its weathering residue closely resemble the Upper Knox Limestones. However, the quarry is almost directly along strike from residuum containing cryptozoan chert, characteristic of the Copper Ridge Dolomite (T.C. 2,394,000 E.; 266,000 N.). For this reason, the limestone is believed to be Copper Ridge or its equivalent, perhaps belonging to the southeastern phase.

Middle Knox Dolomite

Middle Knox Dolomite combines the Chepultepec Dolomite and the Longview Dolomite recognized in the next strike belt to the west by Swingle (1959). The unit extends upward from the sands marking the Cambro-Ordovician boundary to the base of the Upper Knox unit.

Only one area of outcrop is present in the belt west of Sand Mountain. This is on the east slope of the ridge west of Fry Branch just south of U.S. Highway 64 (T.C. 2,392,000 E.; 262,000-264,000 N.). The rock is a thick-bedded, brown, sucrosic, microcrystalline dolomite, containing abundant interbedded black massive chert. The maximum thickness of the Middle Knox Dolomite west of Sand Mountain is about 2,500 feet based on dip angle of 30° (see cross sections, Plate II).

East of Sand Mountain the black, massive-bedded chert and dolomite, underlying the ridge beginning south of Baker Road and continuing southeast along the west side of Cookson Branch to the Great Smoky fault (T.C. 2,398,000 to 2,400,000 E.; 248,000 to 254,000 N.), is correlated with the Middle Knox Dolomite. It is similar in character and bears about the same structural and stratigraphic relationship to the Upper Knox unit as in the west belt.

Upper Knox Unit

The Upper Knox unit extends from the top of the Middle Knox Dolomite (units containing massive black chert) to the base of the Athens Shale. Outcrops of interbedded limestone and dolomite are prominent in a belt approximately 1,000 feet wide along the west side of the base of Sand Mountain. East of Sand Mountain a similar belt

extends from approximately T.C. 2,396,000 E.; 256,000 N. southward to the vicinity of Hilliard-Ladd Cemetery (T.C. 2,396,000 E.; 246,000 N.).

The Upper Knox consists of medium-gray (N5) to dark-gray (N3) finely crystalline limestone, which breaks with a conchoidal fracture, and medium- to thick-bedded, light olive-gray (5Y 6/1), silty and finely crystalline dolomite. Much of the limestone is mottled red or green.

Stratigraphic relationships between the Upper Knox and the other Knox units on the one hand, and Middle Ordovician units on the other are clear cut and obvious in the west belt (Plate I). In the east belt, however, these relationships are less clear, complicated by structural disruption and because the southeastern facies of the Copper Ridge is often a limestone which is difficult to distinguish from the Upper Knox. While the Upper Knox outcrop belt clearly underlies the Athens Shale in the southern part of the area, in the northern part it seems to be overlain by a highly silicious dolomite breccia interpreted as the Copper Ridge or the upper part of the Middle Knox. A typical outcrop of Upper Knox near the intersection of Sloan and Baker Creek Roads (T.C. 2,396,000 E.; 256,000 N.) contains abundant Ceratopora fossils, characteristic of the Upper Knox unit.

Middle Ordovician Units

General Features

Two rock units of Middle Ordovician age overlie the Knox Group in the Parksville quadrangle. The older unit is probably the equivalent of the Athens Shale while the younger unit has many of the

characteristics of the units variously referred to as Tellico Formation, Chota Formation, and Ottosee Shale. The controversy over the Chickamauga Group and its equivalents still rages and attempting to resolve it is beyond the scope of this report. Lithologic descriptions of the rocks are presented and compared with some of the rocks of probable equivalent age elsewhere in the Appalachian Valley. Since correlation of the younger unit appears to be more tenuous than that of the older unit, the younger unit will be referred to in this report simply as the upper Middle Ordovician unit. Correlation of the older unit to the Athens Shale is more certain.

Athens Shale

Definition

The name Athens Shale was proposed by Hayes (1894) for Upper Ordovician shale occurring at the top of the Chickamauga Limestone. Rodgers (1953) assigned the term Reedsville to these shales. Rodgers (1953) and Swingle (1959) use the term Athens for Middle Ordovician sediments occurring between the Lenoir Limestone and the Holston Formation.

Occurrence Within the Parksville Quadrangle

The Athens Shale underlies the prominent topographic feature called Sand Mountain which occupies a large area near the center of the mapped area. In the middle and southern portions of the quadrangle Sand Mountain consists of two ridges separated by an intervening valley. The east ridge appears to have been overridden by the Great Smoky fault. Toward the north Sand Mountain merges into a single

ridge which extends northward into Benton quadrangle (126 NW) where it is shown to be cut off by an extension of the Pulaski fault (Geologic Map of Tennessee, Swingle, et al., 1966). The southward continuation of the Athens, in Cohutta Mountain quadrangle in Georgia, was mapped and described by Salisbury (1961). The thickness of the unit in the southern portion of the Parksville quadrangle, where a complete section is present, is estimated to be about 4,000 feet, which agrees with Salisbury (1961, p. 18).

Lithology

The Athens Shale in this report area is largely composed of calcareous, silty shale, argillaceous, silty limestone, and feldspathic siltstones and sandstones. Coarser clastics are commonly cross-bedded and spheroidal weathering is common. The areas underlain by the coarser clastic units are topographically expressed by the various ridges of Sand Mountain, while the intervening valleys are underlain by the calcareous-rich sediments.

Argillaceous limestones and calcareous shales are softly laminated (not unlike the Sandsuck siltstones). Color on fresh surfaces is olive gray (5Y 4/1) to light olive gray (5Y 5/2), occasionally medium light gray (N6). These rocks characteristically weather to splintery fragments less than one inch long, pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6).

Completely fresh exposures of the coarser siltstones and sandstones were never observed. Even the freshest rocks at least had their original color changed due to weathering of feldspars (and in some cases the dissolving of calcite) and the formation of iron

oxides. The high permeability of these rocks probably contributes to this ubiquitous weathering. Most of the sandstones become very friable after short exposure to the atmosphere, and disintegrate, producing a sand float. Some sandstones, however, are orthoquartzitic, possessing a framework of fused or cemented quartz grains which produce a blocky float upon weathering. Their surfaces are typically very light gray (N8) while beneath the surface a brown to red color is imparted by iron oxides and weathered feldspars.

Rodgers (1953) describes the Athens Shale, in the vicinity of Athens, as partly shaly nodular limestone and partly blue, yellow-weathering very calcareous shale. Northeastward in that strike belt, (the next strike belt northwestward from this report area) in the vicinity of the Monroe-McMinn County line, the Athens Shale grades laterally into the Lenoir Limestone which, at this point, is predominantly a yellow-weathering shaly nodular limestone. The Athens and Lenoir in this area contain no coarse clastic units like those in the Parksville quadrangle.

Swingle (1959) describes the Athens Shale of the Cleveland quadrangle (in the same strike belt as above, but to the southwest) much the same as Rodgers, except he reports thin zones of ferruginous siltstone in the upper portion.

Just north of the McMinn-Polk County line, northeast of Parksville in the same strike belt, the Athens again appears. The Geologic Map of Tennessee, Swingle, et al. (1966) continues to show Athens northeastward to Six Mile where it passes laterally into Sevier Shale. The Sevier Shale on the northwest side of the Bays

Mountain syncline is described by Rodgers (1953) as a blue shaly nodular limestone. Blue or gray, brown-weathering sandstone occurring throughout the formation becomes coarse, feldspathic and noncalcareous to the southeast. A southeastern source area for these sediments is indicated.

Upper Middle Ordovician Unit

Overlying the typical Athens Shale is a sandy, red-weathering calcarenite. Rodgers (1953, p. 80-81) correlated this unit with the Holston Formation, while Salisbury (1961, p. 18) called it the Chota Formation, a name taken from Chota School, Vonore quadrangle, Monroe County, Tennessee, (Proposed by Neuman, 1955, p. 157, to apply to the "Sandstone lentil of the Sevier Formation" of Keith, 1895a, 1896). Neuman described the Chota as stratigraphically underlying the Sevier Shale and overlying the Tellico Formation, even though it closely resembles quartzose calcarenites within the Tellico.

Most of the unit near Wilson Bend, near the southern map boundary, consists of quartzose calcarenite. In several other localities, however, in Parksville quadrangle (T.C. 2,386,000 to 2,390,000 E.; 228,000 to 230,000 W.) the calcarenite is interbedded with a yellow-weathering silty shale, very much like the Athens and the Ottosee. The soil at these locations contains shale chips in a red-brown sandy soil.

The unit is expressed topographically by a series of semi-conical hills, separated by deep saddles, overridden by the Great Smoky fault.

Neuman (1955) had differentiated between the Chota and the red sandstones of the Tellico. Salisbury (1961, p. 19) summarized these differences on the following bases: "1) The calcarenite of the Chota Formation is more than 50 percent calcite, whereas the proportion of noncalcareous material, including detrital grains and clay, is much higher in the sandstone of the Tellico Formation. 2) The Chota contains no feldspar grains, whereas the Tellico has a notable feldspar content. 3) The Chota is characterized by cross-bedding and wavy bedding-plane partings, whereas all current features are very rare in the Tellico. 4) Little quartzose calcarenite of the Chota contains sufficient insoluble material to retain its cohesiveness after the calcium carbonate has been dissolved; weathered rock, therefore, rarely has a thick porous rind. The sandstone of the Tellico, on the other hand, retains its cohesiveness after weathering, even though it becomes quite porous. 5) The Chota Formation produces a deep red soil composed of a mixture of sand and clay, whereas the Tellico produces a soil containing small porous blocks of weathered sandstone and many thin shale chips."

Rodgers (1953) interpreted the sequence in the Parksville quadrangle as Holston Formation overlain by Ottosee Shale. It now seems apparent that Holston-type lithology appears throughout the section of Middle Ordovician at various stratigraphic levels. Thus the term "Holston Formation" has been largely discarded. Moreover, the red quartzose calcarenite in question is not even of Holston-type lithology.

Four thin sections of the red quartzose calcarenite, collected just south of the map boundary between Parksville quadrangle and Cohutta Mountain quadrangle, at Wilson Bend in the Conasauga River, were examined by the present writer to determine whether the criteria cited by Salisbury (1961) could be used. In one thin section, detrital noncalcareous material made up about 50 percent of the section. In the other three it was somewhat less, so that in this respect the rock fell somewhere between Chota and Tellico, but leaned toward Chota. All four sections contained considerable feldspar, mostly fresh, consisting of albite, microcline, and perthite, all exhibiting appropriate twinning and perthitic features. An x-ray diffraction profile of one sample showed quartz, calcite, albite, microcline, and traces of dolomite and muscovite. The presence of feldspar would seem to eliminate Chota. Salisbury (1961, p. 20) reported a few small grains of feldspar in thin section.

Of the four thin sections examined in this study, one was a limestone breccia and three were quartzose calcarenites. The breccia contained, in addition to the same minerals as the quartzose calcarenite, angular fragments of detrital limestone, mostly lithographic, 1 or 2 cm in diameter. The other three sections were similar except for the size of the quartz and feldspar grains. In two samples the grains ranged from 0.1 to 0.55 mm with most grains between 0.2 and 0.4 mm. In a third section they averaged about 0.1 mm and were better sorted. Even though the degree of rounding ranged from angular to well rounded, most grains were angular to subangular. Apparently grain-size sorting was accomplished without either significant abrasion or

chemical alteration of most grains. Since some of the grains were well rounded, it is possible that material was contributed from several sources. Carbonate occurs both in cloudy patches and in well-twinned crystals of sparry calcite.

Crossbedding was not observed by the writer because most of the rocks were overgrown with vegetation. Wavy bedding plane partings, characteristic of the Chota, were observed. Upon weathering, the rock loses its cohesiveness, another characteristic of the Chota.

In the writer's view, this unit cannot be assigned, with any certainty, to either the Chota or the Tellico and he feels that its assignment should not be made until the whole Middle Ordovician problem in East Tennessee has been more thoroughly resolved.

CHAPTER III

MINERALOGY AND PETROLOGY OF THE OCOEE FINE CLASTIC ROCKS

Methods of Study

Due to the fine-grained character of the Ocoee Series argillites in the Parksville quadrangle, microscopic examination does not typically yield detailed information about the mineralogy of these rocks. Therefore, considerable dependence has been placed on x-ray diffraction methods of mineral identification. Even so, the microscope had to be relied upon to detect minute amounts of certain phases and to study textural relationships. In all, about 100 thin sections were studied, their descriptions are summarized in Chapter II. A brief description of the x-ray method used follows.

A Norelco high angle diffractometer (copper radiation $\lambda = 1.5418 \text{ \AA}$) with an x-ray focusing monochromator, was used for all analyses. Each sample was ground to pass a 120 mesh sieve and pressed into a standard aluminum holder. This method results in partial preferred orientation of non-equidimensional minerals, such as the platy clay minerals, enhancing their (00 ℓ) reflections relative to the (hkl) reflections, but this offers no problem in routine mineral identification. For routine analyses the following settings were used: goniometer speed, $1^\circ 2\theta$ per minute; chart speed, $1/2''$ per minute; divergent, scatter, and receiving slits, 1° , 1° , and 4° , respectively; scale, 250 counts full scale; and time constant, 5.

Mineralogy

Muscovite and Paragonite

Muscovite, or some 10 Å layered silicate, is present in every sample of fine-grained Ocoee rocks. In this report the term muscovite will be used as a general term for all layered silicates having a 10 Å spacing. The term "sericite" is used to describe very fine-grained muscovite observed microscopically. Paragonite, the sodium analog of muscovite, was positively detected in about half of the samples x-rayed and may be present in amounts too small to detect (less than 5 percent) in other samples.

Muscovite and paragonite typically occur in the Ocoee rocks, southeast of the Indian Creek fault, as sericitic flakes measuring less than 0.1 mm along the a-axes, which are commonly oriented parallel to the slaty cleavage or to the bedding if secondary slaty cleavage is not developed. Muscovite (and paragonite?) also occurs as micro-porphyroblasts of fibrous aggregates from 0.1 mm to 0.4 mm across, often interleaved with chlorite and cross-cutting the slaty cleavage. Such muscovite is not detrital, but formed by recrystallization.

By contrast, the coarser muscovite in the rocks northwest of the Indian Creek fault and northeast of Baker Creek fault appears to be detrital. Although the matrix has much fine sericite, the detrital origin of the coarser grains is indicated by their generally ragged edges. Much of the coarse micaceous material is difficult to identify as to mineral species because it is in a state of partial decomposition. Mica grains are well oriented parallel to bedding.

In general, the x-ray diffraction profiles reflect an increase in the crystallinity of the muscovite from northwest to southeast. The $(hk\ell)$ reflections for muscovite, which are broad and diffuse northwest of the Indian Creek fault, sharpen southeastward to the fault. Samples from the peninsula between Baker Creek and Indian Creek inlets show muscovite peaks which are rather diffuse but most of the $(hk\ell)$ reflections for the 2M polymorph can be identified. North of the Lake, along U.S. Highway 64, the $(hk\ell)$'s are characteristic of the 1M rather than the 2M polymorph. For example, the (114) reflection of 2M muscovite occurs at $27.8^\circ 2\theta$, and this peak is not present in diffraction patterns of the 1M polymorph.

Samples taken along U.S. Highway 64, about 1,000 feet northeast of Ocoee Dam (T.C. 2,404,000 E.; 260,000 N.), show no peak near 27.8° , yet they have fairly sharp and intense $10 \text{ \AA}$ peaks. From the location of other diffraction peaks it is obvious that the dominant polymorph in these samples is the 1M muscovite. In addition, these samples show unusually intense peaks at about 27.5° , which is the most intense peak for microcline. The overall pattern is identical to several from known Chilhowee Group shales in ⁷Madison County, Tennessee. The samples from the above location are near the contact of the Ocoee and Chilhowee Groups, and on the basis of the diffraction patterns they were assigned to the Chilhowee. Samples taken beginning 1,500 feet farther east on U.S. Highway 64 have peaks near $28^\circ 2\theta$ which increase in intensity eastward. This indicates an increasing percentage of 2M mica in the sample.

Southeast of the Indian Creek fault, the peaks are generally sharp and represent almost exclusively reflections for 2M muscovite.

However, peaks at 24.4° ($3.65 \text{ \AA}$) and about 29.1° ($3.06 \text{ \AA}$) persist on many of the profiles. They are about the same intensity and, in general, their relative intensities decrease southeastward. They are interpreted, respectively, as the $(11\bar{2})$ and the (112) reflections of 1M muscovite. Yoder and Eugster (1955) give the intensities of these peaks as 60 and 50, respectively, and their locations as 24.315° and 29.055° , respectively. The question is, are these samples mixtures of the two muscovite polymorphs, or is the muscovite in a transitional stage from 1M $\rightarrow$ 2M muscovite?

There are two possible reasons for the occurrence of both 1M and 2M reflections in the same sample.

1) They may represent a mixture of two polymorphs. The 2M may be either detrital or recrystallized, whereas the 1M may be sedimentary clay material or have been produced by the recent weathering of 2M muscovite or other aluminosilicate minerals. 2) They may represent transitions between 1M and 2M and not simply a mixture of the two phases.

Yoder and Eugster (1955) published a series of comparative diffraction profiles from synthesized muscovites showing the transition from 1Md $\rightarrow$ 1M $\rightarrow$ 2M with various mixtures of 1M and 2M representing the transition stages (Figure 3). They also show a group of profiles for some pure polymorphs of muscovite (Figure 4). Together with these profile tracings they have tabulated diffraction data for 1M and 2M polymorphs (Tables IV and V). In Figure 3, the intermediate stages represent transition phases between 1M and 2M and not simply physical mixtures of the two polymorphs. The transition is best monitored by observing the changes in the intensities of the $11\bar{2}$

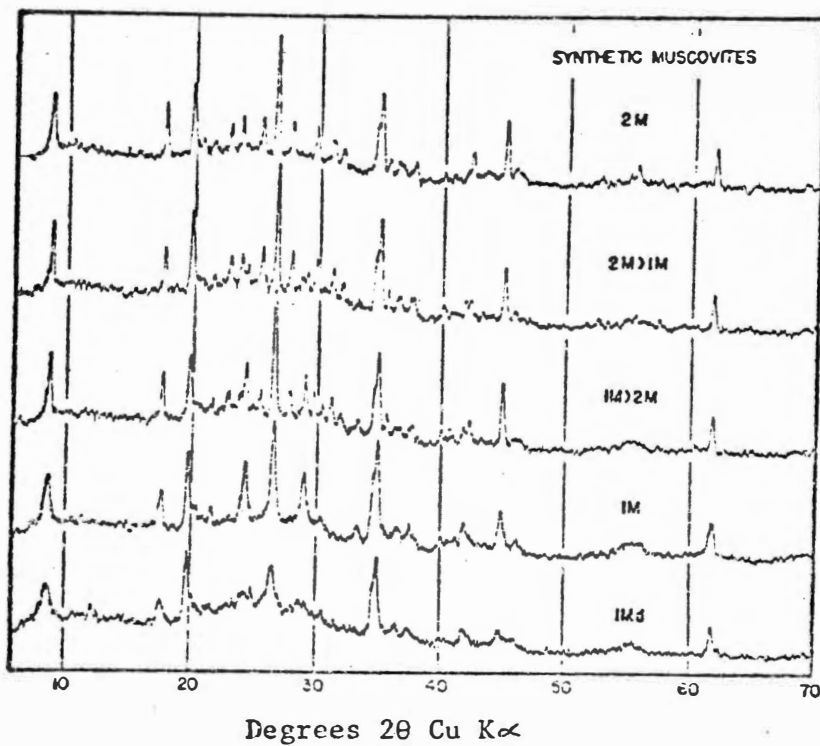


Figure 3. Photograph of x-ray powder patterns of the following synthetic muscovites:

2M: 690°C at 30,000 p.s.i. for 498 hours
 2M > 1M: 710°C at 30,000 p.s.i. for 168 hours
 1M > 2M: 710°C at 30,000 p.s.i. for 182 hours
 1M: 200°C at 15,000 p.s.i. for 4120 hours
 1Md: 200°C at 15,000 p.s.i. for 4120 hours

(Adapted) from Yoder and Eugster, 1955, fig. 10)

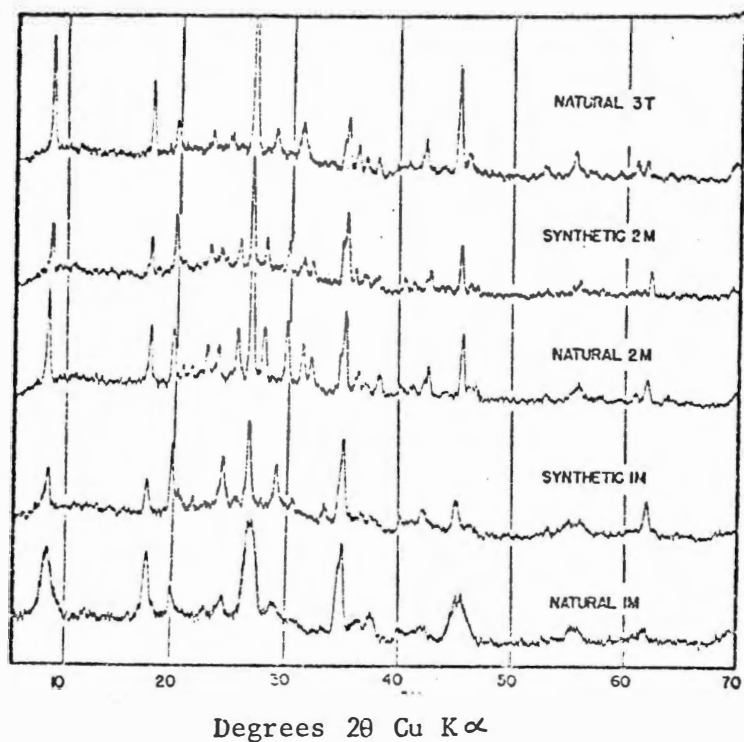


Figure 4. Photograph of x-ray powder patterns of the following micas:

Natural 3T.

Synthetic 2M. Made at 690°C and 30,000 p.s.i. for 498 hours.

Natural 2M.

Synthetic 1M. Made at 200°C and 15,000 p.s.i. for 4120 hours.

Natural 1M.

(adapted by Yoder and Eugster, 1955, fig. 9)

TABLE IV
X-RAY POWDER DATA FOR A SYNTHETIC 1M MUSCOVITE

d(Å)	I	hkl
10.077	100	001
5.036	37	002
4.488	90	020
4.349	27	11 $\bar{1}$
4.115	16	021
3.660	60	11 $\bar{2}$
3.356	100	{003 022}
3.073	50	112
2.929	6	11 $\bar{3}$
2.689	16	023
2.582	50	130
2.565	90	13 $\bar{1}$
2.550	22	200
2.450	11	131
2.405	4	13 $\bar{2}$
2.380	12	11 $\bar{4}$
2.246	8	040
2.219	7	220
2.191	4	041
2.156	20	13 $\bar{3}$
2.109	6	202
2.013	32	005
1.957	7	133
1.900	4	13 $\bar{4}$
1.668	18	11 $\bar{6}$
1.653	12	151
1.635	12	204
1.514	4	135
1.499	33	060

$\text{CuK}\alpha = 1.5418 \text{ \AA}$

d(Å) = interplanar spacing in Å

I = relative intensity based on arbitrary linear scale

(adapted from Yoder and Eugster, 1955, Table 3)

TABLE V
X-RAY POWDER DATA FOR A SYNTHETIC 2M MUSCOVITE

d(Å)	I	hkl
10.014	100	002
5.021	55	004
4.478	55	110
4.458	65	11 $\bar{1}$
4.391	14	021
4.296	21	111
4.109	14	022
3.973	12	112
3.889	37	11 $\bar{3}$
3.735	32	023
3.500	44	11 $\bar{4}$
3.351	100	{006 024}
3.208	47	114
2.999	47	025
2.871	35	115
2.803	22	11 $\bar{6}$
2.589	50	13 $\bar{1}$
2.580	45	116
2.562	90	20 $\bar{2}$
2.514	20	008
2.458	19	13 $\bar{3}$
2.446	12	202
2.396	10	204
2.380	24	133
2.247	12	22 $\bar{1}$
		040
2.236	5	041
2.201	5	221
2.184	7	22 $\bar{3}$
2.149	10	222
2.132	23	043
		135
2.051	6	044
2.010	75	0010
1.975	14	13 $\bar{7}$

$\text{CuK}\alpha = 1.5418 \text{ \AA}$

d(Å) = interplanar spacing in Å

I = relative intensity based on arbitrary linear scale

(adapted from Yoder and Eugster, 1955, Table 4)

(24.315°) and the 112 (29.055°) reflections. They found that the transition was more thoroughly and quickly achieved by both increasing the temperature and the duration of run.

In this report the persistence of 1M reflections in a normally 2M diffraction pattern is interpreted to result from the transition between 1M and 2M muscovite rather than representing a mixture of the two polymorphs in the sample. Furthermore, the 2M polymorph present in the fine-grained rocks of the Wilhite Formation is interpreted as having been formed by metamorphic recrystallization and not as being detrital 2M. This conclusion is based on petrographic study which shows that most of the muscovite is fine-grained sericite; very little of the coarser-grained muscovite is detrital.

As the amount of 2M polymorph increases relative to the 1M polymorph, certain (hkl) reflections appear and increase in intensity while certain reflections for the 1M polymorph are reduced in intensity and are not present in the profile of a pure 2M sample. Two such peaks are the $(112)_{1M}$ at 29.055° and the $(025)_{2M}$ at 29.795° . As the percentage of 2M increases in the sample, the intensity of the $(025)_{2M}$ peak increases relative to the peak intensity of the $(112)_{1M}$. Presumably, the ratios of the intensities of these two peaks should be related to the ratio of the two polymorphs in a given sample. If the ratio I_{025}/I_{112} increases in a given geographic direction it should indicate that the degree of metamorphism is also increasing.

If an increasing I_{025}/I_{112} represents a gradual change in the crystallinity of the 2M polymorph, lines connecting points of equal ratio might be considered as isograds. The isograds, however, would

not represent a reaction at a phase boundary, i.e., a univariant reaction because the $1M \rightarrow 2M$ transition is gradual and not abrupt.

The ratios obtained in this study are plotted on Plate III. Ratios generally increase toward the southeast corner of the map. The lowest values are found on the peninsula on the south side of Ocoee Lake, between Indian Creek and Baker Creek inlets, and along the west and north shores of the Lake at the base of Sugar Loaf, Little, and Bean Mountains. The concentration of low values seems to reflect the less-metamorphosed rocks of the Sandsuck Formation. Ratios here generally are less than 2, increasing gradually southeastward on the peninsula to between 2 and 3. Near the south end of the peninsula there is a sharp increase in the values from between 2 and 3 to between 3 and 6. Sharp changes in the ratios here (and elsewhere) may reflect structural hiatuses or major lithologic changes.

Five distinctive areas (designated by Roman numerals) are plotted on Plate III. Area I, to the northwest, south, and southwest of Area II, has values in the high 1's and 2's, while values in Area II range from 3 to > 10 . The boundary between the two areas also corresponds, in general, to a change in the character of the rocks from interbedded coarse- and fine-grained in Area I to generally fine-grained in Area II. The fine-grained rocks of Area I are mostly those of Group 2 (Chapter II, p. 25), while those of Area II are generally those of Groups 1 and 4. Group 2 rocks contain mostly muscovite with some quartz and lack chlorite and paragonite. Why Group 2 rocks have lower I_{025}/I_{112} ratios is not known. It may be that $1M \rightarrow 2M$ transition in rocks of this bulk composition occurs at a higher temperature.

Another sharp change in both lithologic character and ratio values occurs between Areas I and IV. Ratio values in Area IV generally run in the 4's and 5's and the rocks are very much like those in Area II. Small patches of anomalously high values appear throughout Area IV.

Values in Area III, directly behind the Great Smoky fault, run from 0.8 - 2.7 much like the section of coarse clastics in Area I. In fact, Areas I and III could easily be linked together.

Values in Area V generally exceed 10, which is another way of saying that the $(112)_{\text{IM}}$ and $(11\bar{2})_{\text{IM}}$ reflections have become insignificantly small. The boundary between Areas IV and V marks a sharp rise in ratio values. This boundary does not coincide with a lithologic change, hence it might represent a structural hiatus such as the axis of an overturned isoclinal syncline or a thrust fault.

Another technique used to monitor metamorphic grade using the peak sharpness of illite peaks was somewhat less successful. It is based on the premise that the $10 \text{ \AA}$ peak of illite sharpens as temperature and pressure increase. Weaver (1961) defined the "sharpness ratio" as the ratio of the intensity of the (002) peak at $10 \text{ \AA}$ to the intensity of the same peak at $10.5 \text{ \AA}$. In applying the method to rocks in the Ouachita Structural Belt, he found that the sharpness ratio value ranged from "less than 1 in unmetamorphosed foreland facies rocks to more than 12 in metamorphosed rocks of the interior zone of the Ouachita belt."

Kopp and Sutton (1969) used an alternative method to obtain sharpness ratios, measuring the peak intensity and dividing this

number by the width of the peak at one-half of its overall height.

The latter technique was preferred for two reasons: (1) it is easier to establish a base line and to measure a single peak height and then to measure the width of that peak than it is to measure two different peak heights where the base line is not a straight line, and (2) the maximum intensity of the so-called 10 Å peak does not always occur at exactly 10.0 Å.

This technique seems satisfactory for illite between the very disordered forms and the well ordered 2M muscovite. But once the 2M structure has been attained there is little more sharpening of the 10 Å peak. Apparently SR's over 12 have no meaning. Kubler (1968) writes that measurement of the crystallinity of illite by x-ray diffraction allows a quantitative evaluation of "incipient" metamorphism.

Another problem which interfered with this technique for a number of samples was the contribution of paragonite and, in some cases, perhaps biotite to the 10 Å peak. Although the presence of paragonite is detectable in many samples, there are undoubtedly samples in which this phase contributes to the 10 Å peak but is not present in large enough amounts to be detected as a separate phase. Sharpness ratios obtained on such samples could be erroneous and misleading.

Sharpness ratios are plotted on Plate III only for samples whose profiles contain no apparent contribution to the 10 Å peak by paragonite. Peak height ratios increase sharply upon crossing the Great Smoky fault from the Valley and Ridge, but once within the Blue

Ridge rocks give no consistent results. Sharpness ratios southeast of the fault seem to reflect the mineralogy of the rock as much as or more than the geographic location. Rocks containing primarily muscovite and lacking chlorite usually have sharpness ratios from 60 to 80 (e.g. Group 2) while those containing chlorite have broader 10 Å peaks whose SR's seldom exceed 60. Rocks of Group 2 are usually soft, pea-green mudstones interbedded with conglomerates and rarely contain chlorite. Sharpness ratios of these magnitudes were thought perhaps to result from coarser muscovite grains in Group 2 rocks which would cause a more preferred orientation in the x-rayed sample. However, petrographic examination shows that the muscovite in these rocks is mostly very fine-grained sericite; finer grained, on the average, than rocks generally showing lower sharpness ratios.

Bulk composition could also affect the sharpness ratio since phases such as paragonite and biotite contribute to the 10 Å peak. In addition, ionic substitution in the muscovite lattice might alter the relative intensities of the (00 ℓ) reflections. Kubler (1967 and 1968), who used the sharpness ratio method to determine the degree of crystallinity of illites, states that in rocks with a notably low K/Na ratio, the degree of crystal lattice ordering decreases with increasing temperatures. Although the author could find no information on this in regard to muscovite, the effects of Fe substitution in the chlorite lattice is well known and noted on page 91 of this report. The relative intensities of the (00 ℓ) peaks of muscovite might also be affected by the substitution of Fe which has strong scattering effects.

The two major questions which arise concerning the presence of 2M and 1M muscovite occurring together in the same rocks are: (1) Was the 1M derived through the weathering of preexisting 2M or was it derived from the weathering of other minerals such as trioctahedral micas or feldspars? and (2) Does the present 1M muscovite represent unmetamorphosed or only slightly recrystallized material from pre-metamorphic rocks or has it resulted from the present day weathering of these rocks?

In general, the samples with much 1M muscovite are from highly weathered Sandsuck Shales northwest of the Indian Creek fault. Here, it is difficult to determine whether the less crystallized material is derived through weathering or is simply unmetamorphosed sedimentary material. On the other hand, the amount of apparent weathering appears to have had no effect upon Wilhite rocks. Poorly crystalline material, which is locally present in minor amounts, sometimes partially obscures the muscovite peaks but does not reduce their sharpness or their d-spacings; in particular the I_{025}/I_{112} ratio does not seem effected. It would seem, then, that the 1M muscovites are unmetamorphosed holdovers from the premetamorphosed Ocoee rocks and are not weathering products of the present rocks.

Regarding the second question on the derivation of the sub - 2M micas, Bradley and Grim (1961, p. 222) report, "In shales, representing accumulated detritus from coarser rocks, the determinable grains are generally the characteristic two-layer (2M) muscovite. Other equally micaceous but finer-grained concentrations, presumed to have originated as bentonite, indicate that the determinable

fraction is of the single-layer (1M) structure." They also state (p. 221) that dioctahedral micas deteriorate less rapidly than do trioctahedral micas. Most of the poorly crystalline material, then, is probably not derived from the weathering of 2M muscovite. It has already been stated (page 73) that most of the 2M muscovite in the Wilhite has been derived by recrystallization of pre-existing poorly crystallized muscovite in the same rocks.

Background on Field Occurrences of Paragonite

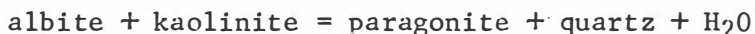
Rosenfeld (1956) discovered that the schists of Glebe Mountain, southern Vermont, have a greasy feeling. J.B. Thompson suggested to him that the mineral might be pyrophyllite. Upon separation and x-raying, however, it was found to be paragonite and to have a $d(002) = 9.60 \pm 0.02 \text{ \AA}$. This smaller d-spacing, relative to muscovite, reflects the smaller size of the Na^+ ion in paragonite relative to the K^+ ion in muscovite. Rosenfeld (1956) states that, "... further studies within the Saxtons River area show that the assemblage, paragonite-quartz, decomposes somewhere within the staurolite-kyanite zone, forming kyanite and sodic plagioclase. Also within the same zone, the assemblage, paragonite-ilmenite-quartz, decomposes into the assemblage, sodic plagioclase-staurolite-rutile. Such reactions point toward the deduction that paragonite is stable within the area only in the relatively lower grades of metamorphism (from the lower-grade part of the staurolite-kyanite zone down). In the presence of calcite and quartz the paragonite component of sericite breaks down within the garnet zone to give the assemblage, sodic plagioclase-

zoisite. The parallel reaction of the assemblage muscovite-calcite-quartz to form the assemblage, microcline-zoisite, occurs in the higher grade part of the staurolite-kyanite zone. The upper limit on the stability of paragonite is determined by its decomposition into sodic plagioclase and corundum."

In this study, Rosenfeld also found the micaceous alteration product of kyanite to be paragonite.

Neatherly (1965) reports paragonite pseudomorphic after kyanite in the Turkey Heaven Mountain area of Alabama. He attributes the formation of the paragonite to retrograde metamorphism of kyanite during the waning stages of regional metamorphism at 580°C to 625°C and 15,000 psi.

Zen (1960) reports paragonite in Lower Paleozoic rocks in the vicinity of the Taconic Range in west-central Vermont. He notes that paragonite is not found in "true slates" in this area but in the higher-grade, highly micaceous phyllites in association with muscovite, chlorite, a little quartz, and rutile, and, in one area, with chloritoid as well. He attributes the absence of paragonite in the lower-grade rocks to the coexistence of kaolinite and albite in sedimentary rocks with the controlling reaction:



He does not, however, say that his low-grade rocks contain the assemblage, kaolinite-albite, nor does his list of mineral assemblages include any containing albite + kaolinite. Zen and Albee (1964) state, "Theoretically, formation of this mineral in schists should

be most favored between the upper biotite and the lower kyanite zones of metamorphism."

However, Milici, Greenberg, and Jones (1966) report a paragonite-bearing phyllitic unit, in the central Virginia Piedmont, which is well below biotite grade. It is within a 15,000 foot thick unit consisting of phyllite, argillite, and slightly metamorphosed subgraywacke and graywacke, with minor amounts of metamorphosed mafic igneous rock (greenstone), between Late Precambrian volcanic rocks and the base of a volcanic unit believed to be of Ordovician age. They observed the following mineral assemblages: (muscovite + paragonite), (quartz + paragonite), and (muscovite + chlorite + paragonite + quartz). Although they describe these rocks as "very low-grade and only barely metamorphosed", the fact that they are phyllites suggests they may possibly be well along within the greenschist facies, at least into the quartz-albite-muscovite-chlorite subfacies. The rocks are located some five miles west of the biotite isograd (metamorphic grade increases eastward).

Elsewhere, paragonite is generally observed coexisting with biotite, garnet, and kyanite (Zen and Albee, 1964, p. 920-921). Milici, Greenberg, and Jones (1966) concede that the occurrence of paragonite in rocks below the biotite isograd may be due to the bulk chemistry of the rock. Such rocks may actually be in the quartz-albite-epidote-biotite subfacies of the greenschist facies but in a compositional field where biotite cannot form. Rocks deficient in potassium may persist with chlorite and lacking biotite well into the stability field of biotite. On the other hand, rocks with

potassium feldspar should produce biotite immediately upon reaching temperatures and pressures within the stability field of the quartz-albite-epidote-biotite subfacies (Hadley and Goldsmith, 1963, p. 98).

Guidotti (1968) attributes the relative scarcity of paragonite to the bulk chemical composition of most pelitic schists. The formation of paragonite requires enrichment in Al_2O_3 and/or NaAlO_2 . Since paragonite commonly occurs with highly aluminous minerals such as chloritoid and kyanite, and rarely with biotite, the chemical composition must plot above the chlorite join on the AFM-diagram for the quartz-albite-muscovite-chlorite subfacies (Figure 5) and above the chlorite-garnet join on the AFM-diagram for the quartz-albite-epidote-almandine subfacies (Figure 6).

Most pelitic schists have a chemical composition below this join and, therefore, cannot contain paragonite as an equilibrium phase. The dependence of paragonite upon Al_2O_3 is illustrated in Figure 7. A composition at X_1 yields muscovite + Al-silicate + paragonite. Note that this assemblage is above the muscovite-paragonite join and does not contain any feldspar, either potassium or sodium. An assemblage at composition X_2 consists of, paragonite + albite + muscovite. At composition X_3 the assemblage is, muscovite + albite. In moving along the path between X_2 and X_3 a phase boundary is crossed where paragonite is no longer stable, the stable assemblage being muscovite + albite. Further depletion of Al results in the addition of potassium feldspar to give the assemblage microcline + albite + muscovite. Note that the path between X_1 and X_4 , in which paragonite goes from a stable to an unstable phase, simply involves

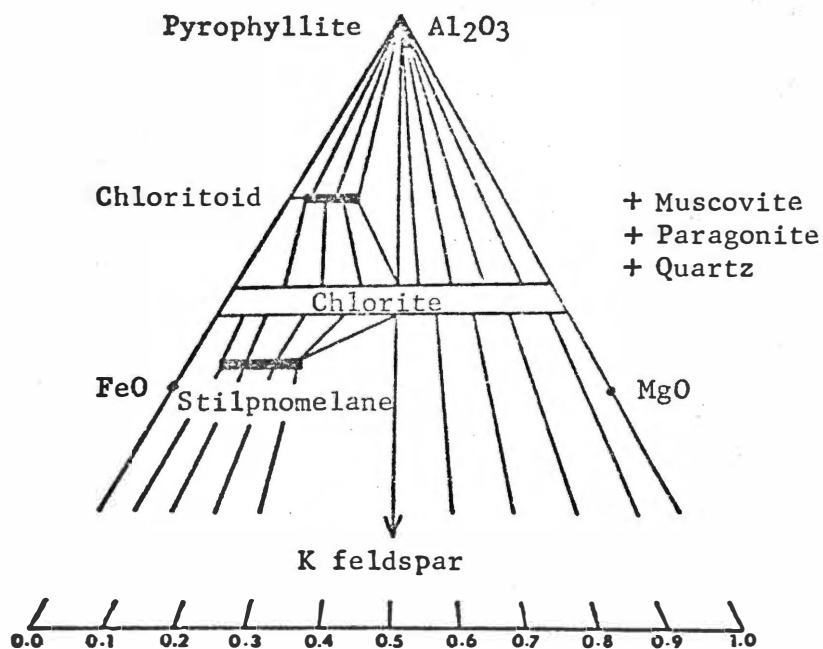


Figure 5. A-F-M projection for the quartz-albite-muscovite-chlorite subfacies in pelitic rocks (adapted from Winkler, 1967, fig. 23 (B 1.1)).

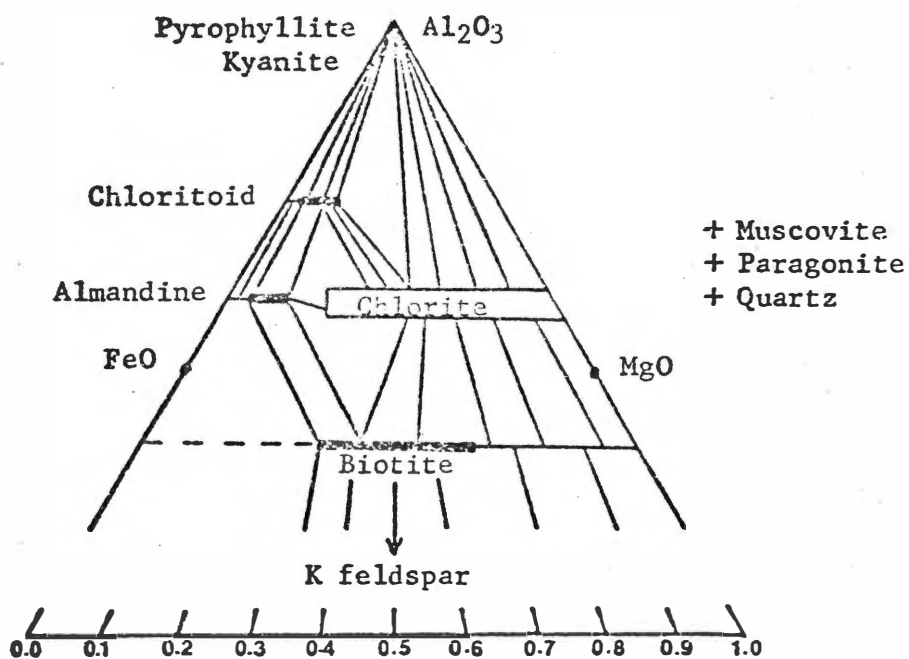


Figure 6. A-F-M projection for the quartz-albite-epidote-almandine subfacies in pelitic rocks (adapted from Winkler, 1967, fig. 26 (B 1.3)).

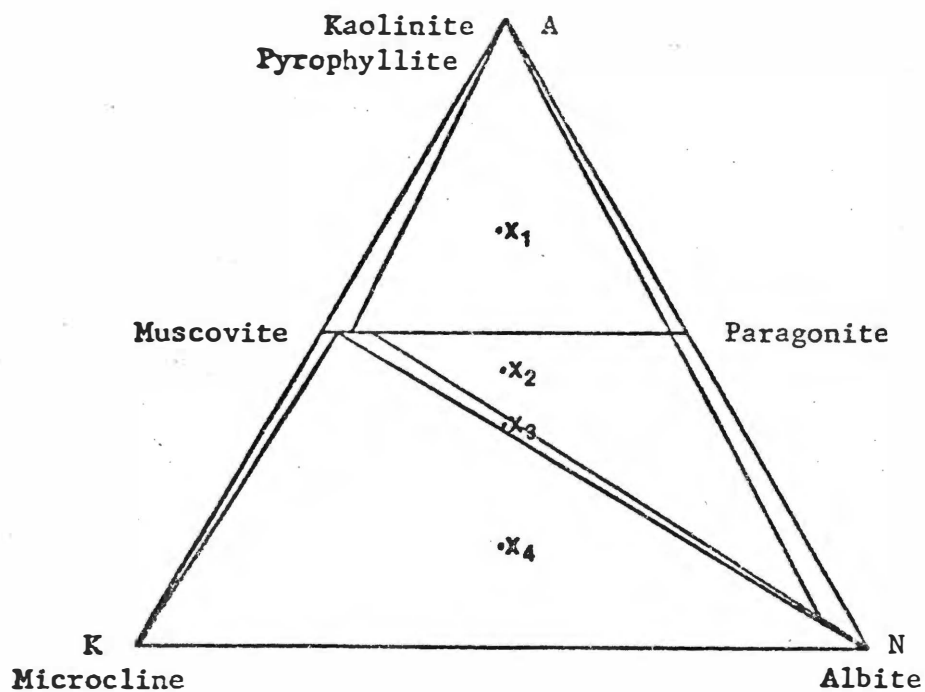
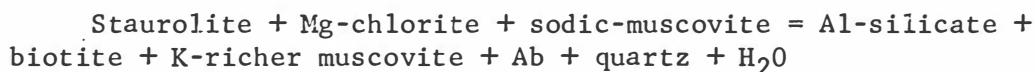


Figure 7. A-N-K diagram showing the stability of paragonite as a function of changing Al_2O_3 at constant Na/K ratio (adapted from Guidotti, 1968, fig. 1).

the depletion Al and the relative enrichment in K + Na. However, the K/Na ratio is not changed. The stability of paragonite in this case, is a function of the $\frac{Al}{K+Na}$ ratio and not just of the $\frac{Na}{K}$ ratio. It is also worth noting that if the bulk composition is changed along the muscovite-albite join toward albite, in either the field of X_3 or X_4 , and that paragonite does not form regardless of how high the Na/K ratio becomes.

It may be determined from Figure 6, page 84, that bulk compositions low enough in Al_2O_3 to contain biotite should not contain paragonite. Assemblages above the garnet-chlorite join may contain paragonite while those below usually do not. Since most metamorphosed pelites above the quartz-albite-muscovite-chlorite subfacies contain biotite, it is easy to see why they do not contain paragonite.

An exception to the above case is the occasional occurrence of the assemblage, kyanite + biotite + paragonite. Guidotti (1968) accounts for such an assemblage through the reaction:



"The modal amounts of muscovite and chlorite decrease and we can think of the Al_2O_3 thereby released as being moved into the K-Na-Al subsystem (forming alumino-silicate). Thus a rock initially too poor in Al_2O_3 to have paragonite may, as a result of increased grade effecting reactions in the KAlFm system, receive an influx of Al_2O_3 into the K-Na-Al system, thus producing the assemblage, kyanite + paragonite + muscovite (plus biotite)" (Guidotti, 1968, p. 969).

Guidotti (1968) explains the absence of the assemblage andalusite + paragonite + biotite, by crossing the PT curves for the

upper stability of paragonite and the reaction first bringing, Al-silicate + biotite, superimposed on the alumino-silicate phase diagram by Althaus (1967) (Figure 8). It can be seen that within the andalusite stability field, the stability limit of paragonite is exceeded before the alumino-silicate + biotite reaction occurs.

Occurrence of Paragonite in the Parksville Quadrangle

The occurrence of paragonite in the area studied appears to be stratigraphically controlled. Its stability is probably due to relatively high concentrations of both Al_2O_3 and Na_2O . This is based solely on theoretical considerations plus five semiquantitative spectrographic analyses, however, as no detailed chemical analyses of the rocks are available.

Chlorite

About four-fifths of the more than 300 samples of fine-grained Ocoee rocks x-rayed had 7 Å, or 7 Å and 14 Å peaks. For most samples in the Wilhite Formation, these peaks represent well-crystallized chlorite while these same peaks in the Sandsuck samples represent kaolinite or poorly crystallized chlorite, based on x-ray analysis.

Chlorite appears microscopically as tiny fibers or scales, or as randomly oriented microblasts consisting of scaly or fibrous aggregates. Within the microblasts the chlorite is commonly interleaved with muscovite. It ranges from colorless to pale gray, pale yellow, pale or dark green. Most of the deeper colored grains show pronounced pleochroism, while many of the lighter colored ones show

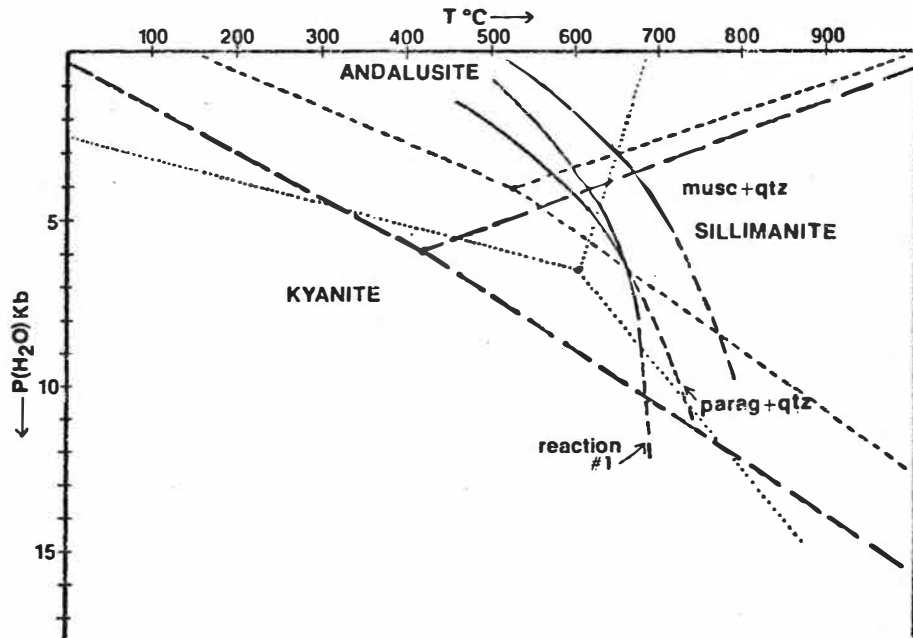


Figure 8. Schematic relation of the paragonite + quartz curve to the curve for reaction #1. Muscovite curve from Evans (1965). Dashed lines = Al-silicate curves of Holm and Kleppa (1966). Small dashes = Al-silicate curve from Newton (1966). Dotted lines = Al-silicate curve from Althus (1967). (Adapted from Guidotti, 1968).

none. Interference colors are mostly anomalous blue, occasionally anomalous brown, and rarely nonanomalous colors are displayed. Since the microblasts are not usually oriented along cleavage or bedding planes they are believed to have formed by chemical recrystallization primarily, and were not strongly influenced by stress.

A yellow to reddish-brown to brown, usually pleochroic phyllosilicate often interleaved with chlorite and muscovite was observed in many thin sections. Under crossed nicols the interference colors are masked by the color of the mineral. The mineral imparts an olive green or brown color to rocks containing large amounts of it. Since these rocks occur as far as ten miles west of the biotite isograd, the possibility that they contained stilpnomelane was considered. However, the presence of stilpnomelane could not be detected in any of the x-ray diffraction patterns, even where present in amounts exceeding 50 percent of the sample.

Upon reexamination of several thin sections, the writer observed cases where brown mica appeared to be replacing green chlorite and was therefore tempted to conclude that it was prograde biotite. This interpretation would have raised two problems: first, it would have necessitated moving the biotite isograd about ten miles west of its present location. Second, the presence of biotite as a phase in most of the assemblages observed would present major problems insofar as equilibrium is concerned. Many of the mineral assemblages already contain several phases, and the addition of biotite or stilpnomelane decreased the possibility that these assemblages were in equilibrium. Also, according to known compositional diagrams, biotite cannot coexist with some of the minerals or combination of minerals present.

Chatterjee (1966) reports the occurrence, in the western Italian Alps, of a "... yellow-brown phyllosilicate mineral, occurring interleaved with chlorite." After detailed analyses of these and other samples containing the same material, he concluded that it was derived in situ by oxidation of primary greenish iron-rich chlorite. "The oxidation process Mg, Fe^{2+} - chlorite $\longrightarrow$ Mg, Fe^{3+} - chlorite is coupled with a simultaneous expulsion of hydrogen from the structure, a mechanism that has been experimentally realized by Orce1 and Renaud (1941, p. 920)." Chatterjee views two possible ways in which oxidation might occur: (1) it may occur after equilibrium has been attained, near the culmination of the thermal episode or, (2) the oxidation may be due to weathering. He presents both arguments but does not prefer one over the other.

Chatterjee's description of oxidized chlorite fits those in the present report area and his explanations of their genesis seem reasonable. This writer, therefore, concludes that the yellow- to reddish-brown to brown pleochroic phyllosilicate in the present report area is oxidized chlorite rather than biotite or stilpnomelane.

Diffraction patterns of samples containing chlorite generally reflect a higher degree of crystallinity toward the southeast corner of the quadrangle, in much the same way as was noted for the trend for muscovite. Most changes in the character of the 7 Å and 14 Å peaks occur in the sharpness ratios of the two individual peaks, the ratio of the intensities of the two peaks (I_7/I_{14}), and the increase in the intensity of the 14 Å peak after heating to 550°C for one hour.

Sharpness of the 7 Å and 14 Å peaks seem related primarily to

weathering; the greater the weathering, the smaller the sharpness ratio. Although the sharpest peaks generally occur southeast of the Indian Creek fault, many samples in this region have diffuse peaks while many samples northwest of the fault have sharp peaks. Through general observation the degree of weathering generally varies inversely with the degree of metamorphism. Because of this the sharpness of these two chlorite reflections could be a function of either the degree of weathering or the metamorphic intensity, or both.

The I_7/I_{14} ratio is a function of the atomic distribution normal to (00l) (Brindley, 1961, p. 270-271). This distribution, in turn, is controlled and altered by both metamorphism and weathering. The lowest values are found northwest of Indian Creek fault where the degree of weathering is the greatest and the degree of metamorphism the lowest. Southeast of the fault the ratio values increase rapidly to a maximum and remain at the maximum (greater than 3) throughout most of the area southeast of the fault. However, a few weathered samples well within the zone of maximum values show low values, indicating changes in the chlorite lattice caused by weathering.

I_7/I_{14} ratios can be used in conjunction with heat treating to distinguish between poorly and well-crystallized chlorite (Brindley, 1961, p. 263-264). Brindley (1961, p. 251) cites various experiments which show that chlorites tend to dehydrate in two stages. The first stage, which corresponds to the decomposition of the brucite layer, produces small changes in the lattice parameters, but large changes in reflected intensity. To determine the crystallinity of chlorite,

elutriated sample mounts are prepared and x-rayed to measure the relative intensities of the 7 Å and 14 Å reflections. The mounts are then heated to 550°C for one hour. In all cases the 7 Å peak either disappears or nearly disappears. If the chlorite is well crystallized the 14 Å is enhanced, if the chlorite is poorly crystallized the 14 Å decreases, usually disappearing completely. Different samples were treated in this manner for this report.

A number of samples on both sides of the Indian Creek fault were heat treated. In general, for samples northwest of the fault the 14 Å peaks were destroyed while for those southeast of the fault enhancement was noted. Samples near the fault sometimes remained essentially unchanged. The position of Indian Creek fault also marks the change from bedding plane cleavage to slaty cleavage in the fine-grained rocks. The behavior of the heat-treated chlorites would seem to substantiate the presence of a sub-chlorite zone within the Blue Ridge province and give credence to the idea that the well-crystallized chlorite formed by progressive metamorphism and that its first appearance marks the lower boundary of the greenschist facies.

One final comment, Kennedy (1970, oral communication), using this technique, found well-crystallized chlorite in argillaceous sediments which show no metamorphic effects, and, although they come from another structural front, the Cumberland Escarpment, they are geographically far removed from any metamorphic terrain. Furthermore, the only unweathered sample from northwest of Indian Creek fault to be treated, showed considerable enhancement of the 14 Å reflection, while several weathered samples well to the southeast of

the fault showed obliteration of the 14 Å peak. Perhaps well crystallized chlorite can form authigenically under certain diagenetic conditions while at the same time normal weathering may easily destroy it. Since the degree of enhancement and/or destruction of the 14 Å peak differs, some modification of this technique might be used to measure the degree of weathering in rocks containing chlorite.

Kaolinite

Kaolinite is believed to be present in many samples, especially in those giving a diffuse 7 Å peak and no 14 Å peak. The presence of kaolinite is difficult to confirm in rocks also containing chlorite. Such samples always appear highly altered, the alteration probably due to weathering in most cases. One sample, #107, is of particular interest. It is described in hand specimen and in thin section on page 29. The x-ray profile shows quartz, muscovite and a diffuse 7 Å peak with a sharpness ratio of about one. Optically it is seen to contain fine-silt to clay-sized quartz, and/or feldspar grains, a very fine-grained cloudy matrix, and very fine-grained sericite. It also contains a dark-brown, slightly pleochroic mica parallel to the general orientation of the sericite. The brown mica is probably oxidized iron-rich chlorite as discussed above (p. 88-89) and contributes to the orange color of the weathering rind. Two textural features are of special interest. Ghosts of kaolinized feldspar rhombs testify to the thorough alteration of the rock. Also, the fine silt-size feldspar grains appear to be sericitized. Sericitization could have occurred before or after lithification, but a

kaolinized rhomb would not be likely to have survived transport, strongly suggesting that it is a result of recent weathering processes. However, it may be that it was kaolinized prior to metamorphism and that somehow the kaolinite survived the low-grade metamorphism.

Microcline (?)

While the presence of microcline in these fine-grained sediments could not be confirmed, a peak at about $27.5^{\circ} 2\theta$ (ranging between 27° and 28°) is present in about 90 percent of the x-ray profiles. This peak is also the most intense peak for microcline (ASTM Cards #10-479 and #12-703). However, microcline should not coexist in equilibrium with paragonite which is a major phase in many of the assemblages. Other common minerals with peaks at approximately the same angular position are chloritoid and paragonite. Although chloritoid is a likely candidate, its two most intense peaks were not observed; neither was the mineral identified in thin section. The peak might be a paragonite reflection for samples containing paragonite, but many samples which do not contain paragonite still have peaks at $27.5^{\circ} 2\theta$. Possibly this peak represents paragonite in those samples where paragonite is present, and microcline in those samples which do not contain paragonite.

Albite

Albite was detected in minor amounts, both optically and by x-ray, in a few samples. Its presence reflects the presence of Na_2O as a component in the system, as does paragonite.

Quartz

Quartz occurs in all but three or four samples. Its presence indicates that the system is generally oversaturated with respect to silica and allows assemblages to be plotted on composition diagrams, most of which include quartz as one of the mineral species present.

Other Minerals

Other minerals detected in small amounts include tourmaline, iron oxides, iron sulfide, and carbon. These minerals, however, probably do not seriously effect the phase equilibrium.

Petrology

Mineral Assemblages

In the discussion which follows, a basic assumption has been made concerning the presence or absence of certain phases. In many cases neither the presence nor the absence of the phases could be confirmed by either optical or x-ray methods. The decision to include or exclude them in a given assemblage was then based on equilibrium considerations. For example, a peak at 27.5° could be the most intense peak for microcline, but because microcline should not co-exist in equilibrium with paragonite, microcline is excluded from the assemblages containing paragonite. The author realizes that most of the assemblages included here represent low grade conditions, hence it is quite possible that equilibrium may not have been attained. However, in the absence of good evidence for the actual existence of

disequilibrium assemblages, none are proposed since they would only complicate any attempts to understand the relationship between initial chemical composition of the parental rocks and the final mineral assemblages observed. Future more detailed studies of these rocks might reveal evidence supporting the existence of disequilibrium assemblages, but such assemblages are omitted from this discussion.

The following mineral assemblages were either observed to be present or could be present:

1. quartz + muscovite
2. quartz + muscovite + kaolinite
3. quartz + muscovite + paragonite
4. quartz + muscovite + paragonite + kaolinite
5. quartz + muscovite + paragonite + albite
6. quartz + muscovite + microcline?
7. quartz + muscovite + albite
8. quartz + muscovite + microcline? + albite
9. quartz + muscovite + chlorite
10. quartz + muscovite + chlorite + kaolinite
11. quartz + muscovite + chlorite + albite
12. quartz + muscovite + chlorite + microcline?
13. quartz + muscovite + chlorite + albite? + microcline?
14. quartz + muscovite + chlorite + paragonite
15. quartz + muscovite + chlorite + paragonite + kaolinite
16. quartz + muscovite + chlorite + paragonite + albite
17. quartz + muscovite + chlorite + paragonite + dolomite
18. quartz + muscovite + chlorite + paragonite + dolomite + albite
19. quartz + muscovite + chlorite + dolomite + albite

By far the most common mineral assemblages are numbers 1, 9, and 14 while the rest are either subordinate or questionable. Even where the latter assemblages are found, carbonate and albite are only present in minor amounts and the presence of microcline in any of the samples is in doubt. Several facts about the bulk chemistry of the rock becomes apparent from examining the mineral assemblages:

(1) The bulk chemical composition of the fine-grained rocks is nearly constant, and (2) The rocks have a high mole percent Fe and Al

relative to Na and K; the $\frac{Al}{Na+K} > 1$. Semi-quantitative spectrographic analyses of six samples bear this out. The analyses also show $\frac{FeO}{MgO} \approx 1$. (All chemical ratios in this report are molar ratios).

The mineral assemblages are presented on multicomponent, isothermal, and isobaric phase diagrams in Figure 5 (page 83), 9, 10, 11, 12. The compositional variations between the minerals and the effect of bulk chemical composition on the resultant mineralogy is thereby emphasized. Because of the difficulty of representing multicomponent systems in two dimensions, (where only three components can be easily shown) a series of diagrams is used to depict the various phases relative to each other and the components of the diagram.

The mineral assemblages discussed here are from the Wilhite Formation. The matrices of the coarser-grained Wilhite and Sandsuck rocks were not studied at this time. The following diagrams, all with excess silica, will be considered:

1. The A-N-K diagram: Al_2O_3 ; Na_2O ; K_2O (Figure 9)
2. The A-C-F(M) diagram: Al_2O_3 ; CaO ; $FeO + MgO$ (Figures 10 and 11, pages 99 and 100).
3. The A-K-F(M) diagram: Al_2O_3 ; $K_2O + MgO$ (Figure 12, page 101).
4. The A-F-M projection: Al_2O_3 ; FeO ; MgO (Figure 5, page 83)

The precise location for given mineral assemblages on these diagrams could not be determined because quantitative chemical analyses were not available and the absolute amounts of the phases present are very difficult to measure either optically or by x-ray.

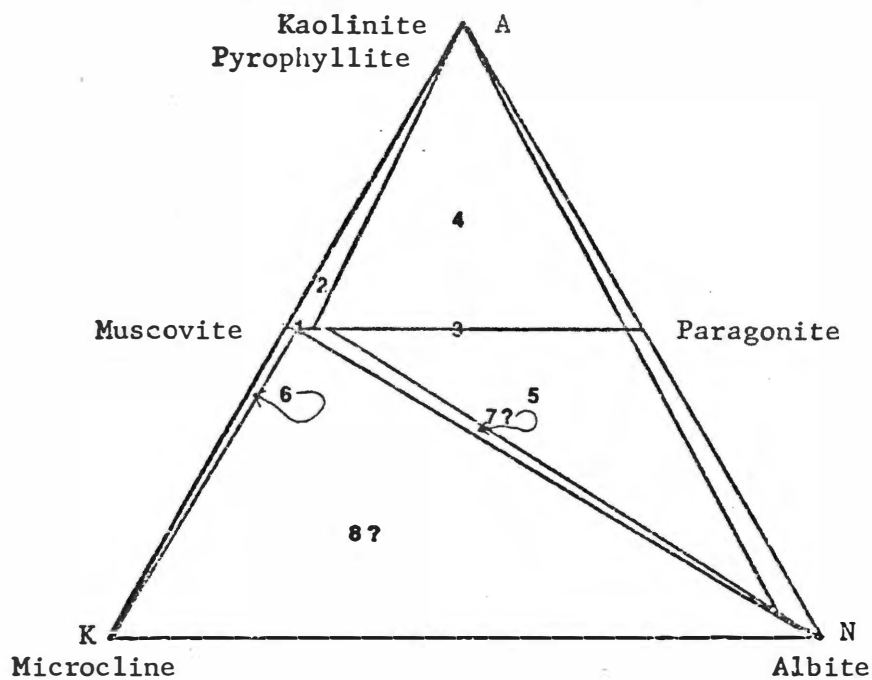


Figure 9. A-N-K diagram with appropriate assemblages from Parksville quadrangle plotted by number (see text). (Adapted from Zen, 1960, fig. 3).

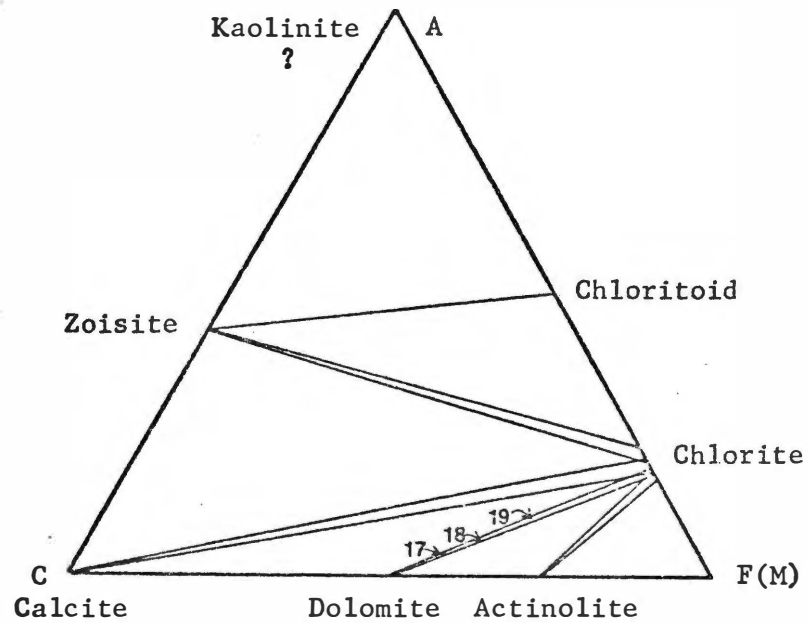


Figure 10. A-C-F(M) diagram for the quartz-albite-muscovite-chlorite subfacies with appropriate assemblages from Parksville quadrangle plotted by number (see text). (Adapted from Zen, 1960, fig. 4).

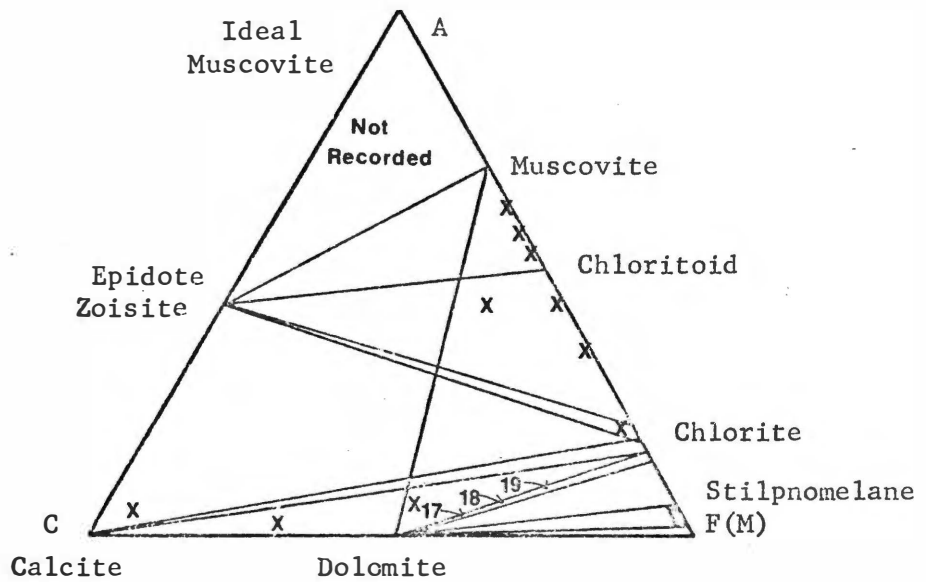


Figure 11. A-C-F(M) diagram for the quartz-albite-muscovite-chlorite subfacies, modified by Turner (1968) after Zen (1960), (noted by X). Assemblages from Parksville quadrangle are noted by number (see text).

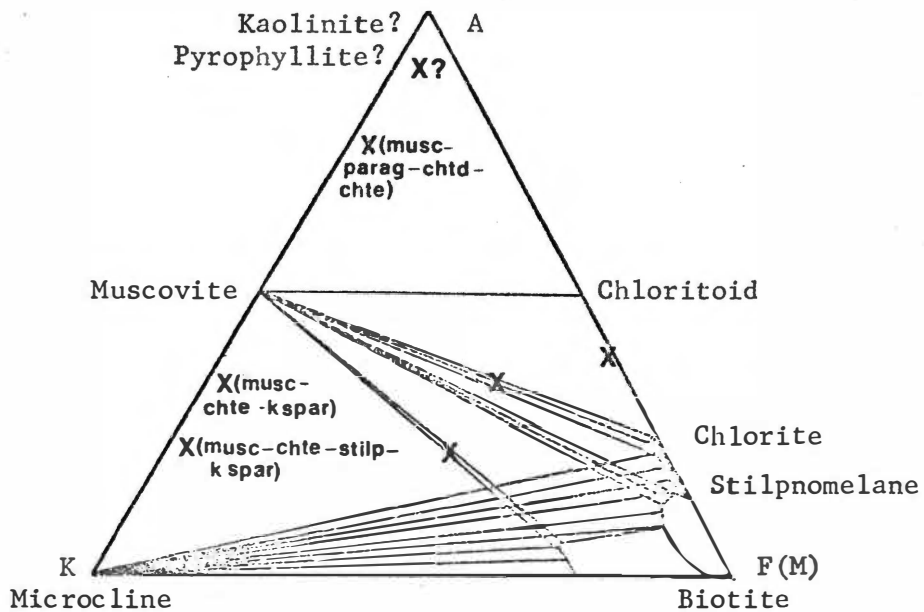


Figure 12. A-K-F(M) diagram for the quartz-albite-epidote-biotite subfacies showing the mineral assemblages after Zen (1960).

A-N-K Diagram

The following values are assigned to the apices of this ternary diagram: "A" = $(\text{Al}_2\text{O}_3 - \text{K}_2\text{O} - \text{Na}_2\text{O})$; "N" = NaAlO_2 ; "K" = KAlO_2 . With the addition of free silica to those components they then become respectively: "A" = kaolinite or an aluminum silicate; "N" = $\text{NaAlO}_2 + 3\text{SiO}_2 = \text{NaAlSi}_3\text{O}_8$ (albite); "K" = $\text{KAlO}_2 + 3\text{SiO}_2 = \text{KAlSi}_3\text{O}_8$ (microcline) (Zen, 1960, p. 145). Zen (1960) suspected his "A" component was kaolinite in many cases, but could not detect it. This writer has definitely detected kaolinite in some of his samples, especially in the more weathered ones. Whether the kaolinite persists as an equilibrium metamorphic phase or is a post-metamorphic alteration product, such as produced by weathering, is not known. Keller (1970) cites several sources that suggest kaolinite may be a stable phase in many low- to high-grade metamorphic rocks, and also in igneous rocks. If kaolinite is present in the sedimentary environment it may survive and be stable under certain metamorphic conditions; however, if it is not present initially, it is not likely to be produced by metamorphism.

What is the "A" phase in the assemblages if kaolinite is not present? Zen (1960) reports no trace of pyrophyllite in the low-rank metamorphic rocks of Vermont in spite of its previous reported occurrence in that area. Perhaps there are small amounts of kaolinite in most of the samples but these cannot be detected by x-ray in the presence of significant amounts of chlorite.

Mineral assemblages from Wilhite rocks appropriate to the diagram are numbers 1 through 8 (page 95). These assemblages consist primarily of muscovite and varying amounts of quartz; other phases

are usually present in only minor amounts. In Figure 9 (page 98), assemblages which are known to be present are noted by the number corresponding to the assemblages on page 95 and those whose presence is in question are, in addition, noted by (?).

A-C-F(M) Diagram

The A-C-F(M) diagram has for its apices: "A" = $(\text{Al}_2\text{O}_3 - \text{Na}_2\text{O} - 3\text{K}_2\text{O})$; "C" = CaO; and "F(M)" = $\text{FeO} + \text{MgO} + \text{MnO}$, and assumes all the potassium to be in muscovite and all the Na to be in albite. As pointed out by Zen (1960), the diagram has the disadvantages of not automatically excluding incompatible phases such as kaolinite and albite, as can be seen in Figure 9 (page 98), and excludes phases such as chloritoid when paragonite is "properly" projected to occupy the "A" corner. Zen also points out that phases along the A-C boundary are not well-known. Very few fine-grained argillites of the Wilhite Formation in the Parksville area plot on the A-C-F(M) diagram and none on the A-C boundary, so that the shortcomings of the diagram do not effect plotting of the bulk of the rocks in the report area.

Wilhite assemblages in the Parksville area that plot on the diagram (see Figure 10, page 99) are numbers 17, 18, and 19 (page 95) and are represented by only six samples of about three-hundred samples recorded.

Figure 10 (page 99) is the classical A-C-F(M) diagram as used by Zen (1960), Winkler (1967), and others. Turner (1968) used a modified form of the diagram, to plot Zen's data, on which he projected muscovite onto the A-F(M) boundary (Figure 11, page 100). In

order to plot assemblages 17, 18 and 19 (page 95), the presence of the phases of other components must be projected onto the A-C-F(M) diagram. The composition then has to plot in the narrow field between the two joins connecting chlorite and dolomite. Since the phases muscovite and paragonite plot near the "A" corner of the A-K-N diagram, it is difficult to imagine that these phases project onto the A-C-F(M) diagram so near to the C-F(M) boundary to allow dolomite + chlorite to coexist with muscovite + paragonite $\pm$ albite. Turner (1968, p. 282) points out that carbonates in the greenschist facies typically occur with such aluminum-poor phases as chlorite, talc, and stilpnomelane and that the only Ca-Al phase is clinozoisite-epidote. There are several possible explanations for the coexistence of dolomite with highly aluminous phases. (1) Existing petrographic data are incomplete and the validity or non-validity of projections cannot be demonstrated. Any two-dimensional diagrams presently in use are inadequate to illustrate such assemblages. (2) Because the phases occur in the same sample does not mean they are in contact nor in a position to react with each other. In thin sections studied, the dolomite is usually selectively concentrated along bedding planes and is seldom ubiquitous. (3) Carbonate minerals could have been introduced after metamorphism. However, introduction along bedding surfaces after metamorphism is highly unlikely; such introduced carbonates would more likely occur along fracture or cleavage planes not coincident with bedding.

Zen (1959) reports the following assemblages: (1) calcite + dolomite + chlorite; (2) calcite + kaolinite + chlorite; (3) calcite + dolomite + kaolinite; and (4) dolomite + chlorite + kaolinite, from

unmetamorphosed sediments and sedimentary rocks. He relates the four phases in the reaction: calcite + chlorite + CO_2 = dolomite + kaolinite + quartz + H_2O . Thus it appears possible to have dolomite in equilibrium with high aluminous phases. If the "A" corner can be plotted as $(\text{Al}_2\text{O}_3 + 3\text{Na}_2\text{O})$, corresponding to paragonite, the assemblage paragonite + albite + dolomite could be an equilibrium assemblage. Since chlorite can coexist with dolomite and high aluminous phases separately, perhaps it can then coexist in an assemblage with both dolomite and an aluminum silicate.

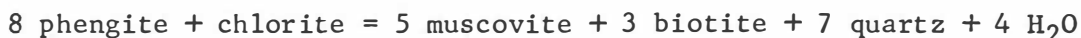
A-K-F(M) Diagram

The A-K-F(M) diagram is one of the most useful and pertinent of the composition diagrams for the pelitic sediments of the Parksville area. Figure 12 (page 101), after Zen (1960), is the classical A-K-F(M) diagram with appropriate phases projected from other component regions. All of the highly aluminous metasediments, i.e., those containing paragonite, plot near the "A" corner of the diagram and consist of assemblages with muscovite, paragonite, chloritoid, and chlorite. Assemblages with muscovite and microcline but no paragonite occur toward the "K" corner. Although biotite is represented in this diagram one may plot assemblages occurring below the biotite isograd by simply deleting the biotite field.

Assemblages in the Parksville area containing paragonite plot in the "A" corner of the diagram and those with microcline (if, indeed there are any) in the field which includes the "K" corner. The major problem in using Figure 12 (page 101) is that all assemblages which

plot in the field at the "A" corner contain chloritoid which is noticeably absent from the rocks in the Parksville quadrangle. In order to display properly assemblages in the Parksville area, a diagram omitting chloritoid, such as that shown in Figures 13a and b based on carefully determined bulk chemical composition, would have to be used. Assemblages appropriate to the A-K-F(M) diagram are plotted on Figure 13a. Assemblages 12 and 13 (page 95) might also be plotted on Figure 13 if the variation in composition between FeO and MgC is taken into consideration (as in the A-F-M projection).

The absence of chloritoid in these assemblages, as well as the absence of biotite in glaucophane schists and low-grade greenschists, may be due to compositional variations in some of the phases present which, in turn, is a function of the physical variables. Ernst (1963) has discussed the petrologic significance of phengites (Fe-rich muscovites) in low-grade assemblages. Phengites are typically poor in Al and rich in Si and in Fe and/or Mg. Substitution of Fe^{+2} or Mg^{+2} for Al^{+3} in an octahedral site creates a charge imbalance which is satisfied by the substitution of an Si^{+4} for an Al^{+3} in a tetrahedral site. Fe^{+3} will also replace octahedrally coordinated Al^{+3} . According to Ernst, phengitic micas only occur at low temperatures and relatively high pressures, and are controlled by the reaction:



which occurs with increasing temperature in Barrovian-type greenschists and marks the biotite isograd. The appearance of biotite in regionally metamorphosed assemblages occurs at increasingly higher temperature as pressure increases ($P_{\text{H}_2\text{O}} = P_{\text{total}}$). The converse is

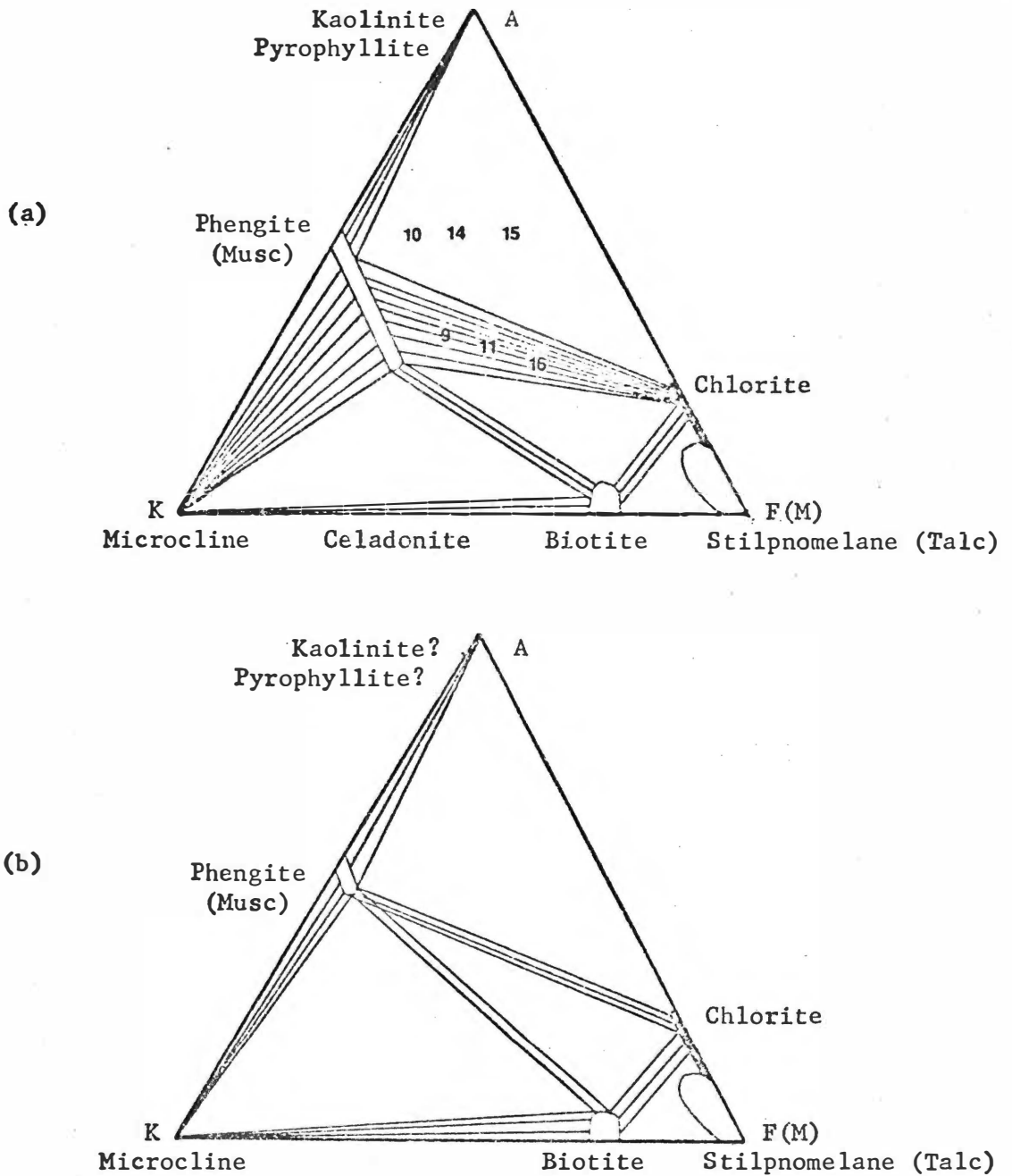


Figure 13. A-C-F(M) diagram for the quartz-albite-epidote-biotite subfacies. 13a shows an expanded composition field for muscovite while 13b shows a reduced field resulting from the reaction: $8 \text{ phengite} + \text{chlorite} = 5 \text{ muscovite} + 3 \text{ biotite} + 7 \text{ quartz} + 4 \text{ H}_2\text{O}$. Appropriate assemblages from Parkville quadrangle are plotted by number on 13a (adapted from Ernst, 1963).

evidenced by the appearance of biotite in the lowest-grade assemblages of the relatively low-pressure Abukuma-type of regional metamorphism (Winkler, 1967, p. 117).

Figure 13, modified from Ernst (1963), shows schematic isobaric, isothermal sections of a portion of the system $K_2O - R_2O_3$ ($Al_2O_3 + Fe_2O_3$) - RO ($MgO + FeO$) with excess silica + water. Figure 13a shows the expansion of the compositional field of dioctahedral mica and Figure 13b shows the typical assemblages above the biotite isograd following the above reaction from left to right.

Velde (1965, p. 904-905) has stressed the importance of high P_{H_2O} in the formation and stabilization of phengite. He also calculates a positive ΔV for the breakdown phengite. It then appears that phengite is denser than its breakdown products muscovite and biotite and should be favored by high P_{total} as well as high P_{H_2O} .

The absence of chloritoid is easily explainable on the basis of bulk chemical composition by the use of Figure 5 (page 83) if the $\frac{MgO}{MgO + FeO} \geq 0.5$. On the other hand if this ratio < 0.5 , chloritoid should be present. The analyses referred to above (pages 96-97) indicate the $\frac{MgO}{MgO + FeO} \sim 0.5$, thus without more complete chemical data it cannot be determined whether chloritoid should be present. If, however, we assume that the $\frac{MgO}{MgO + FeO} < 0.5$, the presence of this phase may be a function of other variables, particularly the f_{O_2} . A high f_{O_2} favors a high Fe_2O_3/FeO . Since chloritoid utilizes only Fe^{+2} , iron oxidized to the ferric state would be unavailable for chloritoid but could be utilized by phengite or chlorite. It also may be possible that in the partitioning of Fe^{+2} , phengite and/or chlorite are favored over chloritoid, especially at higher total

pressures. A high f_{O_2} is further suggested by the widespread occurrence of oxidized chlorite.

Choudhuri (1970) describes two mineral assemblages in chlorite zone schists from Singhbhum, Eastern India. One assemblage contains chloritoid, quartz, sericite and minor chlorite while the other contains quartz, sericite, chlorite, with minor chloritoid. Both assemblages contain notable amounts of hematite and minor magnetite. Chlorite in the latter assemblage shows signs of oxidation while that in the former assemblage does not. Choudhuri attributes the presence of hematite to the conversion of magnetite during a rise in the f_{O_2} . He suggests that in the chloritoid-rich assemblage, chloritoid is somehow able to coexist with hematite, but in the chlorite-rich, chloritoid-poor assemblages, chloritoid was oxidized to chlorite and the chlorite itself was oxidized.

Although several experimental investigations have been made of the upper stability limits of chloritoid, (Halferdahl, 1961; Horschek, 1967 and 1969; Ganguly, 1968; Ganguly and Newton, 1968), none have been conducted on its stability in lower-grade assemblages, making it difficult to interpret the petrogenesis of such assemblages in natural systems. Evidence that somewhat higher than normal pressures prevailed in the area is obtained by studying thin sections from rocks of increasing metamorphic grade eastward along Ocoee Gorge. In Ca-rich rocks the only Ca phase observed, even well above the biotite isograd, was calcite. Normally calcite should be breaking down, with the loss of CO_2 , to form epidote or clinozoisite even below the biotite stability field. However, epidote or clinozoisite do not appear until well above the garnet isograd.

A-F-M Projection

The A-F-M projection (Figure 5, page 83) for the quartz-albite-muscovite-chlorite subfacies was devised by Thompson (1957) and is based on a four component, three-dimensional diagram. Projections are then made onto two-dimensional space. The major advantage of this projection is that it allows FeO and MgO to be treated as separate components. This is probably significantly important regarding the rocks of the Parksville area as they appear to contain about equal atom percents of Mg and Fe. Thus, the A-C-F or A-K-F diagram can not be used with MgO simply excluded as a component.

Evidence for Phase Equilibrium

Mineral assemblages of the Wilhite Formation in the Parksville area have been presented on or related to phase diagrams derived from thermodynamic principles which assume chemical equilibrium among the phases present in any given assemblage. Evidence for or against equilibrium must therefore be cited.

One of the most useful criteria on which to base any test of equilibrium is the Gibbs phase rule. Although adherence to the phase rule is not sufficient to prove equilibrium, it must be met for equilibrium to exist. Simply, the phase rule states that the variance (or degrees of freedom) of a system equals the number of compositional plus physical variables minus the number of restraining conditions. Let "C" be the number of components or chemical species which are distributed among "P" phases. The composition of each phase is defined by the mole fraction of each component in the phase. Since

the sum of the mole fractions equals 1, there are $(C-1)$ compositional variables for each phase, and $P(C-1)$ for all of the phases in the system. There are assumed to be 2 physical variables, temperature and pressure. It is assumed that there is only one pressure, the load pressure (P_T) which equals the pressure of the fluids in the pore space of the rock (P_f). At shallow depths this assumption is not valid, but by the time metamorphism starts it is generally considered to hold true.

The total number of relations among components is expressed as $C(P-1)$. If "F" equals degrees of freedom, total variables = $P(C-1)+2$, and total restraining conditions equal $C(P-1)$, then

$$F = P(C-1)+2-C(P-1)$$

$$F = C-P+2$$

Goldschmidt (1911a, 1911b) examined the Oslo hornfelses in light of the phase rule. Variance was fixed at 2, corresponding to temperature and pressure. He found that $P=C$ (i.e.) a given mineral assemblage could persist in an equilibrium state over a range of temperature and pressure or $F=2$. He later referred to the situation in which the phase rule was written as $P=C$ as the "mineralogical phase rule" (Goldschmidt, 1911c).

Rocks from the Wilhite Formation in the Parksville quadrangle appear to obey the phase rule and appear to contain equilibrium assemblages, providing microcline is not present in assemblages with paragonite.

Textural relationships in the Wilhite Formation indicate that chemical equilibrium was attained. Certainly the presence of microporphyroblasts is evidence for recrystallization. Grain boundaries

of the micaceous minerals indicate growth in place rather than a detrital origin.

CHAPTER IV

STRUCTURE

Regional Structural Features

The Parksville quadrangle lies within both the Valley and Ridge and Blue Ridge Provinces of the southern Appalachians, the two provinces being separated by the Great Smoky fault. Rocks lying within the Valley and Ridge province are unmetamorphosed Paleozoic sediments which have been deformed by folding and faulting. Rocks of the Blue Ridge Province are presumed to be older, partly of early Cambrian and partly of Precambrian age, and are also folded and faulted, but slightly metamorphosed, with the metamorphic intensity increasing southeastward.

The low-angle Great Smoky fault has carried rocks of the Blue Ridge Province many miles northwestward over the rocks of the Valley and Ridge Province. It has been little disturbed since its emplacement which postdates the regional metamorphism and the development of slaty cleavage. Southeast of the Great Smoky fault, within the Blue Ridge Province, are a host of other faults and fault systems together with numerous folds. These structural features have been discussed at length for the Great Smoky and Unaka Mountains of Tennessee, northeast of the Little Tennessee River (Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965), for the Blue Ridge in the northwest corner of Cohutta Mountain quadrangle, Georgia (Salisbury, 1961), and for the Piedmont at Cartersville, Georgia (Kelser, 1950; Croft, 1963; Fairley, 1966).

Appalachian Valley and Ridge

The Valley and Ridge rocks within the report area are Middle Cambrian to Middle Ordovician in age. They are mainly folded rather than faulted, in contrast to those of the Valley and Ridge to the northwest. Structurally, they form a syncline (here named the Sand Mountain syncline) which is part of the structure that forms the southeastern-most belt of Valley and Ridge rocks running nearly the full length of the Appalachians in Tennessee. This synclinal belt is 8 to 20 miles in width and is known as the Bays Mountain synclinorium in northeastern Tennessee. Bordering the synclinorium to the northwest are a series of thrust faults which include the Carter Valley and Rocky Valley faults in northeastern-most Tennessee, and the Dumplin Valley and Chestuee faults in the central portion of the belt. The Dumplin Valley fault fades out about 4 miles west of Etowah, Tennessee, and the Chestuee fault either ends or becomes indistinct 1 1/2 miles northwest of this report area. In general, thrust faults bounding strike belts in the Valley and Ridge become less distinct southward, especially on the east side of the Valley.

Other major structural features within the Valley and Ridge portion of the Parksville quadrangle are: (1) the Cookson Creek thrust fault (here named), which consists of a flap of lower Knox and Conasauga Shale thrust over Middle and Upper Knox and Athens Shale in the northeast part of the Valley and Ridge sector, (2) the Cloud Branch fault, a break in the Cookson Creek thrust flap, which brings Conasauga Shale over lower Knox; it probably dies out between U.S. Highway 64 and the south shore of the Ocoee River, and (3) a

small fault, located near the southwest corner of the report area, which shows an apparent right-lateral displacement at the surface.

Sand Mountain Syncline

Ages of the rocks in the Sand Mountain syncline range from Cambrian to Middle Ordovician and encompass, in ascending order, the following units: the Conasauga Shale, the Maynardville Limestone, the Knox Group, the Athens Shale, and the upper Middle Ordovician unit (Plate II). The northwest limb dips 25° to 35° SE. A noticeable change in strike occurs just north of Old Fort (T.C. 2,378,000 E.; 248,000 N.). This change is reflected in a change in the trend of prominent topographic features from nearly N-S to $N30^{\circ}$ E. Lesser fluctuations in strike also occur.

The synclinal axis is located in the valley between the two ridges on Sand Mountain. Beds on the west ridge parallel the trend of the ridge and dip 15° to 60° SE, averaging about 30° . Strikes of beds on the east ridge also follow the trend of that ridge and dips average 30° - 40° W. In the intervening valley strikes of beds vary considerably and dips are gentle, usually not more than 5° or 10° . Beds on the east ridge just south of T.C. 2,394,000 E.; 248,000 N., turn abruptly, striking almost east-west and dipping to the south at 5° - 35° , suggesting the presence of the nose of a south plunging anticline here. Between T.C. 248,000 N. and 254,000 N., the east and west ridges are parallel and the synclinal axis is essentially horizontal.

South of T.C. 248,000 N. the Sand Mountain syncline plunges to the south, the east limb passing beneath the overthrust plate of

the Great Smoky fault. The direction of plunge is also indicated by the addition of younger rocks of the upper Middle Ordovician unit within the syncline. This belt of rocks extends from Wilson Bend, at the southern map boundary, northeastward for about 2 miles where it passes beneath the overthrust plate of the Great Smoky fault. Bending of the synclinal axis eastward and then southward beneath the Great Smoky overthrust plate suggests a rapid divergence of the east and west limbs causing the syncline to plunge rapidly southward (south of T.C. 248,000 N.).

North of T.C. 254,000 N., the strike of the west ridge of Sand Mountain changes abruptly from almost due north to $N30^{\circ}E$, while the east ridge either ends abruptly or turns northwestward and converges with the west ridge at Sloan Gap (T.C. 2,390,000 E.; 258,000 N.). Dips of beds at Sloan Gap are eastward, and there is no indication that the beds are overturned. Beds to the north along strike, in a highway cut along U.S. Highway 64, however, are vertical or dipping toward the west. This is not believed to be the east limb of the major synclinal structure, however, but only minor anticlinal flexure within that structure (Cross section A-A', Plate II).

This writer believes that the convergence of the east and west ridges of Sand Mountain, at Sloan Gap, is only apparent and that the east ridge ceases its northward trend, perhaps due to a facies change along strike in which the more resistant ridge-forming rocks phase out. The attitudes of Upper Knox beds cropping out at the east of Sand Mountain support this interpretation. As the ridge apparently turns westward, rocks in the Knox belt continue to strike northeast-

ward parallel to the west ridge and with Upper Knox outcrops at the base of the west ridge. Beds in the eastern belt of Upper Knox dip 35° - 40° W. while those in the west belt dip about 30° E. It appears that beds in the east ridge of Sand Mountain change strike to a more northeasterly direction along with those in the west ridge and that an essentially non-plunging syncline continues to the northern boundary of the report area. The east limb of this syncline lies beneath a thrust plate of Lower Knox.

Cookson Creek Thrust Fault

A major thrust fault, here named the Cookson Creek thrust fault, extends from the northern map boundary just west of the Ocoee River, along the east base of Sand Mountain following a sinuous path which turns to the north along Cookson Branch and then turns back to the south. It continues generally southward sub-parallel to the trace of the Great Smoky fault until the Great Smoky fault overrides its trace near the Tennessee Valley divide (T.C. 2,394,000 E.; 240,000 N.).

The following evidence supports the existence of the Cookson Creek thrust fault: (1) Along the east base of Sand Mountain Lower Knox, which may be Copper Ridge equivalent, is in direct contact with Athens Shale, so that at least 2,000 feet of section are missing; and (2) Upper Knox dips beneath Lower Knox near the intersection of Sloan Gap and Cookson Creek Roads (T.C. 2,396,000 E.; 256,000 N.). South of the point where the trace of the fault diverges from the Athens-Knox contact, Upper Knox is in normal stratigraphic contact with basal Athens. Southeast of Cookson Branch, the fault separates the footwall,

a ridge of Middle Knox, from the hanging wall of Lower Knox which, in turn, is the footwall of the Great Smoky fault. From Cookson Branch southward to the Tennessee Valley Divide, the Cookson Creek thrust fault brings Knox over Knox, and Knox over Athens.

The sinuous trace of the fault suggests a very low-angle fault plane, probably with a gently undulating surface.

Dips of beds on the thrust plate are generally steep in the east becoming more gentle westward. However, the paucity of good outcrops makes this difficult to actually determine.

The surface trace of the Cookson Creek thrust fault and other possible associated faults north of the report area can only be conjectured, but they appear to join other faults which eventually pass beneath the Great Smoky fault. A similar low-angle thrust fault is the Pulaski fault, whose sinuous trace begins north of Roanoke, Virginia and winds southward along the Valley and Ridge to the vicinity of Newport, Tennessee where it becomes lost in a myriad of low angle thrusts which are indistinguishable from the Great Smoky fault at this point.

At several places along the Great Smoky fault, faults similar to the Pulaski fault emerge from and disappear beneath the Blue Ridge thrust sheet. The Bullet Mountain fault emerges near Tariffville, Tennessee and passes beneath the Great Smoky thrust sheet again at the north end of Starr Mountain. Salisbury (1961) in the N.W. quarter of Cohutta Mountain quadrangle shows the Fairy fault emerging from beneath the Great Smoky thrust sheet. Southwest of Cohutta Mountain quadrangle several small faults involving Valley and Ridge rocks are

closely associated with the Great Smoky fault (Butts and Gildersleeve, 1948). Near Cohutta Springs, Georgia, a minor thrust fault carrying Conasauga Shale over younger Paleozoic rocks emerges from beneath the Great Smoky thrust sheet and extends southwestward into the valley, dying out west of Ramhurst, Georgia. Another small fault emerges and disappears beneath the main thrust sheet about 15 miles northeast of Cartersville, Georgia. It thrusts Weisner Quartzite and Shady Dolomite over Shady Dolomite and the Rome Formation. A similar type of fault is shown south of Cedartown, Georgia. Here Knox Dolomite is thrust upon the Rockmart Shale of Mississippian age and the Knox Dolomite.

Cloud Branch Fault

The strip of Conasauga Shale and Maynardville Limestone, which crops out between the Ocoee River (T.C. 2,400,000 E.; 262,000 N.) and the northern map boundary (T.C. 2,402,000 E.; 270,000 N.) is believed to have been brought up by thrusting within the Cookson Creek fault flap along a southeast dipping plane which joins the Cookson Creek thrust fault at depth (Plates I and II).

Minor Fault

One additional structural feature is of great enough magnitude to warrant comment. A minor fault occurs in the vicinity of T.C. 2,376,000 E.; 238,000 N. An apparent right lateral offset in the Maynardville Limestone and the ridge directly east of the outcrop belt of Maynardville, dies out eastward before reaching Sand Mountain.

The apparent offset results where the south block has been rotated counterclockwise relative to the north in eastward dipping beds (Plate I). The point where it dies out to the east could mark the hinge of the fault.

The Blue Ridge

Introduction

The Blue Ridge rocks are highly deformed especially near the trace of the Great Smoky fault. Interpretation of many of the structural features is complicated by the absence of good marker beds. At many places, faulting brings together clastic rock units which are very similar in appearance. Structural features within the Blue Ridge sector of the report area had to be deduced by making use of one or more of the following features: (1) juxtaposition of rock types separated by a fault contact, (2) juxtaposition of rocks with and without slaty cleavage, (3) sharp discontinuities in the attitude of slaty cleavage in adjacent areas, (4) changes in strikes and dips of beds, (5) topographic trends, and (6) metamorphic discontinuities.

There may be conflicts between the interpretive factors listed above. For example, a structural discontinuity may suggest a fault where no metamorphic discontinuity exists. Or, two adjacent areas may appear structurally continuous but be separated by a sharp metamorphic discontinuity. The techniques used here are not fool-proof and, as implied in Chapter III, include the I_{025}/I_{112} ratio

technique, used to monitor metamorphic grade. In discussing the structural features, some arguments both for and against their existence will be cited. The only structural features plotted are those of great enough magnitude to be significant on a 1:24,000 scale map.

Structural Framework

The Ocoee rocks of Parksville quadrangle are part of a structural block (Figure 2, page 7) bounded on the west and north by the Great Smoky fault and on the east and south by the Sylco Creek-Alaculsy Valley fault. In length, the block extends from the intersection of the Great Smoky and Alaculsy faults near Cisco, Georgia, 3.6 miles south of the Georgia - Tennessee State line, northeastward to the northeast end of Starr Mountain, a distance of some 33 miles. Average width of the block is about 4 miles. North of the Ocoee River the Chilhowee Group, whose structural configuration is synclinal, is exposed. South of the Ocoee River the Chilhowee is present only as slices along the trace of the Great Smoky fault. It is that portion of the structural block south of the Ocoee River which is of greatest concern in this report and whose structure is described below.

General Structural Features

Rocks within the structural block have been compressed into tight folds by compressional forces directed toward the northwest. In spite of the many tight folds, however, the overall structural

configuration appears to be synclinal or basinal (Plates I and II). Toward the southwest corner of the block, at the intersection of the Alaculsy and Great Smoky faults (Cohutta Mountain quadrangle), compressional forces were directed in an increasingly northerly direction, resulting in increased compression or "pinching" toward the southwest. This change in the direction of compressional forces is born out by the westward convergence of topographic trends (ridges) and structural features, such as the Sylco Creek-Alaculsy Valley fault. The resulting gross feature, here named the Parksville synclinorium, has resulted in rocks of the upper Wilhite unit being downfolded and preserved. Deformation causing the Parksville synclinorium occurred either prior to, or synchronous with metamorphism, as the strikes and dips of slaty cleavage are remarkably consistent even though the attitudes of beds show great variation. Later, minor flexures occurred during emplacement of the Blue Ridge thrust sheet. Examples are the downwarp along Devils Branch (T.C. 2,400,000-2,402,000 E.; 240,000-244,000 N.) and to the southeast of Indian Creek fault (T.C. 2,406,000-2,410,000 E.; 250,000-254,000 N.) resulting in preservation of upper Wilhite rocks.

All of the faults within the Blue Ridge sector of Parksville quadrangle, with the exception of the proposed Baker Creek fault, appear to postdate the development of the slaty cleavage. Most of them are probably associated with the emplacement of the Blue Ridge thrust sheet.

Topographic Trends

In order to obtain an adequate view of topographic trends in the Blue Ridge Sector of the report area it is necessary to follow these trends into the neighboring quadrangles, Caney Creek, Tennessee (126 SE) on the east and Cohutta Mountain, Georgia 15' quadrangle, mapped by Salisbury (1961), directly to the south.

The Sylco Creek-Alaculsy Valley linement has been interpreted as the trace of a fault thrusting rocks of the Wilhite Formation over less metamorphosed rocks of the Sandsuck Formation (Geologic Map of Tennessee, Swingle, et al., 1966). Beginning in the northeast corner of the structural block considered in this report (west of the mouth of Sylco Inlet, Caney Creek, Tennessee quadrangle, 126 SE) a parallel relationship between Sylco Ridge and Sylco Creek is observed. The extension of Sylco Ridge trends southwestward into the N.W. corner of Cohutta Mountain quadrangle, paralleling the Alaculsy Valley linement to its junction with the trace of the Great Smoky fault.

Likewise, topographic trends which frame the western boundary of the structural block, beginning with Bean and Little Mountains, in Parksville quadrangle, generally parallel the trace of the Great Smoky fault southward into Georgia where they converge with the Sylco Creek-Alaculsy Valley linement.

Ridges between Sylco Creek and the Great Smoky fault front generally parallel most closely their nearest structural boundary, converging toward the southwest near the intersection of the Great Smoky and Alaculsy Valley faults, in Georgia. This convergence

becomes apparent in the south-central portion of Parksville quadrangle between ridges following the drainage of Minnewauga Creek (T.C. 2,392,000 E.; 228,000 N.) and those paralleling Sawmill and Halfway Branches (T.C. 2,398,000-2,404,000 E.; 226,000-232,000 N.).

Topographic features are delineated by stream erosion which is strongly influenced by the structure and character of the underlying rocks. At first glance, the pattern of the tributary streams appears to be dendritic, therefore unrelated to the underlying structure. Closer inspection, however, reveals that the stream pattern is actually trellis. Two distinctive elements are present: (1) the major streams, which have been superimposed due to uplift of an overlying erosion surface, and (2) their major tributaries which are almost entirely controlled by the structure, i.e., the old structure underlying the new uplifted erosion surface. The superposed (or superimposed) nature of the major rivers is suggested by such features as incised meanders, chute cutoffs, and incised braided patterns (the latter two may be recent features). Examples are the Conasauga and Jacks Rivers in the Cohutta Mountain quadrangle, Georgia (note that the Conasauga River is structurally controlled between its intersection with the Alaculsy Valley fault and the Georgia - Tennessee State line); the Conasauga River in Parksville quadrangle; the Ocoee River in Caney Creek, Parksville and Benton quadrangles; the Hiwassee River in Oswald Dome and Benton quadrangles; and Chestuee Creek in Benton quadrangle.

Structural control of the major tributaries such as Sawmill, Halfway, Devils, and Sina Branches is attested to by the parallelism

between the streams, strikes of the beds, and trends of the ridges. The haphazard and apparent dendritic appearance is due to the complexity of structures within this block.

Strikes and Dips

Beds

Strikes and dips of beds are plotted on Plate I. In spite of some variation, there is general uniformity which enables a number of structural trends and features to be interpreted. Attitudes are especially chaotic on the peninsula between Indian Creek and Baker Creek inlets and northwest of the Indian Creek fault (so named in this report). However, strikes southeast of the fault follow a general northeast trend. Dips northwest of the axis of Parksville synclinerium (so named in this report, Plate I) are generally southeast while those southeast of the axis are generally northwest. Local variations and deviations from the main trend, however, are numerous.

Slaty Cleavage

Strikes and dips of slaty cleavage are also plotted on Plate I. Virtually all slaty cleavage strikes northeast and dips southeast. Even where there are minor variations, deviation from the general trend is much less frequent than in the case of bedding attitudes. One noticeable change in strike of the slaty cleavage occurs in the Devils Branch area (T.C. 2,400,000-2,404,000 E.; 240,000-244,000 N.) and is accompanied by a change in the strike

of beds in the same area. Slaty cleavage symbols are noticeably absent north of the Baker Creek and Indian Creek faults because no secondary cleavage has developed in these rocks.

Parksville Synclinorium

The axis of the Parksville synclinorium bisects the area between Sylco Creek and the Blue Ridge front into roughly two equal parts. It also generally coincides with a major I_{025}/I_{112} ratio discontinuity between values greater than 10, to the southeast, and values between 4 and 6, to the northwest (Plate III).

Although there are no distinct marker beds in the Wilhite rocks (except for the paragonite-bearing argillites comprising the Upper Wilhite), a synclinal structure is suggested by the outcrop pattern of Upper Wilhite argillite surrounded by Lower Wilhite consisting of interbedded argillite and conglomerate, and the reversal of dip from southeast in the northwest to northwest in the southeast. That the synclinorium is doubly plunging toward the center is indicated by: (1) the outcrop pattern of Upper Wilhite surrounded by Lower Wilhite, (2) convergence of the strikes of the beds, which parallel the Sylco Creek-Alaculsy Valley linement and the Great Smoky fault and (3) the general trends of the ridges which parallel the strikes of the beds (Plate I).

Structural data from the neighboring Caney Creek quadrangle (126 SE) would be helpful but, unfortunately, the quadrangle has not yet been mapped. In Caney Creek quadrangle, the conglomeratic sandstone, which comprises Sylco Ridge (running parallel to Sylco

Creek on the west and cropping out along U.S. Highway 64 opposite Sylco Inlet) dips nearly vertically and the tops of the beds appear to be toward the west. If this is true, then these beds contain the oldest rock unit between the Sylco Creek-Alaculsy Creek fault and the main trace of the Great Smoky fault.

Smaller-scale folds, paralleling the axis of the Parksville synclinorium, are suggested by local reversals of dips (Plate I).

Cross Folds

The folds discussed above are believed to have formed previous to or synchronous with the regional metamorphism. Other structures, related to the emplacement of the Blue Ridge thrust sheet, are gentle warps which often cross the trend of the earlier folding. The most obvious example is the preservation of Upper Wilhite in the downwarp along Devils Branch. This downwarp probably controls the drainage of Devils Branch. Further evidence for this downwarp is the deviation of both the bedding and slaty cleavage strikes, crossing Devils Branch, arcuately toward the northwest. Also, the general trend of the ridges, which parallel the Great Smoky fault, becomes obscured in the area of Devils Branch, indicating disruption of the structurally controlled ridges by a subsequent tectonic event.

A similar occurrence is suggested by the outcrop pattern near the mouth of Baker Creek (T.C. 2,408,000 E.; 250,000 N.). The preservation of Upper Wilhite rocks and indistinct ridge trends suggest a downwarp. The Lower Wilhite which crops out between there and Devils Branch may indicate an east-west trending arch.

The development of such flexures was probably influenced by irregularities on the footwall surface during emplacement of the thrust sheet. West-southwest of Devils Branch, the trace of the fault and of the ridges change trend toward the northeast suggesting an upwarp at this location. The upwarp may be caused by the thrust sheet overriding the east ridge of Sand Mountain.

Great Smoky Fault

The presence of the Great Smoky fault is clearly indicated by the following criteria: (1) Topographic expression - The trace of the fault is generally expressed by a significant change in topography at the boundary between the Blue Ridge Province and the Valley and Ridge Province. The fault can be traced fairly accurately across the quadrangle on a topographic map. (2) Lithologic discontinuity - At the Blue Ridge - Valley and Ridge boundary, rocks of presumed Early Cambrian and Precambrian ages on the southeast overlie rocks of Middle Cambrian and younger on the northwest. (3) Structural discontinuity - The relatively simply structured, nonschistose rocks of the Valley and Ridge are contrasted to the more highly contorted rocks of the Blue Ridge which, in most places across the fault, possess slaty cleavage. (4) Metamorphic discontinuity - There is a sharp increase in metamorphic grade crossing the fault to the southeast. Valley and Ridge rocks show virtually no effects of metamorphism while those of the Blue Ridge show definite effects. The change in metamorphic character is obvious on visual inspection, but has also been determined by the more quantitative sharpness

ratio (SR) method (Kopp and Sutton, 1968). (5) Fault zone - At several locations along the trace of the fault, the fault zone is exposed and Blue Ridge rocks are seen to overlie Valley and Ridge rocks.

The relatively smooth trace of the fault suggests that the dip of the fault plane is comparatively steep, perhaps 25° to 45° SE. Further evidence for a steeply dipping fault is the absence of windows southeast of the structural front exposing Valley and Ridge rocks. If the fault plane were nearly horizontal, one would expect to find windows in areas of lower elevation such as at Ocoee Lake and the Valley of Minnewauga Creek at Willis Springs. Even though Ocoee Lake is filled with water and the valley of Minnewauga Creek is covered with alluvium, there is no indication that Valley and Ridge rocks lie beneath the cover.

Little Mountain Fault

The Little Mountain fault, named by the writer, is shown on the Geologic Map of Tennessee, Swingle, et al. (1966) and by Rodgers (1953, Plate 13). The present author agrees with this general location. The trace of the fault joins the main trace of the Great Smoky fault directly north of Little Mountain and south of Sugar Loaf Mountain at Baker Creek Road. Its path is relatively non-sinuuous, passing between Bean (named Chilhowee on map at extreme northeast corner) and Little Mountain, along the eastern base of Little Mountain, behind Ocoee Dam No. 1, and following near the eastern base of Sugar Loaf Mountain.

Evidence for this fault is as follows: (1) That the older Sandsuck rocks overlies the younger Chilhowee which underlie Little Mountain. Little and Sugar Loaf Mountains lie in a fault slice caught between the Great Smoky and Little Mountain faults. (2) Highly sheared rock occurs along U.S. Highway 64 just northeast of Ocoee Dam No. 1. The highway appears to have been excavated along the fault zone for a short distance. (3) Samples of argillite from along U.S. Highway 64, 0.2 miles northeast of the dam contain 1M muscovite typical of Chilhowee shales elsewhere (see page 67, this report). A sample taken from 0.2 miles farther northeast contains 2M muscovite and is clearly Sandsuck.

Although the contact between the Sandsuck and Chilhowee is not visible along the east base of Sugar Loaf Mountain, the close proximity of the two units strongly suggests they are separated by a fault. Rocks of the Sandsuck exposed in cuts along the service road at the base of Sugar Loaf Mountain are highly sheared and complex structurally, suggestive of a fault zone. This writer has previously expressed disagreement with Rackley's (1951) extension of the fault southward to Cookson Creek and has presented evidence that it joins the main trace of the Great Smoky fault just south of Sugar Loaf Mountain (Rackley, 1951, and this report page 45).

The Little Mountain fault probably dips at a slightly greater angle than does the main Great Smoky fault, joining the main Great Smoky fault at depth. The relationship between the two faults is interpreted as one of imbricate thrusting, similar to other locations along the Blue Ridge front in Tennessee (King, 1964, Plates 1 and 9; Neuman and Nelson, 1965, Plates 1 and 4; Rackley, 1951, figure 4).

Baker Creek Fault

The trace of Baker Creek fault (T.C. 2,404,000-2,406,000 E.; 252,000-256,000 N.), named by the author, and not shown on previous maps, runs approximately north-south following Baker Creek inlet and connects the traces of the Little Mountain and Indian Creek faults. Recognition of this fault is based mainly on the fact that rocks on the west side of the inlet possess slaty cleavage and have been mapped as Wilhite Formation while those on the peninsula east of the inlet do not possess slaty cleavage and belong to the Sandsuck Formation. However, there is no detectable metamorphic discontinuity based on the I_{025}/I_{112} ratio (Plate III). The position of the Wilhite rocks to the west of the Sandsuck rocks, suggests that it is a very low-angle fault along which Wilhite rocks have overridden those of the Sandsuck Formation. The peninsula between the Indian and Baker Creek inlets represents a window in the thrust sheet.

Indian Creek Fault

The trace of the Indian Creek fault, named by the author, and not shown on previous maps, extends from the eastern map boundary at T.C. 254,000 N. southwestward to Cookson Branch and from there follows Cookson Branch northwestward to intersect the trace of the Great Smoky fault.

Presence of this fault near the south end of the peninsula separating Indian and Baker Creek inlets is based on (1) the juxtaposition of Sandsuck rocks, with no slaty cleavage on the north,

with Wilhite rocks, with good slaty cleavage, on the south, and (2) the I_{025}/I_{112} ratio which averages about 2 north of the fault and about 5 to the south (Plate III). The fault zone is strongly deformed with asymmetrical, overturned, and breached folds toward the northwest. The juxtaposed rocks are separated by a very narrow zone, the transition from one rock type to another being very abrupt.

Southwest of Baker Creek inlet (where Baker Creek and Indian Creek faults intersect) Wilhite rocks are present on both sides of the fault and there is no appreciable difference in the I_{025}/I_{112} ratio (Plate III). There is, however, a marked discrepancy between the strikes and dips of both bedding and slaty cleavage across the fault.

With the absence of the I_{025}/I_{112} ratio discontinuity, which is present northeast of Baker Creek inlet, the argument for the existence of the Indian Creek fault southwest of Baker Creek inlet is not strong. An alternative interpretation would have the fault follow the I_{025}/I_{112} disconformity, shown by region II, (Plate III). Region II would be an overthrust plate of an essentially horizontal thrust fault. The writer prefers the first interpretation because the intense structural deformation at the southeastern end of the peninsula indicates a fault plane of moderate dip. Also, there is no strong structural evidence for a fault elsewhere along the I_{025}/I_{112} discontinuity.

Ball Play Fault

The Ball Play fault (T.C. 2,390,000-2,392,000 E.; 224,000-238,000 N.) appears to be a subsidiary of the Great Smoky fault

where rocks of the Ocoee Group are thrust westward over those of the Chilhowee Group, in a manner similar to the Little Mountain fault. Interpretation of this fault is based mainly on the superposition of Ocoee upon Chilhowee rocks and, to a lesser extent, linear structural features which parallel the fault. No metamorphic discontinuity is recorded because the Chilhowee rocks are all coarse clastics and contain no argillaceous material which could have recorded metamorphic intensity.

Willis Springs Fault

The trace of the Willis Springs fault, named by the author and not previously mapped, extends northward from the junction of the Conasauga River and Minnewauga Creek (T.C. 2,392,000 E.; 226,000 N.) northward along Minnewauga Creek, up Cove Field Branch and follows the trend of the topography to join the main trace of the Great Smoky fault (T.C. 2,394,000 E.; 240,000 N.). It thrusts Wilhite upon Wilhite.

The presence of the fault is based upon (1) a discontinuity in the I_{025}/I_{112} ratio values which range from 0.6 - 2.5 in the western block and from 4 - 6 in the eastern block; and (2) the topographic and drainage pattern. It may pass into a fold northward.

Possible Additional Fault

A possible fault is indicated by disruption of strata, irregularities in the topography and drainage patterns, and an I_{025}/I_{112} discontinuity along Sheeds Creek Road, just north of the

Conasauga River, between T.C. 2,392,000 E. and 2,398,000 E. The trend of the ridges turns abruptly from nearly north-south to east-west and is paralleled by Saw Mill Branch 0.1 miles north of the road. Although the strata are highly deformed, the attitude of the slaty cleavage remains essentially the same on both sides of the discontinuity, suggesting that the beds were disrupted prior to or during the formation of the slaty cleavage. The I_{025}/I_{112} ratio usually exceeds 10 south of the discontinuity and ranges from 4 to 6 to the north.

There are two possible explanations for the apparent discrepancy. (1) Faulting may have followed metamorphism and the formation of the slaty cleavage, moving the two blocks into juxtaposition without rotating them with respect to each other and, thus, preserving the alignment of their cleavages. (2) Faulting may have followed metamorphism but preceded a later period during which alignment of the platy minerals may have taken place. During the event which formed the cleavage, metamorphic intensity would have had to have been sufficient to increase the grade in the northern blocks, but not intense enough to produce a retrograde reaction in the southern block.

Age of Deformation

The structural features were probably formed between the major pulse of Blue Ridge metamorphism, dated at 350 m.y. (Bickford and Wetherill, 1965), and the end of the Appalachian Orogeny which closed the Paleozoic Era, put at 225 m.y. (Harland, Smith, and

Wilcox, 1964), a period of 100 to 150 m.y. Some structures succeeded each other in a continuing process while others may have been episodic, i.e., separated by periods of relative quiescence. Approximate dates for some of the events and their resultant structures may be obtained by correlation with structures already dated elsewhere in the Appalachians.

Sequence of Development of Structures in Blue Ridge Sector

One of the oldest structures in the Blue Ridge sector of the Parksville quadrangle appears to be the Baker Creek fault. Its trace is overlapped by the Indian Creek fault, hence it predates the latter. Slaty cleavage in the Wilhite rocks of the overthrust sheet of the Baker Creek fault, is rather poorly developed and discordant with the slaty cleavage in the Wilhite across the Indian Creek fault. Sandsuck, in the footwall of the Baker Creek fault, has no slaty cleavage at all, suggesting the rocks in the overthrust sheet are of a slightly higher grade. However, metamorphic intensity as measured by the I_{025}/I_{112} ratio method (Plate III) indicates no difference in the degree of metamorphism suffered by the two formations, suggesting faulting occurred prior to metamorphism.

A period of deformation, due to compressional forces directed toward the northwest, probably preceded the main pulse of thermal metamorphism. The deforming forces would reach these rocks long before the "slower moving" thermal energy did. Perhaps several periods or more, then less intense application of deforming forces occurred during the thermal maximum. A late pulse of deforming

forces, perhaps during the waning stage of thermal energy could have produced the Great Smoky and associated faults. The slaty cleavage was probably produced toward the end of the period of deformation, during the waning stages of thermal metamorphism, while the rocks were yet under great stress but confined so that deformation could no longer take place. Good evidence for the cleavage postdating the deformation is that the cleavage cross cuts highly deformed strata without being deformed or deflected itself. Probably the tight folds within the Parksville synclinorium were produced at this time.

The Indian Creek fault is probably associated with the early stages of the event that produced the Great Smoky fault. As mentioned above (page 135), the Indian Creek fault is younger than the Baker Creek fault. If it intersects the trace of the Great Smoky fault at Cookson Branch, as shown in Plate I, it must also predate the Great Smoky fault because the latter has not been offset. The Indian Creek fault, the Alaculsy Valley fault, and the squeezing that occurred toward the southwest corner of the structural block, were probably all produced during emplacement of the Great Smoky fault, sometime before the episode ended. Convergence of slaty cleavage toward the southwest corner of the structural block suggests that final deformation of the block occurred after the cleavage had been developed.

Little Mountain, Willis Springs, and Ball Play faults bound slices broken off during emplacement of the Great Smoky fault. The relative age of the Parksville synclinorium is unknown. The metamorphic discontinuity, nearly coincident with the axis of the

synclinorium suggests that the synclinorium developed late, relative to the metamorphism of these rocks. Whether it was produced at the same time as the slaty cleavage or at the time of the Great Smoky faulting cannot be determined. However, the gentle warps such as those described at Devils Branch and southeast of the trace of Indian Creek fault appear to be synchronous with emplacement of the Great Smoky fault as they have modified pre-existing structural trends.

Ages of the structures in the Valley and Ridge Province are no older than Mississippian as Mississippian rocks are involved in the frontal structures of the Great Smoky to the northeast (Geologic Map of Tennessee, Swingle, et al., 1966). King (1964, p. 130) writes: "Pennsylvanian and early Permian rocks northwest of the Valley and Ridge Province are conformable with earlier Paleozoic rocks, but their clastic and continental nature indicates that deformation to the south was in progress during their deposition.... The writer once thought it possible that the southeastern part of the Valley and Ridge Province was involved in this deformation of Pennsylvanian and early Permian time. Discovery of Pennsylvanian rocks in windows along the northwest edge of the Valley and Ridge Province, opposite the Great Smoky Mountains, and the likelihood that they extend some distance southeastward under the thrust sheets of that province, made this less attractive.... Deformation of even the southeastern part of the Valley and Ridge Province probably occurred later than the Pennsylvanian, although it was perhaps completed by the end of the Paleozoic era." In the Parksville area, the Great Smoky thrust sheet overlies pre-existing Valley and Ridge structures (Plate I).

CHAPTER V

CONCLUSIONS AND SUGGESTIONS FOR FURTHER STUDY

The boundary separating the Blue Ridge and Valley and Ridge Provinces in the Parksville quadrangle is a thrust fault. Valley and Ridge rocks of known Paleozoic age are in contact with Blue Ridge rocks of entirely different character which correlate with rocks in the Great Smoky Mountains presumed to be of Precambrian age. The rocks in the Valley and Ridge sector are virtually unmetamorphosed (or show only incipient metamorphism), whereas those of the Blue Ridge sector show definite metamorphic effects, albeit, low grade. The physiographic boundary also marks a change between the broad, open structure of the Valley and Ridge, dominated by a major syncline, and the more strongly deformed rocks of the Blue Ridge, characterized by tight, asymmetrical and breached folds and numerous faults. While the structural trends in the two provinces are not identical, the general northeast-southwest direction of all structures suggests that they may have been formed by the same general deforming forces.

Within the Blue Ridge sector crosscutting and converging relationships exist between structures within the Blue Ridge. While structures adjacent to the Great Smoky fault tend to parallel that fault, structures adjacent to the converging Sylco Creek-Alaculsy Valley fault parallel this fault resulting in a convergence of structures towards the southwest corner of the structural block.

Metamorphic intensity in the Blue Ridge sector generally increases southeastward, but the lines of equal intensity do not necessarily parallel the trace of the Great Smoky fault but more closely parallel the trends of the Sylco Creek and Indian Creek faults. A technique for monitoring increasing metamorphic intensity in these very low grade rocks, was developed, but it is not perfected. This method, which uses the I_{025}/I_{112} ratio shows some promise, but it may also reflect variations in bulk chemical composition of the rocks as well as metamorphic intensity. Nevertheless, use of this ratio reveals some interesting relationships between structural and metamorphic discontinuities.

The mineralogy and petrology of the fine-grained Wilhite Formation rocks are of interest. These rocks were apparently derived from high aluminum pelites. It was possible to recognize and map a separate unit, here called the Upper Wilhite, on the basis that it contains the sodium-rich dioctahedral mica paragonite. The most common Wilhite mineral assemblage consists of quartz, muscovite, and chlorite, with the addition of paragonite in the Upper Wilhite. Chloritoid was never found to be a phase although it should be favored by the bulk chemical composition of many of these rocks. It is possible that in rocks whose bulk chemistry favors chloritoid, its presence or absence is controlled by other factors, such as the f_{O_2} ; perhaps to some extent by the P_{H_2O} and P_T . In high f_{O_2} environments chloritoid would not be favored, since chloritoid requires Fe^{+2} rather than Fe^{+3} in its structure. Possible evidence for a high f_{O_2} in the fine-grained rocks of the Parksville quadrangle is the ubiquitous presence of oxidized chlorite.

This research has suggested many possible areas worthy of further study. Some of the most interesting of these are: 1) Detailed structural analysis of the structural block, bounded by the Great Smoky fault and Sylco Creek fault, by mapping in much finer detail, concentrating on attitudes of bedding and cleavage, and by doing petrofabric studies, might help to unravel the complex metamorphic-deformational history of this fringe zone which was apparently only slightly metamorphosed. 2) An attempt should be made to extend the paragonite-bearing unit beyond this report area and to determine its extent and usefulness as a mappable unit. 3) The I_{025}/I_{112} ratio method needs to be refined so that the effects of variation in bulk chemistry may be accounted for. 4) Mineral parageneses in other Blue Ridge rocks of bulk chemical composition and metamorphic grade similar to those of the Wilhite of Parksville quadrangle should be investigated to determine the factors which control the stability of chloritoid. 5) The possible effects of low grade metamorphism on the matrix minerals in the coarser-grained conglomerates needs to be investigated.

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PLATE II GEOLOGIC CROSS SECTIONS PARKSVILLE QUADRANGLE Polk And Bradley Counties, Tennessee By Thomas C. Sutton 1971

EXPLANATION

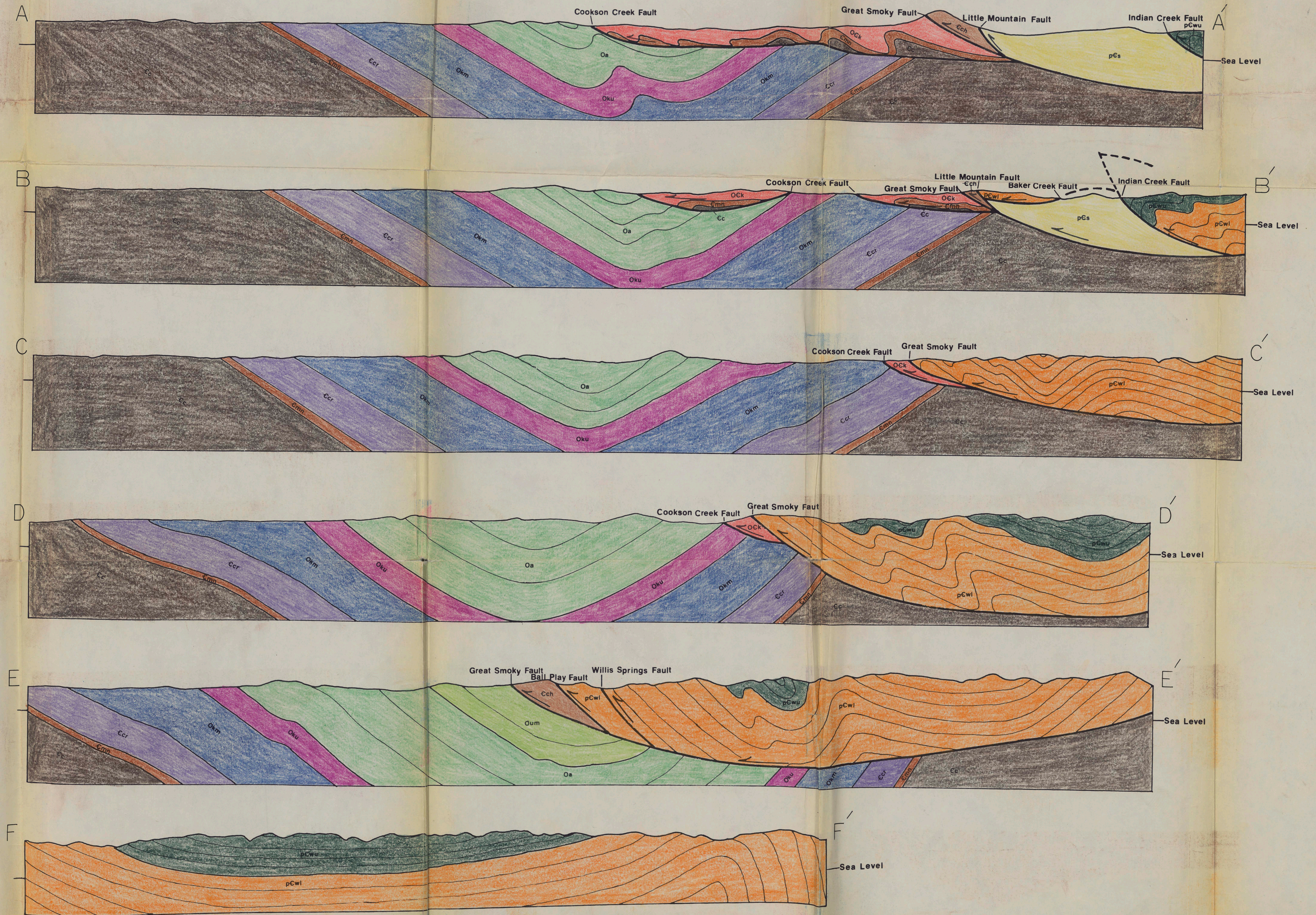
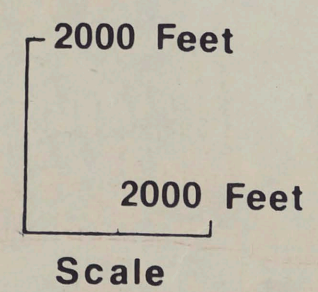
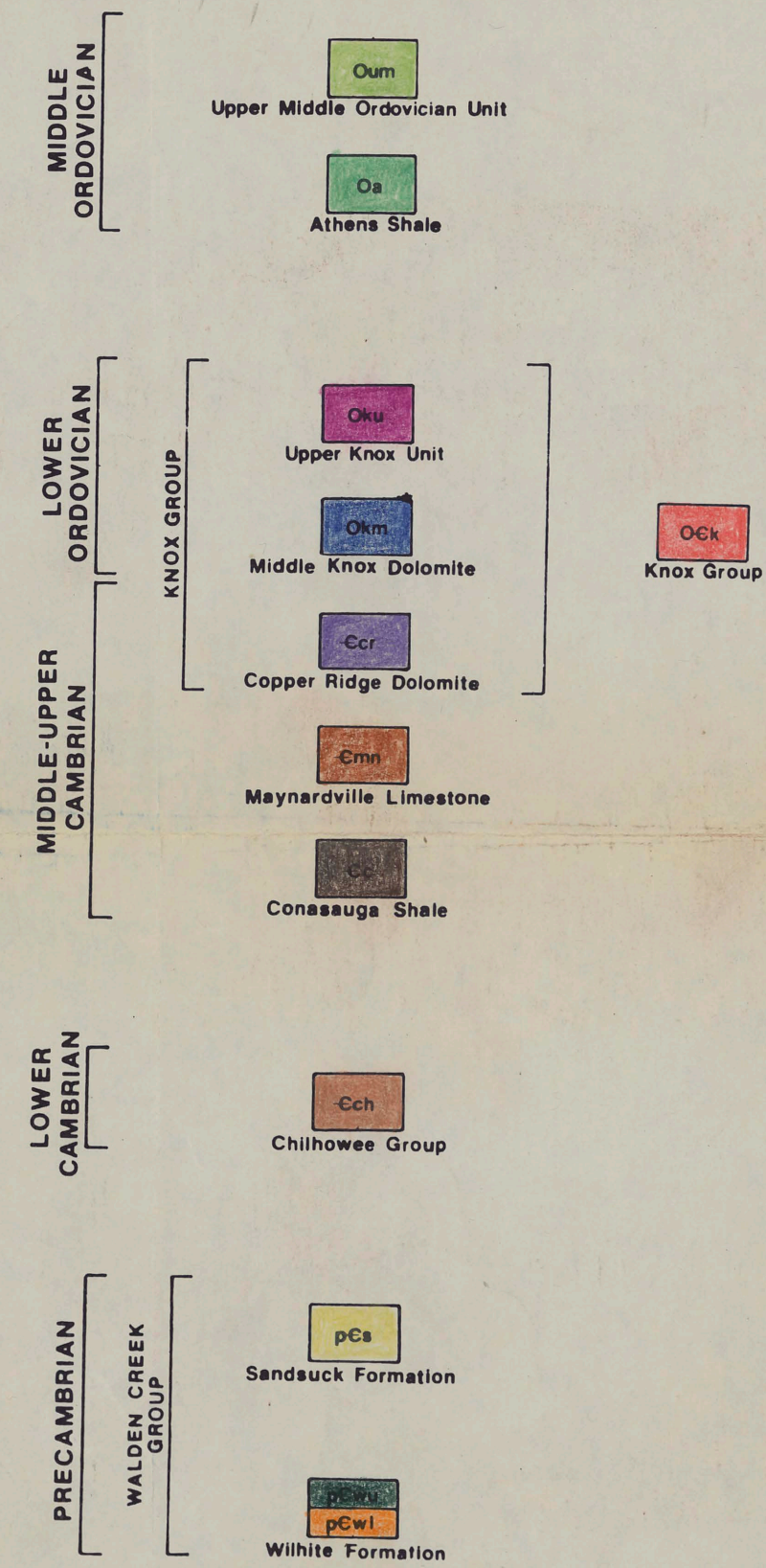
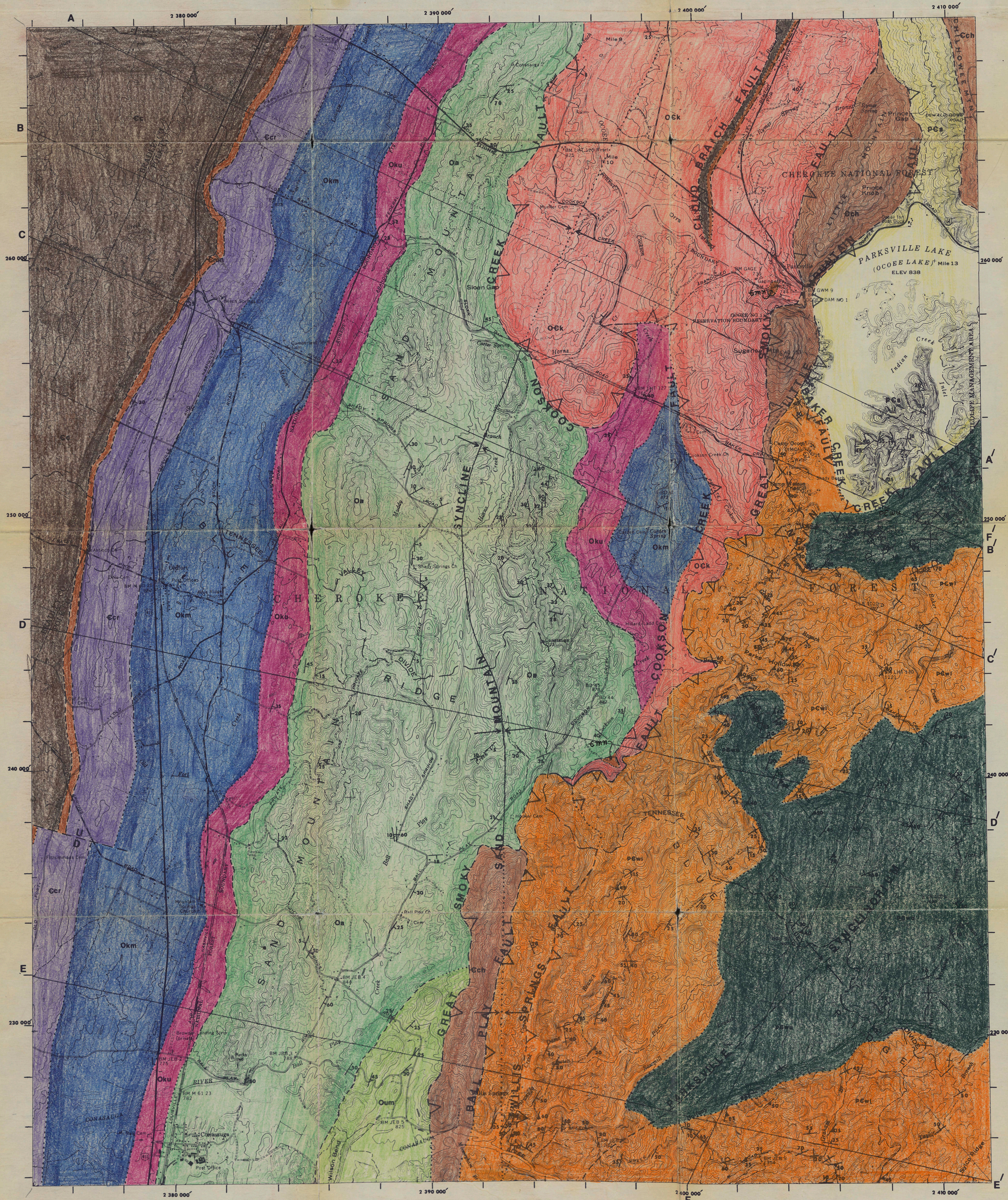
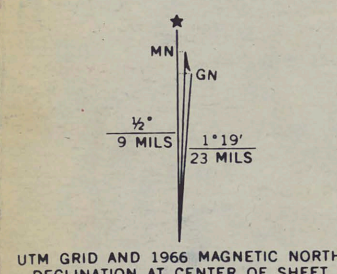
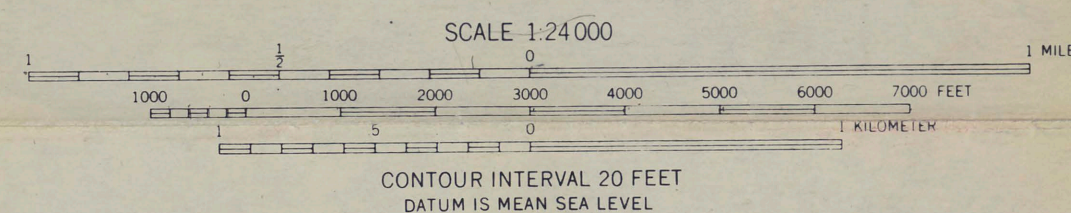


PLATE I

GEOLOGIC MAP
PARKVILLE QUADRANGLE
Polk And Bradley Counties, Tennessee

By
Thomas C. Sutton
1971



EXPLANATION

