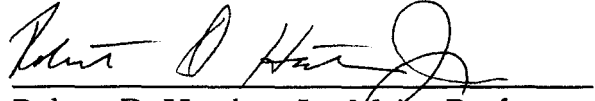
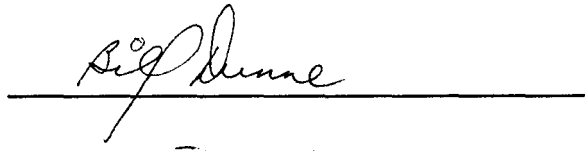


To the Graduate Council:

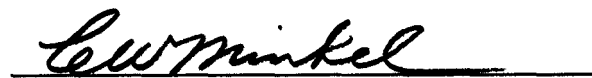
I am submitting herewith a thesis written by Mark W. Carter entitled "Stratigraphy and Structure of part of the Western Blue Ridge Foothills, Polk and Monroe Counties, Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.


Robert D. Hatcher, Jr., Major Professor

We have read this thesis
and recommend its acceptance:




Accepted for the Council:


Associate Vice Chancellor
and Dean of the Graduate School

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a Master's degree at The University of Tennessee, Knoxville, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of the source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his absence, by the Head of Interlibrary Services when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature Mark W. Goff
Date April 21, 1994

*Stratigraphy and Structure of part of the Western Blue Ridge
Foothills, Polk and Monroe Counties, Tennessee*

*A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville*

*Mark Wayne Carter
May, 1994*

Dedication

This thesis is dedicated to my loving wife,

Aina Marie

for helping me accomplish my goals.

Acknowledgments

I would like to thank my major professor, Dr. Robert D. Hatcher Jr., for introducing me to this project and for his guidance and patience during my research. Dr. Hatcher has been an instructor, mentor, employer, and friend over the past three years, and I owe him many thanks. I would also like to thank my other committee members, Dr. Thomas W. Broadhead and Dr. William M. Dunne, for their comments, criticisms, and assistance during this investigation. Partial support for this project by a Geological Society of America Research Grant (#4880-92) and the George D. Swingle Memorial Fellowship Award is greatly appreciated.

Many thanks to Catherine Lombardi for assistance in the field, and to Steve Martin, Don Geddes, and Dr. Kauko Laajoki for their assistance and spirited discussions of western Blue Ridge Geology in the field and in the office (I still think it's Sandsuck, Kauko!). Don McClanahan deserves recognition for his graphics assistance and friendship. I am also very grateful to Dr. Sam Swanson for his encouragement and friendship. Thanks also to the fine folks in Polk County, including everyone at Adams Store (no gold yet, Sissy!), Emmet Adams, August Lee, and Homer Lindner, for their friendship during my fieldwork. No thanks to the bears on McCulley Mountain and Basin Lead. Lastly, special thanks to my family and friends in Mechanicsville, Virginia, and Rockford, Illinois, and especially to my wife, Aina, for emotional support and encouragement throughout the duration of this project.

Abstract

The Upper Proterozoic Walden Creek Group (Ocoee Supergroup) is a thick sequence of metasedimentary rocks that underlies the western Blue Ridge Foothills belt in eastern Tennessee. Traditional interpretation suggests that rocks of the Walden Creek Group represent synrift sedimentation along the Late Proterozoic Laurentian margin. These rocks were later regionally metamorphosed, cleaved, folded, and thrust westward during two Paleozoic orogenies (Taconic and Alleghanian). Recent hypotheses from uncorroborated paleontological evidence suggest that the Walden Creek Group is no older than Silurian, deposited into a post-Taconic successor basin, and subsequently metamorphosed and deformed only during the Alleghanian orogeny. Stratigraphic and structural data from this study in the Foothills belt of southeastern Tennessee support traditional views about the age, depositional setting, and structural chronology of the Walden Creek Group.

Detailed geologic mapping (1:12,000 and 1:24,000) of a 209 km² (84 mi²) area indicates that the Walden Creek Group sequence in southeastern Tennessee is broken by the Miller Cove and Maggies Mill faults. Lithologic similarities between the footwall and hanging wall of the Maggies Mill fault provide a partially complete stratigraphic section. Mapping confirms that the middle and upper members of the Sandsuck Formation (Walden Creek Group) are conformably overlain by the Lower Cambrian Chilhowee Group, and that the Wilhite Formation (Walden Creek Group) conformably overlies rocks of the Great Smoky Group (Ocoee Supergroup). The upper conformable contact with the Chilhowee Group implies that at least the middle and upper members of the Sandsuck Formation can be no younger than Early Cambrian. The lower conformable contact with the Great Smoky Group was previously interpreted to be the southern continuation of the Greenbrier fault.

Rocks of the study area are deformed by four generations of folds and cleavages, and four regional thrust faults. F₁ folds are overprinted by regionally dominant F₂ folds and axial-

planar slaty cleavage (S_2). F_2 and S_2 are related to regional Barrovian-type metamorphism. Pressure-solution cleavage (S_{2a}) probably developed late in the same event that produced F_2 folds and axial-planar S_2 cleavage. Strain analysis (R_f/ϕ , normalized Fry, and Flinn methods) yield values that range between 1.18 to 1.63, 1.30 to 1.73, and 2.43 to 4.92 (R_{xy} [$X \geq Y \geq Z$]), respectively. Strain values appear to be the product of one non-coaxial western Blue Ridge event, but it is unclear whether this event occurred before or during F_2 and S_2 development. Crenulation cleavage (S_3), spaced cleavage (S_{3a}), F_3 folds, and F_4 folds may have developed during a later deformational event dominated by regional brittle faulting. These brittle faults (Great Smoky, Maggie's Mill, Miller Cove, and Bullet Mountain faults) separate rocks of the study area into three western Blue Ridge frontal thrust sheets (Great Smoky, Maggie's Mill, Miller Cove thrust sheets), and one Valley and Ridge thrust sheet (Bullet Mountain thrust sheet).

Stratigraphic and age relationships, and sedimentological characteristics of Great Smoky and Walden Creek Group rocks in southeastern Tennessee, southwestern North Carolina, and northwestern Georgia suggest that the Ocoee depositional basin at this latitude evolved during rifting of the Laurentian margin in the Late Proterozoic to Early Cambrian. Rifting was followed by stabilization of the rift basin and passive margin development during the Early Cambrian. The Wilhite Formation may be the western equivalent of the Nantahala and Brasstown Formations, and the Murphy Marble in the Murphy Belt. Carbonate clasts in breccia of the lower member of the Sandsuck Formation may have been derived from the Murphy Marble as base-of-slope deposits. Structural analysis of Foothills belt rocks in the study area suggests that subsequent deformation along the Laurentian margin occurred during the Taconic orogeny with the development of regional metamorphism, F_1 and F_2 folds, axial-planar slaty cleavage (S_2), and pressure-solution cleavage (S_{2a}). Regional brittle thrust faults, crenulation cleavage (S_3), spaced cleavage (S_{3a}), F_3 folds, and F_4 folds deformed these rocks during the Alleghanian orogeny.

Table of Contents

<i>Chapter</i>	<i>Page</i>
I. Introduction	1
Location of study area	4
Questions to be addressed	7
Methodology	7
 II. Late Proterozoic to Early Paleozoic Stratigraphy of the Southeastern Laurentian Margin	 8
Introduction	8
Historical background	8
Lithostratigraphy in southeastern Tennessee and western North Carolina	19
Snowbird Group	19
Great Smoky Group	20
Copperhill Formation	21
Wehuttty Formation	21
Boyd Gap Formation	24
Buck Bald Formation	24
Lower lithofacies	25
Upper lithofacies	25
Walden Creek Group	34
Wilhite Formation	34
Feldspathic metagraywacke member	35
Feldspathic metasandstone member	38
Quartzite member	39

Metasiltstone lithofacies	40
Sandsuck Formation	44
Lower member	46
Middle member	52
Upper member	54
Chilhowee Group	57
Cochran Formation	57
Nichols Shale	58
Nebo Quartzite	58
Murray Shale	59
Hesse Quartzite	59
Helenmode Formation	60
Rocks beneath the Great Smoky fault	60
Shady Dolomite	61
Rome Formation	61
Conasauga Group	62
Knox Group	62
Age of the Walden Creek Group-Stratigraphic and paleontological evidence	63

III. Structure of the Western Blue Ridge Frontal Thrust

Sheets, Southeastern Tennessee	67
Introduction	67
Previous structural studies	67
Structure in southeastern Tennessee	72
Folds	72
F ₀ folds	77

F ₁ folds	80
F ₂ folds	80
F ₃ folds in the Miller Cove thrust sheet	85
F ₃ folds west of the Miller Cove thrust sheet	88
F ₄ folds in the western Blue Ridge thrust sheets	91
S-surfaces	91
S ₀ (bedding)	92
Cleavage in the Miller Cove thrust sheet	98
S ₂ (Slaty cleavage)	98
S _{2a} (Pressure-solution cleavage)	104
S ₃ (Crenulation cleavage)	104
Cleavage in the Great Smoky and Maggies Mill thrust sheets	109
S ₂ (Slaty cleavage)	109
Spaced cleavage (S _{3a}) in the Great Smoky thrust sheet	110
Spaced cleavage (S _{3a}) in the Bullet Mountain thrust sheet	115
Faults	115
Great Smoky fault	118
Structure beneath the Great Smoky thrust sheet	120
Bullet Mountain fault	121
Miller Cove fault	122
Maggies Mill fault	129
Minor faults	133
Strain analysis	134
Methodology	137
Results of study	140
Discussion of results	152

Conclusions	156
IV. Depositional and Structural Chronology of the Western Blue Ridge in Southeastern Tennessee	158
Introduction	158
Depositional history of the Ocoee Supergroup, southeastern Tennessee	158
Depositional characteristics and environments of the Ocoee Supergroup, southeastern Tennessee	159
Structural chronology of the Laurentian margin, southeastern Tennessee and western North Carolina	170
Structural chronology of the western Blue Ridge, southeastern Tennessee	171
V. Conclusions	177
References Cited	180
Appendix	194
Vita	233

List of Figures

<i>Figure</i>	<i>Page</i>
I-1 Regional geologic and metamorphic isograd map of the western and eastern Blue Ridge in Tennessee, North Carolina, South Carolina, and Georgia.	2
I-2 Geographical location map of eastern Tennessee and western North Carolina. . .	5
II-1 Regional correlation of Late Proterozoic - early Paleozoic stratigraphy in eastern Tennessee, southwestern North Carolina, and northern Georgia.	9
II-2 Stratigraphic correlation chart showing changes in the stratigraphic nomenclature of the Ocoee Supergroup by various authors through time.	11
II-3 Map showing western Blue Ridge fossil localities.	17
II-4 Schematic (no horizontal scale) stratigraphic diagram for Great Smoky Group, Walden Creek Group, and Chilhowee Group formations as exposed in the study area.	22
II-5 QMF diagram for coarse-grained rocks of the Great Smoky Group in eastern Tennessee, southwestern North Carolina, and northern Georgia.	26
II-6 Characteristic lithologies of the Buck Bald Formation (Great Smoky Group).	28
II-7 Structural and lithologic characteristics along the Walden Creek Group and Great Smoky Group contact.	32
II-8 QMF diagram for coarse-grained rocks of the Wilhite Formation in the study area, and Snowbird Group in eastern Tennessee and western North Carolina.	36
II-9 Characteristic lithologic features of the metasiltstone lithofacies, Wilhite Formation.	41
II-10 QMF diagram for coarse-grained rocks of the Sandsuck and Cochran formations in the study area.	47
II-11 Typical carbonate lithologies in the lower member of the Sandsuck Formation. . .	50

III-1	Four thrust sheets, bounding thrust faults, and major folds in the study area.	73
III-2	Major structural elements of the western Blue Ridge in southeastern Tennessee, southwestern North Carolina, and northern Georgia.	75
III-3	Mesoscale characteristics of soft-sedimentary F_0 folds.	78
III-4	Mesoscale characteristics of tectonic F_1 folds.	81
III-5	Mesoscale characteristics of F_2 folds in the Miller Cove thrust sheet.	83
III-6	Lower-hemisphere equal-area projection of 3 F_3 folds in the Miller Cove thrust sheet.	86
III-7	Lower-hemisphere equal-area projection of 21 F_3 fold measurements from the Maggie Mill, Great Smoky, and Bullet Mountain thrust sheets.	89
III-8	Constituent cleavage morphologies of five cleavage zones in the study area.	93
III-9	Lower-hemisphere equal-area projections of S_0 (bedding) data.	96
III-10	Mesoscopic characteristics of slaty cleavage (S_2) in the Miller Cove thrust sheet.	99
III-11	Characteristic slaty cleavage (S_2) microstructures.	101
III-12	Meso- and microstructural characteristics of pressure-solution cleavage (S_{2a}) in the Miller Cove thrust sheet.	105
III-13	Meso- and microscopic characteristics of crenulation cleavage (S_3) in the Miller Cove and Great Smoky thrust sheets.	107
III-14	Meso- and microstructural characteristics of slaty cleavage (S_2) in the Great Smoky and Maggie Mill thrust sheets.	111
III-15	Characteristic mesoscopic spaced cleavage (S_{3a}) structures in the Great Smoky thrust sheet.	113

III-16	Mesoscopic characteristics of spaced cleavage (S_{3a}) structures in the Bullet Mountain thrust sheet.	116
III-17	Miller Cove fault fabrics.	125
III-18	Alternative interpretations for the development of the Miller Cove fault.	127
III-19	Maggies Mill fault fabrics.	131
III-20	Location of samples used for strain analysis.	138
III-21	X/Y axial ratios as determined by the R_f/ϕ method.	141
III-22	Lower-hemisphere equal-area projections of strain ellipsoid axes.	143
III-23	Flinn diagram of normalized Fry and R_f/ϕ strain values in each thrust sheet.	145
III-24	X/Y axial ratios as determined by the normalized Fry method.	147
III-25	Flinn diagrams of flattened quartz pebbles and granitoid pebbles from Black Mountain, (station number FAR 2), Farner 7.5-minute quadrangle.	150
III-26	Common microstructures in the Great Smoky and Miller Cove thrust sheets.	153
IV-1	Schematic fence diagram through the restored Ocoee basin.	161
IV-2	Orogenic evolution diagram of the Late Proterozoic to late Paleozoic Laurentian margin in southeastern Tennessee.	172

List of Tables

<i>Table</i>	<i>Page</i>
A-I Structural measurements corresponding to stations in the study area.	195
A-II Modal analyses of coarse-grained clastic rocks from the study area.	224
A-III Modal analyses of Sandsuck Formation carbonate rocks from the study area.	227
A-IV Size orders of folds in the study area.	228
A-V Measurements of quartz pebble principal axes and axial ratios.	229
A-VI Measurements of granitoid pebble and cobble principal axes and axial ratios.	230
A-VII Results of 3-dimensional strain analysis using the R_f/ϕ method.	231
A-VIII Results of 3-dimensional strain analysis using the normalized Fry method.	232

List of Plates

I	Geologic Map of Parts of the McFarland, Mecca, Farner, and Oswald Dome 7.5-Minute Quadrangles, Southeastern Tennessee (scale 1:24,000).....	In Pocket
II	Station Map.....	In Pocket
III	Retrodeformed Cross Sections, A-A' and B-B'.....	In Pocket

Chapter I

Introduction

New hypotheses and interpretations have challenged the traditional views about the stratigraphy and structural chronology of the western Blue Ridge in the southern Appalachians. For more than four decades, the Ocoee Supergroup, which is the principal lithostratigraphic unit in the western Blue Ridge of eastern Tennessee, southwestern North Carolina, and northwestern Georgia (Fig. I-1), has been thought to represent synrift sedimentation along the Late Proterozoic Laurentian margin (Stose and Stose, 1944; King and others, 1958; DeWindt, 1975; Rankin, 1975; Hatcher, 1978; Rast and Kohles, 1986; Naylor and Follo, 1988). Assuming this depositional history, the sequence was subsequently deformed during the Taconic and Alleghanian orogenies (Butler, 1972; Hatcher, 1978; Glover and others, 1983; Kish, 1989; Drake and others, 1989; Connelly and Dallmeyer, 1990, 1991; Woodward and others, 1991; Connelly and Woodward, 1992). Recently formulated hypotheses from paleontological and stratigraphic evidence suggest that parts of the western Blue Ridge stratigraphy, including at least the upper part of the Ocoee Supergroup, may be much younger (Middle Ordovician to Mississippian) than originally thought (Tull and Groszos, 1988, 1990; Unrug and Unrug, 1990; Thompson and Tull, 1991; Unrug and others, 1991; Tull and others, 1993). According to these new hypotheses, these units were deposited above the regional basal Middle Ordovician unconformity into post-Taconic successor basins (possibly during the Acadian orogeny), and subsequently intensely deformed only once during the Alleghanian orogeny (Tull and Groszos, 1988, 1990; Unrug and Unrug, 1990; Thompson and Tull, 1991; Unrug and others, 1991; Tull and others, 1993). If these interpretations are valid, the chronology of tectonic events and subsequent deformation of the Laurentian margin must be revised.

Figure I-1: Regional geologic and metamorphic isograd map of the western and eastern Blue Ridge in Tennessee, North Carolina, South Carolina, and Georgia. Study area within light-colored box in the western Blue Ridge. Map compiled and modified from a number of sources including Brown (1985), Hardeman (1966), Hatcher and Hopson (1989), and Pickering (1976).

Stratigraphic abbreviations:

Valley and Ridge units: D-M - Devonian and Mississippian; MO - Middle Ordovician; Ck - Conasauga and Knox Groups.

Ocoee Supergroup units: cs - Cades Sandstone; gs - Great Smoky Group; rbs - Rich Butt Sandstone; s - Snowbird Group; wc - Walden Creek Group; wms - Webb Mountain and Big Ridge Sandstone.

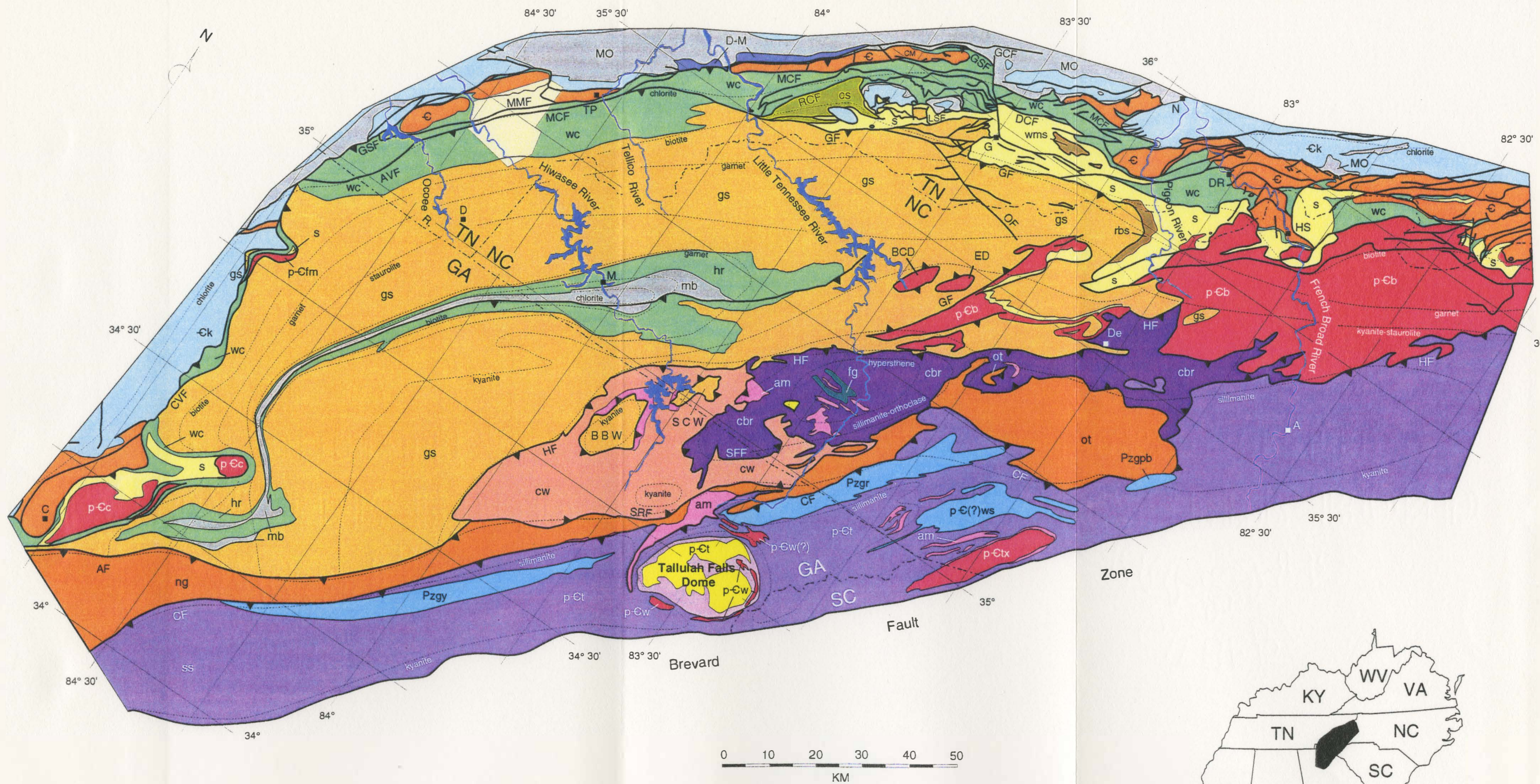
other western Blue Ridge units: C - Chilhowee Group, Shady Dolomite, and Rome Formation (includes the Sandsuck Formation on Chilhowee Mountain); hr - Hiwassee River Group; mb - Mineral Bluff Group; pCb - undifferentiated Proterozoic basement complex; pEc - Corbin Gneiss; pCfm - Fort Mountain Gneiss.

central and eastern Blue Ridge units: am - amphibolite; cbr - central Blue Ridge complex; cw - Coweeta Group; fg - felsic gneiss; ng - New Georgia Group; ot - Otto Formation; pCt - Tallulah Falls Formation; pCtx - Toxaway Gneiss; pCw - Wiley and Sutton Creek gneisses; pCw(?) - possible Wiley and Sutton Creek gneisses; pCws - Whiteside granite; Pzgapb - Pink Beds granite; Pzgr - Rabun granite; Pzgy - Yonah gneiss; ss - Sandy Springs Group.

Fault abbreviations: AF - Allatoona fault; AVF - Alaculsy Valley fault; CF - Chattahoochee fault; CVF - Cartersville fault; DCF - Dunn Creek fault; GF - Greenbrier fault; GCF - Guess Creek fault; GSF - Great Smoky fault; HF - Hayesville fault; LSF - Line Springs fault; MCF - Miller Cove fault; MMF - Maggies Mill fault; OF - Oconaluftee fault; RCF - Rabbit Creek fault; SFF - Shope Fork fault; SRF - Soque River fault.

Other geologic abbreviations: BBW - Brasstown Bald window; BCD - Bryson City dome; ED - Ela dome; SCW - Shooting Creek window.

Geographic abbreviations: A - Asheville; C - Cartersville; CM - Chilhowee Mountain; D - Ducktown; De - Dellwood; DR - Del Rio; G - Gatlinburg; HS - Hot Springs; M - Murphy; N - Newport; TP - Tellico Plains.



This study focuses on the stratigraphy, age, depositional, and tectonic setting of the Walden Creek Group (uppermost Ocoee Supergroup). Reports of Silurian to early Mississippian microfossils from the Walden Creek Group (Unrug and Unrug, 1990; Unrug and others, 1991) have raised questions concerning the nature of the contact between the Walden Creek Group and other units in the western Blue Ridge of known or inferred ages. Paleontological evidence (e.g., Unrug and Unrug, 1990; Unrug and others, 1991), which has yet to be reproduced by others (Broadhead and others, 1993), and lack of corroborating stratigraphic and structural evidence, may fail to justify a reinterpretation of the age and tectonic setting of the Walden Creek Group. The purpose of this study is to provide new data that will assist in defining the stratigraphic constraints and structural chronology of the Walden Creek Group in a portion of the southeastern Tennessee Blue Ridge Foothills.

Location of study area

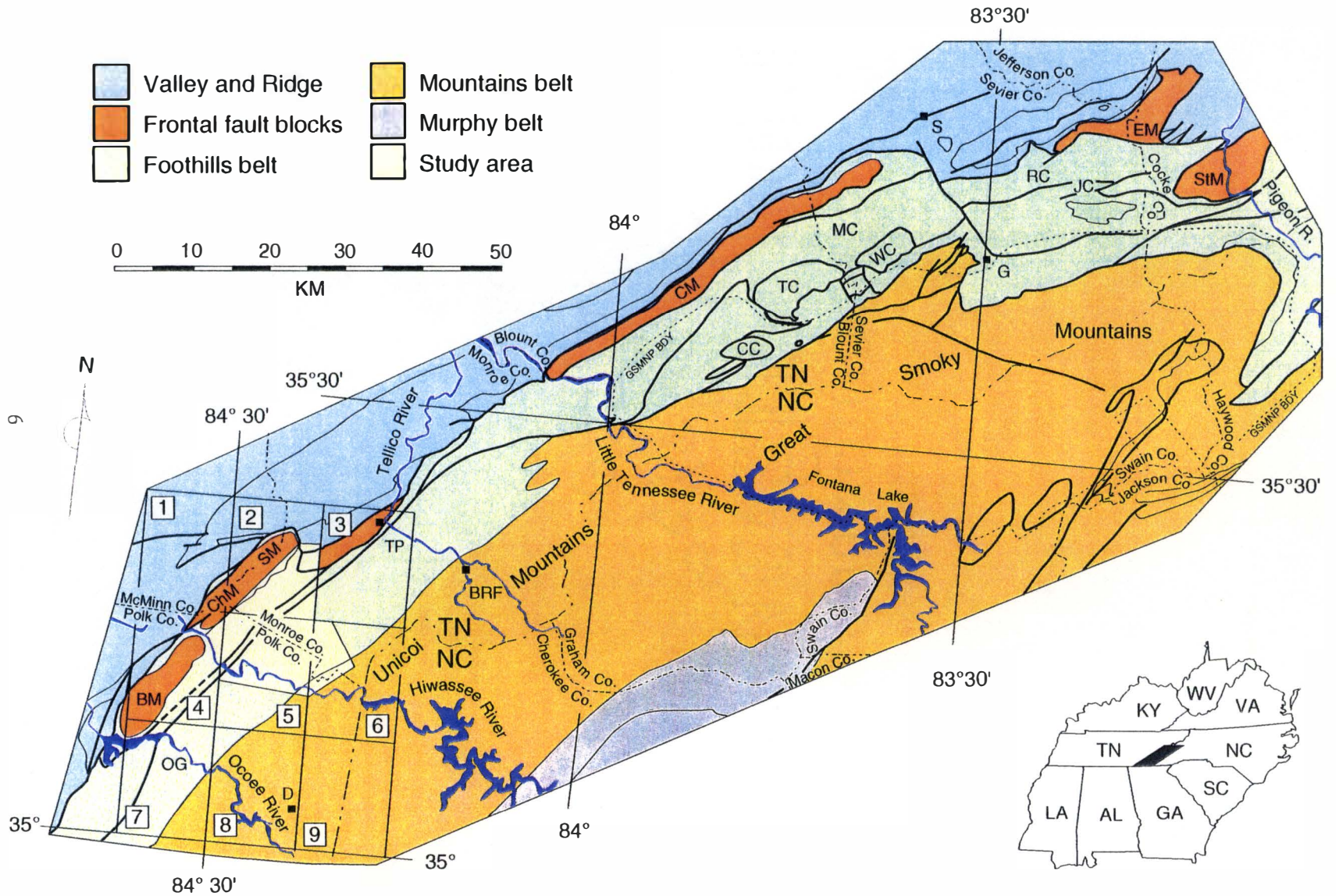
Rodgers (1953) subdivided the western Blue Ridge of eastern Tennessee and western North Carolina into three physiographic subprovinces: (1) the westernmost frontal Blue Ridge fault blocks; (2) the Foothills belt; and (3) the easternmost Mountains belt (Fig. I-2). The study area sits astride these three subprovinces in Polk and Monroe Counties, Tennessee (Fig. I-2). The study area occupies an area of approximately 209 km² (84 mi²), and is located in parts of the Farner, McFarland, Mecca, and Oswald Dome 7.5-minute quadrangles (Fig. I-2; Plate I). The area is bounded to the south by the Hiwassee River, to the northwest by the southeastern slopes of Chestnut and Starr Mountains, and to the east by the Unicoi Mountains (Fig. I-2). Rocks in the study area range from the lowest Chilhowee Group formations (youngest), through the entire sequence of Walden Creek Group strata, and into the uppermost formations of the Great Smoky Group (oldest) (Fig. I-1; Plate I).

Figure I-2: Geographical location map of eastern Tennessee and western North Carolina. Study area within light colored box.

Index to 7.5-minute quadrangles in southeastern Tennessee and southwestern North Carolina:

(1) Etowah; (2) Mecca; (3) Tellico Plains; (4) Oswald Dome; (5) McFarland; (6) Fanner; (7) Caney Creek; (8) Ducktown; (9) Isabella.

Geographic abbreviations: BM - Bean Mountain; BRF - Bald River Falls; CC - Cades Cove; ChM - Chestnut Mountain; CM - Chilhowee Mountain; D - Ducktown; EM - English Mountain; G - Gatlinburg; GSMNP BDY - approximate boundary of the Great Smoky Mountains National Park; JC - Jones Cove; MC - Miller Cove; OG - Ocoee Gorge; RC - Richardson Cove; S - Sevierville; SM - Starr Mountain; StM - Stone Mountain; TC - Tuckaleechee Cove; TP - Tellico Plains; WC - Wear Cove.



Questions to be addressed

Specific questions to be addressed by this study include: (1) the lithology and areal extent of Walden Creek Group lithostratigraphy in southeastern Tennessee; (2) the stratigraphic relationship between the Walden Creek Group and the Chilhowee and Great Smoky Groups; and (3) the structural history and kinematics of the area, with emphasis on slaty cleavage development. Answers to these questions will be used to draw conclusions concerning the age and depositional setting of the Walden Creek Group sequence, retrodeform rocks in the study area, and model the chronology of tectonic events that shaped the Late Proterozoic to middle Paleozoic Laurentian margin.

Methodology

This research employed detailed mapping (1:24,000 and 1:12,000) of the study area which was conducted from January, 1992 to February, 1993, and consisted of foot traverses along streams, ridges, logging roads, county roads, and state highways, mostly across regional strike. Structural measurements of bedding, cleavage surfaces, folds, and lineations were collected from numerous stations throughout the study area (Plate II, Table A-I*) using a Brunton compass. Structural analyses were aided using Stereonet™ software developed for the Macintosh™ personal computer by R. W. Allmendinger (Cornell University). Petrographic studies were conducted using a Leitz Orthoplan Pol™ polarizing microscope, and strain studies (normalized Fry and R_f/ϕ methods) were performed using software developed by A. Yonkee (University of Utah) for the Macintosh personal computer.

* All tables may be found in Appendix.

Chapter II

Late Proterozoic to Early Paleozoic Stratigraphy of the Southeastern Laurentian Margin

Introduction

The Ocoee Supergroup has been estimated by King and others (1958) to be an approximately 15 km thick succession of dominantly clastic metasedimentary rocks that comprise the stratigraphic core of the western Blue Ridge in eastern Tennessee, western North Carolina, and northern Georgia (Fig. II-1). Ocoee Supergroup strata nonconformably overlie Middle Proterozoic (Grenvillian) basement rocks in the Blue Ridge of western North Carolina and northwestern Georgia (Hayes, 1900; Keith, 1907a, 1907b; Stose and Stose, 1949; King and others, 1958; Odom and others, 1973; Costello, 1978; Cressler and others, 1979; McConnell and Costello, 1980; Costello and others, 1982; McConnell and Costello, 1982, 1984; Costello, 1986; Rankin and others, 1989; Hatcher and Goldberg, 1991). To the east, the Ocoee Supergroup is stratigraphically overlain by Late Proterozoic-Ordovician or younger rocks of the Murphy belt (Keith, 1907a; Nuttall, 1951; Hurst, 1955; King and others, 1958; Hadley, 1970; Tull and others, 1991; Tull and others, 1993). Westward, the Ocoee Supergroup lies stratigraphically beneath the Lower Cambrian Chilhowee Group (King, 1964; Neuman and Nelson, 1965; Walker and Driese, 1991).

Historical Background

Rocks of the Ocoee Supergroup have been recognized as a prominent stratigraphic unit in the western Blue Ridge for more than 130 years. Safford (1856) is credited with first recognizing and classifying the rocks in the Ocoee River Gorge (Fig. I-2) in southeastern Tennessee as "Ocoee conglomerates and slates" (Fig. II-2). Safford (1856, 1869) also concluded that these rocks are conformably overlain by rocks he recognized on Chilhowee Mountain,

Figure II-1: Regional correlation of Late Proterozoic - early Paleozoic stratigraphy in eastern Tennessee, southwestern North Carolina, and northern Georgia. Number key in stratigraphic units denotes author(s) and contributor(s) who defined the stratigraphic unit. No thicknesses or time durations are indicated by the size of individual blocks.

Index to number key:

1 - Safford (1856); 2 - Safford (1869); 3 - Hayes (1891); 4 - Walcott (1891); 5 - Hayes (1895, 1900); 6 - Keith (1895); 7 - Campbell (1899); 8 - Keith (1903); 9 - Keith (1904); 10 - Keith (1907a); 11 - King and others (1944); 12 - King (1949); 13 - Hurst (1955); 14 - King and others (1958); 15 - King and Furguson (1960); 16 - Hurst and Schlee (1962); 17 - King (1964); 18 - Fairley (1965); 19 - Neuman and Nelson (1965); 20 - Hernon (1968); 21 - Merschat and Wiener (1973); 22 - Mohr (1973); 23 - Wiener and Merschat (1978); 24 - Keller (1980); 25 - Mack (1980); 26 - McConnell and Costello (1980, 1982, 1984); 27 - Wiener and Merschat (1981); 28 - Costello and others (1982); 29 - Ausburn (1983); 30 - Walters (1988); 31 - Lewis (1988); 32 - Unrug and Unrug (1990); 33 - Costello (1991); 34 - Tull and others (1991); 35 - Woodward and others (1991); 36 - this thesis.

Figure II-2: Stratigraphic correlation chart showing changes in the stratigraphic nomenclature of the Ocoee Supergroup by various authors through time.

**Mohr
(1973)**

South of the Little Tennessee River

West			East		
Hayes (1895)	Wiener and Merschall (1978, 1992)	Keith (1907a)	LaForge and Phalen (1913)	Hurst (1955)	Hernon (1968)
Murray Shale		Valleytown Formation	Valleytown Formation	Brasstown Formation	Brasstown Formation
Nebo Sandstone		Brasstown Schist	Brasstown Schist	Tusquitee Quartzite	Tusquitee Quartzite
Nichols Shale		Tusquitee Quartzite	Tusquitee Quartzite	Nantahala Slate	Nantahala Slate
Cochran Conglomerate		Nantahala Slate	Nantahala Slate		
Sandsuck Shale				Dean Fm	Dean Fm
Thunderhead Conglomerate		Great Smoky Conglomerate	Great Smoky Formation	Hothouse Fm	Hothouse Fm
				Hughes Gap Fm	Hughes Gap Fm
				Copperhill Fm	Copperhill Fm
Pigeon Slate	Fanner Formation				Wehuty Fm
Citico Conglomerate	Buck Bald Formation				
Willite Slate	Boyd Gap Formation	Hiwassee Slate			
?					

Basement
rocks

Basement
rocks

Tennessee, and named “Chilhowee sandstones and shales” (Fig. II-2). Both the Ocoee and Chilhowee “formations” were assigned to the Cambrian and Lower Ordovician Potsdam Group.

Safford’s (1856, 1869) work on the rocks in Ocoee River Gorge and on Chilhowee Mountain was modified by Keith (1895, 1896, 1903, 1904, 1907a, 1907b) and Hayes (1891, 1895), who reclassified Safford’s Ocoee rocks into mappable units (Fig. II-2). Keith (1895) did not recognize the depositional and structural complexities of the terrane and originally miscorrelated the rocks of his Ocoee “group” with “Silurian” rocks of the Valley and Ridge province. He later rescinded this notion by reassigning Ocoee and Chilhowee rocks to the “Cambrian Series” (Keith, 1904). Hayes (1891) also originally assigned Ocoee rocks to the Silurian in accordance with Keith’s (1895) view, but he too later recognized the greater antiquity of the sequence by tentatively assigning rocks of the Ocoee series to the “Algonkian” (Later Precambrian) (Hayes, 1895). While Keith (1895, 1896, 1903, 1904, 1907a, 1907b) worked primarily in eastern Tennessee and western North Carolina north of the Little Tennessee River, Hayes (1891, 1895, unpublished geologic maps of the Cartersville and Dalton 30-minute quadrangles, 1900) mapped in southeastern Tennessee and northwestern Georgia south of the Little Tennessee River. Ocoee stratigraphy defined by Keith (1895, 1896, 1903, 1904, 1907a, 1907b) and Hayes (1891, 1895, unpublished geologic maps of the Cartersville and Dalton 30-minute quadrangles, 1900) would remain separable until united by Mohr (1973, 1975) (Fig. II-2).

The first significant contribution to Ocoee stratigraphy north of the Little Tennessee River following the completion of Keith’s (1907a, 1907b) work on the Nantahala and Roan Mountain 30-minute quadrangles was made by Stose and Stose (1944, 1949), who formally elevated Ocoee rocks in the Great Smoky Mountains region to “series” status. Furthermore, Stose and Stose (1949) redivided Keith’s older stratigraphic succession (Fig. II-2) and assigned the Ocoee “series” to the Precambrian, but assigned carbonates and interbedded shales from the upper part of the Nantahala Slate to the Ordovician Tellico Formation.

This assignment of Ocoee carbonates and interbedded shales to the Ordovician (Stose and Stose, 1949) was questioned by King (1949), who concluded the base of the Cambrian must be at the base of the Chilhowee Group, the oldest strata in the southern Appalachians containing Early Cambrian fossils, because these clastic rocks rest unconformably on the underlying Catoclin Greenstone in northern Virginia, the Mount Rogers volcanics and Grenville basement in southwestern Virginia and northeastern Tennessee, and by analogy on the Ocoee "series" in eastern Tennessee. King's (1949) work was significant in that it assigned the entire Ocoee Series, including carbonates and shales in the upper part to the Precambrian.

The definitive work on the stratigraphic succession of Ocoee rocks north of the Little Tennessee River was completed by P. B. King and others (1958). King and others (1958) redivided Ocoee strata into three groups and defined their constituent formations (Fig. II-2). Keith's (1904) Snowbird formation was elevated to group status. Rocks of Keith's (1904) Great Smoky conglomerate were also elevated to group status, although equivalent rocks in northern Georgia had previously been defined as the Great Smoky Group several years earlier by Hurst (1955). Lastly, rocks originally defined by Keith (1895, 1904) as the Wilhite slate, Citico conglomerate, Pigeon slate, and Sandsuck shale, were incorporated into the Walden Creek Group. Several formations defined by King and others (1958), including the Rich Butt Sandstone, Cades Sandstone, and Webb Mountain and Big Ridge rocks, were not classified with any of these groups because stratigraphic relations between these formations and the three groups were not demonstrable. Subsequent workers (Walters, 1988; Lewis, 1988; Woodward and others, 1991) have interpreted these formations to be part of the Great Smoky Group based on palinspastic reconstructions of cross sections through the Ocoee basin.

During this time, the stratigraphy of rocks equivalent to the Ocoee "series" in the Ducktown region of northern Georgia, southeastern Tennessee, and southwestern North Carolina, south of the Little Tennessee River, was being deciphered by Hurst (1955). Hurst (1955) was not the first to study the rocks in the Ducktown Basin; Safford's (1856) type locality

of Ocoee rocks was less than ten miles to the west along the Ocoee River, Hayes (1895, 1900, unpublished) had mapped Ocoee rocks to the southwest, and LaForge and Phalen (1913) had mapped Ocoee rocks in the same vicinity in Georgia (Fig. II-2). Although several more regional works were published after LaForge and Phalen (1913) (Jonas, 1932; Stose and Stose, 1944; Van Horn, 1948; Stose and Stose, 1949; Furcron, 1953), Hurst's (1955) was the first detailed, comprehensive report on the Ocoee rocks south of the Little Tennessee River.

Hurst (1955) elevated rocks that LaForge and Phalen (1913) had mapped as the Great Smoky formation to the Great Smoky Group and subdivided it into constituent formations (Fig. II-2). Furthermore, Hurst (1955) formally introduced a revised Murphy belt stratigraphy, and reconfirmed Keith's (1907a) initial report that Murphy belt rocks rest stratigraphically above Great Smoky Group lithologies. Later, Hurst and Schlee (1962) correlated some rocks in Ocoee Gorge (Fig. I-2) formerly mapped as the Wilhite slate by Hayes (1895) with Murphy belt rocks.

Hurst (1955) faced the same problem as King (1949) with defining the base of the Cambrian System in northwestern Georgia. Although no unconformity was recognized, Hurst (1955) observed a distinctive lithologic break between coarse-grained rocks of the Great Smoky Group and finer-grained rocks of the lowermost formations of the Murphy belt. Hurst (1955) concluded that the base of the Cambrian must be at the contact between the Murphy belt and the Great Smoky Group, assigning equivalent Ocoee rocks south of the Little Tennessee River to the Precambrian.

The Ocoee stratigraphy outlined and mapped by King and others (1958) north of the Little Tennessee River and Hurst (1955) south of the river remained relatively unchanged with few modifications. Hernon (1968) revised Hurst's (1955) Great Smoky Group stratigraphy in the Ducktown region of Tennessee (Fig. II-2). Mohr (1973, 1975) united the Great Smoky Group stratigraphy of King and others (1958) with Hurst's (1955) stratigraphy in the vicinity of Fontana Lake (Fig. I-1) in North Carolina (Fig. II-2). Meanwhile, Mersch and Wiener (1973) and Wiener and Mersch (1978) expanded upon Hurst and Schlee's (1962) reconnaissance of

Ocoee and Murphy belt rocks west of the Ducktown region in Tennessee and redefined the Great Smoky Group sequence in that area (Fig. II-2).

Southwestward, in northwestern Georgia, McConnell and Costello (1980, 1982, 1984), Costello and others (1982), and Costello (1991) defined and mapped Great Smoky Group lithologies south of Hurst's (1955) area (Fig. II-1). McConnell and Costello (1980, 1982, 1984) also redefined Hayes' (1895, unpublished, 1900) older stratigraphy in the region and tentatively correlated rocks that lie unconformably above Grenville basement gneiss with the Snowbird Group in the vicinity of the Great Smoky Mountains National Park (Fig. II-1). Furthermore, rocks originally mapped as the "Wilhite slate" by Hayes (1895, unpublished, 1900) were formally correlated with the Walden Creek Group of Tennessee (McConnell and Costello, 1982, 1984).

Most recently, Unrug and Unrug (1990) and Unrug and others (1991) reported Silurian to early Mississippian macrofossil fragments, agglutinated foraminifera and calcareous foraminifera from shales enclosing carbonate olistoliths of the Wilhite Formation throughout the Foothills belt in eastern Tennessee (Fig. II-3). These fossils come from the same belt of rocks that Stose and Stose (1949) previously mapped as the Ordovician Tellico Formation. In light of these fossil discoveries, Unrug and Unrug (1990) and Unrug and others (1991) proposed that the Walden Creek Group (and possibly the entire Ocoee Supergroup) is mid Paleozoic rather than Precambrian as previously interpreted (King, 1949). These new paleontological data also led several workers (Tull and Groszos, 1990; Unrug and others, 1991; Tull and others, 1993) to speculate that the Walden Creek Group may be correlative to recently paleontologically dated Paleozoic rocks (Mineral Bluff group) (Figs. I-1; II-3) above a regional Middle Ordovician unconformity in the Murphy belt (Tull and Groszos, 1988, 1990; Tull and others, 1991; Tull and others, 1993).

Figure II-3: Map showing western Blue Ridge fossil localities. Knoll and Keller's (1979) fossil localities from Walker and Rast (1991).

Index to symbols:

Black circles - Macrofossil fragments, agglutinated foraminifera, and calcareous foraminifera (Unrug and Unrug, 1990; Unrug and others, 1991).

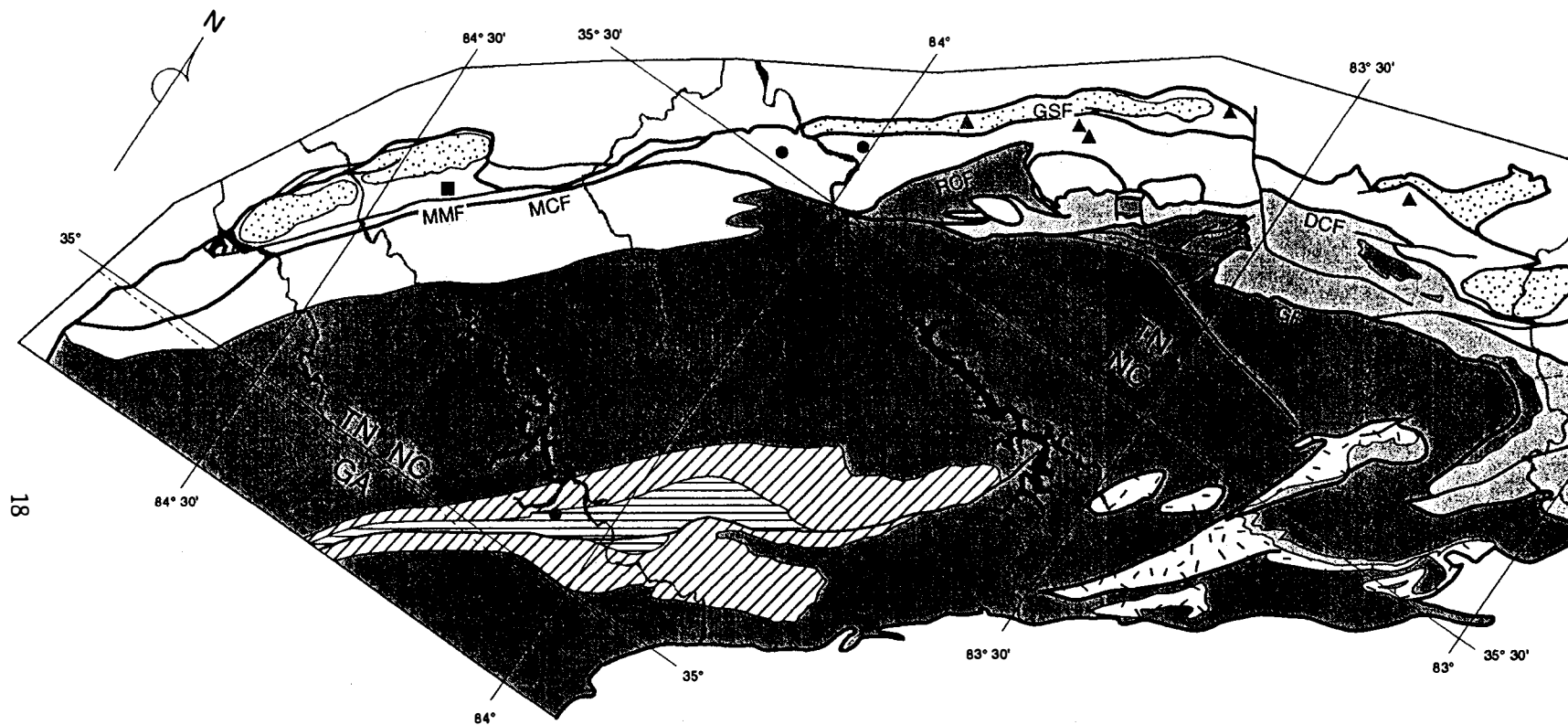
Gray circle - Pelmetazoan echinoderm column (Tull and others, 1993).

Black square - Soft-bodied metazoan (Rackley, 1951; Phillips, 1952; Broadhead and others, 1991) and trace fossil (this report).

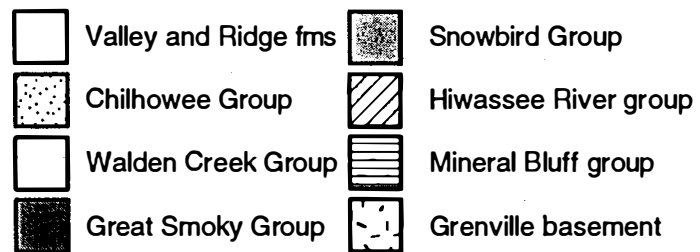
Black triangles - *Bavlinella faueolata* (shepleva) (Knoll and Keller, 1979).

Gray triangle - *Indiana tennesseensis* (Laurence and Palmer, 1963).

Fault abbreviations: DCF - Dunn Creek fault; GF - Greenbrier fault; GSF - Great Smoky fault; MCF - Miller Cove fault; MMF - Maggies Mill fault; RCF - Rabbit Creek fault.



0 10 20 30 40 50
KM



In the sections that follow, I will examine the evidence in the study area that addresses these correlations. Some of these interpreted correlations are included only for their historical value. Present-day knowledge, both local and regional, indicates they are no longer viable.

Lithostratigraphy in southeastern Tennessee and western North Carolina

No complete stratigraphic section of Ocoee Supergroup strata exists north or south of the Little Tennessee River because faulting has dissected the entire sequence. A partially complete stratigraphy can be pieced together through lithostratigraphic correlations across fault blocks. Unrug and Unrug (1990) cautioned against this practice, citing reservations by other workers (King and others, 1958; Hamilton, 1961), who also suggested that formations in the footwalls of thrusts may not correlate with similar units in the hanging walls. If these correlations across fault blocks are correct, however, the Ocoee Supergroup could represent more than 15,000 m (50,000 ft) of basin sedimentation (as estimated by King and others, 1958), approximately twice as thick as the entire accumulated thickness of Paleozoic carbonate shelf and orogenic clastic wedge deposits of central-east Tennessee (Rodgers, 1953; Harris and Milici, 1977).

Snowbird Group

The Snowbird Group is the lowest unit in the Ocoee sequence and rests nonconformably upon Middle Proterozoic basement rocks in western North Carolina (Keith, 1907a, 1907b; Stose and Stose, 1949; King and others, 1958; Odom and others, 1973). The Snowbird Group is a relatively clean, feldspathic, coarse- to fine-grained succession of sandstone and siltstone in the Great Smoky Mountains region (King and others, 1958). Snowbird Group lithologies form a southeast-thinning wedge that attains a maximum estimated thickness of 4,000 to 5,500 m (13,000 to 17,000 ft) (King and others, 1958; Hadley and Goldsmith, 1963). The Snowbird Group is conformably overlain by rocks of the Great Smoky

Group in the southeastern Great Smoky Mountains approximately 20 km south of the Pigeon River (King and others, 1958). North of the Pigeon River, however, Keller (1980) mapped previously unrecognized Walden Creek Group lithologies in an area traditionally thought to be underlain by Snowbird Group rocks, and demonstrated that the Walden Creek Group also rests conformably on the Snowbird Group. This stratigraphic relationship is similar to the one outlined more recently by McConnell and Costello (1984) for rocks lying nonconformably above Grenville basement in the Cartersville and Fort Mountain districts of northwestern Georgia. There, Snowbird Group rocks consisting of an interlayered sequence of metaconglomerate, metasandstone, metasilstone, and graphitic phyllite is conformably overlain by rocks interpreted by McConnell and Costello (1984) to be equivalent to Walden Creek Group rocks in Tennessee. Snowbird Group rocks have been interpreted by some workers to underlie the Foothills belt of southeastern Tennessee in the vicinity of the study area (Wiener and Merschat, 1978; Merschat and Hale, 1983; Wiener and Merschat, 1992).

Great Smoky Group

The Great Smoky Group is the dominant lithostratigraphic unit at this latitude in the western Blue Ridge, with a strike belt more than 242 km (150 miles) long and 65 km (40 miles) wide (Fig. I-1). Great Smoky Group lithologies extend southward from the Pigeon River in Tennessee and North Carolina to the Cartersville District of Georgia. They extend eastward, stratigraphically beneath the Hiwassee River group (Tull and others, 1991) of the Murphy belt succession. They also extend structurally beneath the Hayesville-Allatoona fault system and reappear beneath the Hayesville thrust sheet in the Brasstown Bald and Shooting Creek windows (Hopson and others, 1989). The Great Smoky Group is the thickest unit in the Ocoee succession, with a maximum estimated thickness of more than 8,000 m (25,000 ft) in the vicinity of the Great Smoky Mountains National Park (Hadley and Goldsmith, 1963; King, 1964). There, the Great Smoky Group is composed of granule conglomerate and coarse to fine sandstone

interbedded with layers of silty or argillaceous slate and phyllite (King, 1964), but similar lithologies also occur in Great Smoky Group rocks in southeastern Tennessee (Fig. II-4) and northern Georgia.

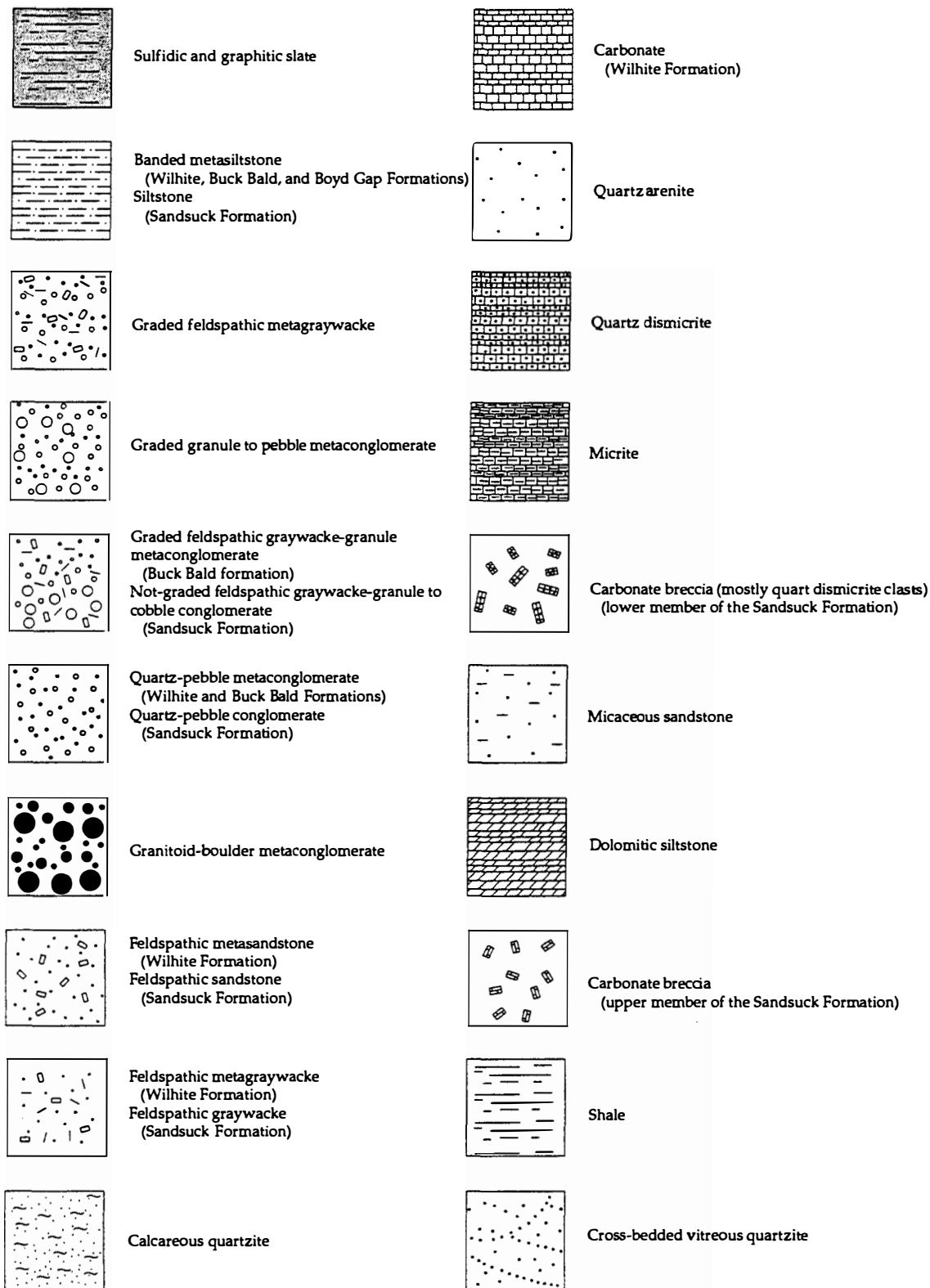
Copperhill Formation

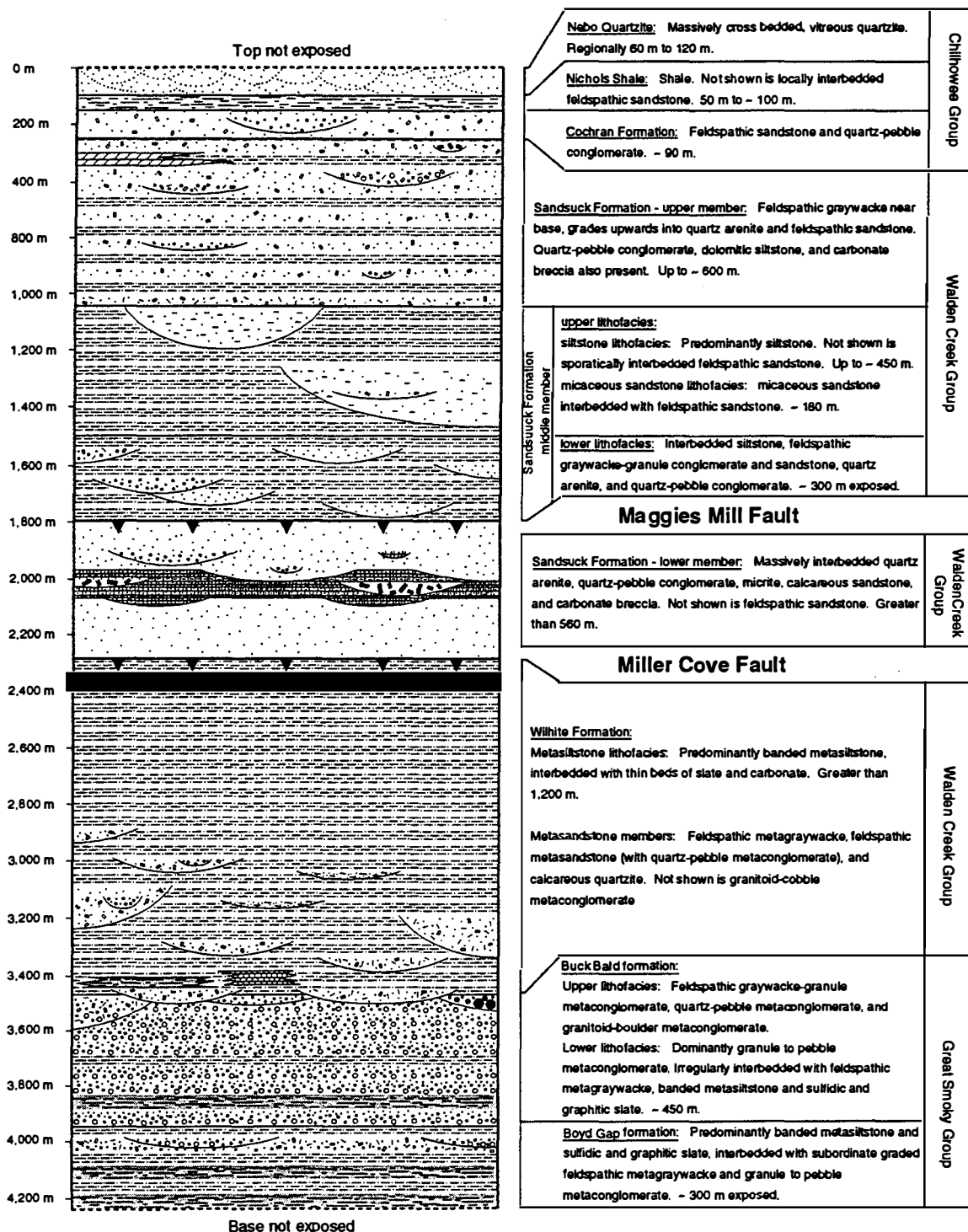
The lowest formation of the Great Smoky Group mapped south of the Little Tennessee River in the vicinity of the study area is the Copperhill Formation. Hurst (1955) described the Copperhill as a dominantly coarse-grained unit, consisting principally of very thin to thickly bedded metagraywacke containing irregular interbeds of mica schist. Locally, horizons of metaconglomerate, quartzite, and metaarkose are interbedded with and grade into the metagraywacke. These rocks lie conformably(?) above an unnamed and unmapped lower formation which Hurst (1955) described only as a staurolite-mica schist of unknown thickness and extent (Hurst and Schlee, 1962). Although internal deformation restricts a more precise measurement, Hurst (1955) estimated the Copperhill Formation to be between 600 m and 1,500 m (2,000 ft and 5,000 ft) thick in the Ducktown region of southeastern Tennessee.

Wehutty Formation

The Wehutty Formation (as defined by Hernon, 1968) and its western equivalent, the Farner Formation (as defined by Merschat and Wiener, 1973 and Wiener and Merschat, 1978), consists predominantly of fine- to medium-grained, graphitic and sulfidic schist that locally alternates with feldspathic quartzite, feldspathic metagraywacke, and metaconglomerate, all of which can occur in zones tens of meters thick (Hernon, 1968, 1969; Merschat and Wiener, 1973; Wiener and Merschat, 1992). As defined by Hernon (1968, 1969), the Wehutty Formation actually includes the upper part of Hurst's Copperhill Formation, and is conformable with it, although the contact is locally faulted. A similar gradational contact exists between the Copperhill and Farner formations farther west. The Wehutty and Farner

Figure II-4: Schematic (no horizontal scale) stratigraphic diagram for Great Smoky Group, Walden Creek Group, and Chilhowee Group formations as exposed in the study area.





formations are estimated to be about 1,200 m (4,000 ft) thick near the Tennessee-North Carolina state line, but may thin northwestward to less than 750 m (2,500 ft) (Hernon, 1968; Merschat and Hale, 1983).

Boyd Gap Formation

The Boyd Gap Formation stratigraphically overlies the Farner Formation, and is stratigraphically equivalent to the Hothouse, Ammons, Hughes Gap, and Grassy Branch formations farther east. The Boyd Gap consists dominantly of fine-grained, thin- to thick-bedded, sulfidic and graphitic slate, metasiltstone, fine- to very coarse-grained, graded metagraywacke, and sporadically interbedded granule to pebble metaconglomerate. Rocks of the Boyd Gap Formation crop out along the southeastern edge of the study area and consist of medium to light gray metasiltstone and dark gray to black, sulfidic and graphitic slate, locally interbedded with light gray, fine- to coarse-grained feldspathic metagraywacke (Fig. II-4). Primary depositional banding that ranges in thickness from 0.8 to 1.7 cm is characteristic of the metasiltstone. The Boyd Gap Formation is estimated to be about 2,400 m (8,000 ft) thick (Merschat and Hale, 1983), but only about the upper 300 meters are exposed in the study area. The best exposure of Boyd Gap Formation metasiltstone in the study area is at the southeast end of a southwestward facing roadcut approximately 1.4 km (0.87 mi) north of the confluence of Rough Branch and the Hiwassee River, Farner 7.5-minute quadrangle (Plate I).

Buck Bald Formation

The Buck Bald Formation conformably overlies the Boyd Gap Formation and is the uppermost unit of the Great Smoky Group in southeastern Tennessee. The Buck Bald Formation is the western equivalent of the Dean Formation which occupies the same stratigraphic position beneath Murphy belt rocks in North Carolina. The Buck Bald Formation is divisible into two lithofacies in the study area: a heterogeneous lower lithofacies consisting of

interbedded, coarse- and finer-grained rocks, and a coarser-grained, upper lithofacies consisting of three distinct lithologies (Fig. II-4).

Lower lithofacies. The heterogeneous lower lithofacies is similar to but coarser-grained than the underlying Boyd Gap Formation and consists of an irregularly interbedded succession of medium gray to grayish green granule to pebble metaconglomerate; medium to light gray fine-grained feldspathic metagraywacke; medium to light gray banded metasiltstone; and dark gray to black, sulfidic and graphitic slate. Bed thickness in the coarser-grained rocks ranges from about one meter to less than ten meters and graded beds are typical. Bed thickness in the finer-grained rocks is usually less than 1.5 m. The most common lithology of this facies is the granule to pebble metaconglomerate which consists of a poorly to moderately sorted mixture of subrounded quartz grains, slightly smaller subangular feldspar grains (andesine and oligoclase), and varying amounts of lithic (sedimentary) fragments in a clay-chlorite-muscovite-rich matrix (Fig. II-5; Table A-II). White quartz is the most common constituent, but rutilated blue quartz also occurs and is very diagnostic of this lithology, as are dark gray to black, graphitic shale (now slate) clasts that range in diameter from 2 to 10 cm (Fig. II-6A). The lower lithofacies is estimated to be 450 m (1,500 ft) in the southeast, but appears to thin westward to less than 150 m (500 ft).

Upper lithofacies. The three coarser-grained lithologies that constitute the upper lithofacies include feldspathic graywacke-granule metaconglomerate; quartz-pebble metaconglomerate; and granitoid-boulder metaconglomerate. Feldspathic graywacke-granule metaconglomerate forms graded beds, generally thicker than 1.5 m, and consists of predominantly blue quartz and feldspar grains in a chlorite-rich, micaceous matrix (Fig. II-5; Table A-II) that imparts a bluish-green color to the fresh rock. The uppermost, finer-grained beds of this facies are compositionally and texturally similar to the metagraywacke in the overlying Wilhite

Figure II-5: QMF diagram for coarse-grained rocks of the Great Smoky Group in eastern Tennessee, southwestern North Carolina, and northern Georgia. QMF diagram modified from Pettijohn (1949).

(A): Compositional fields, Great Smoky Group rocks north of the Little Tennessee River:

Elkmont Sandstone (King, 1964) (n = 3) 

Thunderhead Sandstone (King, 1964) (n = 12) 

(B): Compositions, Great Smoky Group rocks south of the Little Tennessee River:

Graywackes, Boyd Gap and Buck Bald formations (Salisbury, 1961) (n = 10) 

Present study, granule to pebble metaconglomerate, Buck Bald Formation:

White circle - 0.4 km (0.25 mi) southeast of Cane Island, south bank of Hiwassee River
McFarland 7.5-minute quadrangle (station MCF 1668).

Gray circle - Yearling Gap, Farner 7.5-minute quadrangle (station FAR 28).

Present study, feldspathic graywacke-granule metaconglomerate, Buck Bald Formation:

Black circle - 1.35 km (0.8 mi) southwest of Yearling Gap, Farner 7.5-minute quadrangle
(station FAR 71)

Note: The feldspar content of sample FAR 71 may be lower than typical by up to 15 percent due to the decomposed nature of the feldspars.

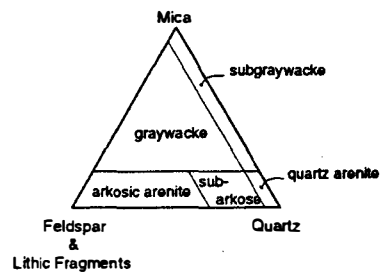
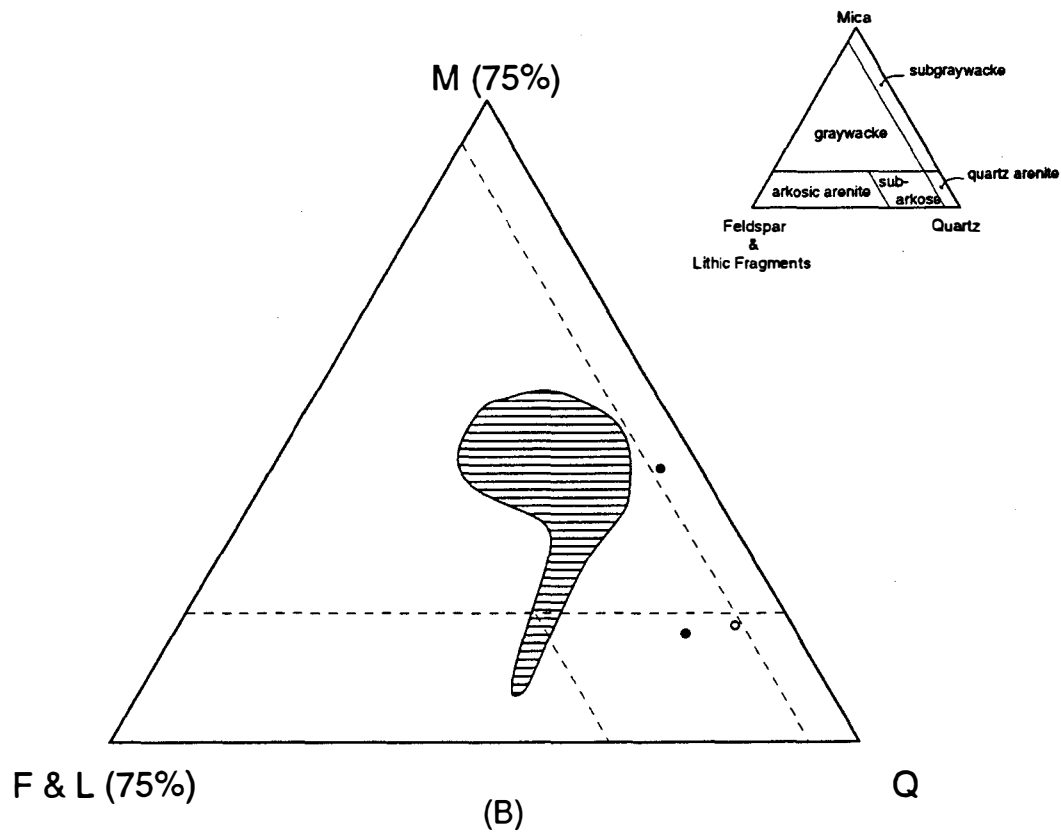
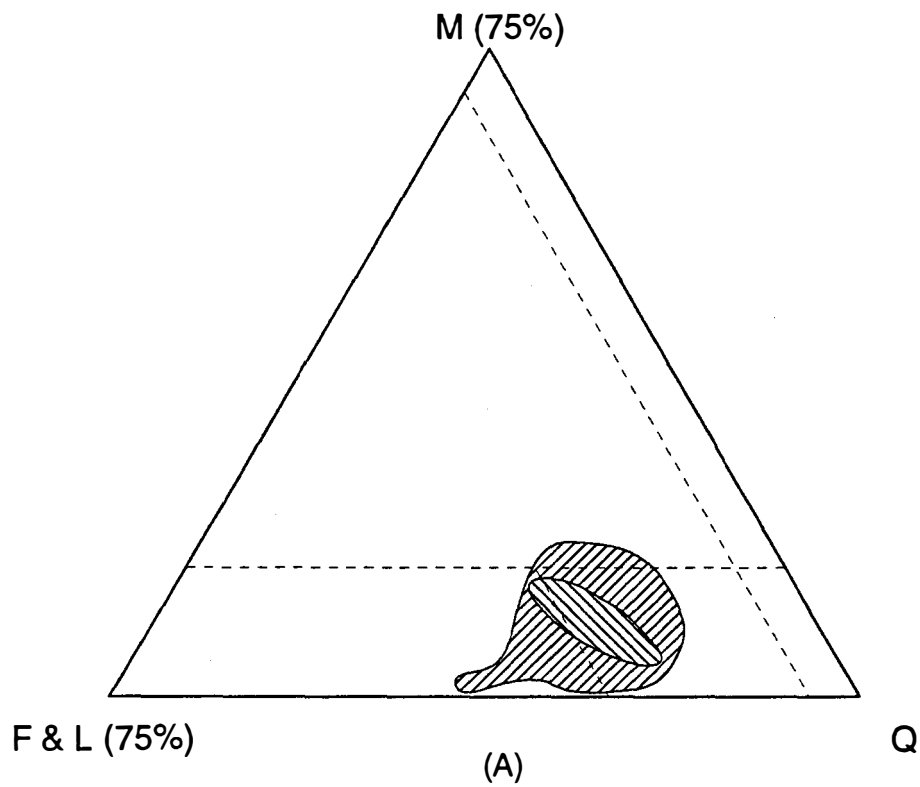


Figure II-6: Characteristic lithologies of the Buck Bald Formation (Great Smoky Group). (A) Slate clasts in granule to pebble metaconglomerate, Towee Creek Boating Site (station MCF 263), McFarland 7.5-minute quadrangle. SL: slate clast. Brunton compass approximately 7.5 cm across. (B) Granitoid-boulder metaconglomerate, 0.6 km (0.4 mi) upstream from the confluence of the Hiwassee River and Wolf Creek (station MCF 751), McFarland 7.5-minute quadrangle. Hammer is approximately 32 cm long.



(A)



(B)

Formation. The feldspathic graywacke-granule metaconglomerate is estimated to be 120 m (400 ft) thick. Quartz-pebble metaconglomerate also forms massive graded beds commonly more than three meters thick, and consists dominantly of white quartz pebbles, granitoid pebbles, and similarly sized, dark gray to black shale (now slate) clasts, as well as smaller, subordinate feldspar and carbonate clasts. A fine-grained, chlorite rich, sandstone matrix gives the fresh rock a light greenish-gray color. The quartz-pebble metaconglomerate is estimated to be 45 m (150 ft) thick. Granitoid-boulder metaconglomerate is the most distinctive lithology of the Buck Bald Formation and is composed mostly of metaconglomerate interbedded with subordinate metasandstone and metasilstone. The metaconglomerate consists of rhythmically bedded granule- to boulder-size granitoid clasts, as well as granule- to pebble-size quartz, quartzite, carbonate, and slate clasts, all in a finer-grained, chlorite-rich metasandstone matrix (Fig. II-6B). Beds range from less than 30 cm to more than 1.5 m thick, and commonly grade from the coarser-grained metaconglomerate into finer-grained metasandstone and metasilstone, which are compositionally and texturally equivalent to the rocks in the overlying Wilhite Formation. The granitoid-boulder metaconglomerate is estimated to be less than 60 m (200 ft) thick.

The three lithologies of the upper lithofacies form thin, discontinuous lenses along the top of the Buck Bald Formation and appear to channel and cut into the underlying interbedded lithologies of the lower lithofacies (Fig. II-4). The presence of blue quartz and black, graphitic shale clasts, as well as the gradational nature of the bedding, however, are characteristic of other Great Smoky Group rocks in the western Blue Ridge and suggest an affinity to the Buck Bald Formation (Great Smoky Group) rather than the overlying Wilhite Formation (Walden Creek Group).

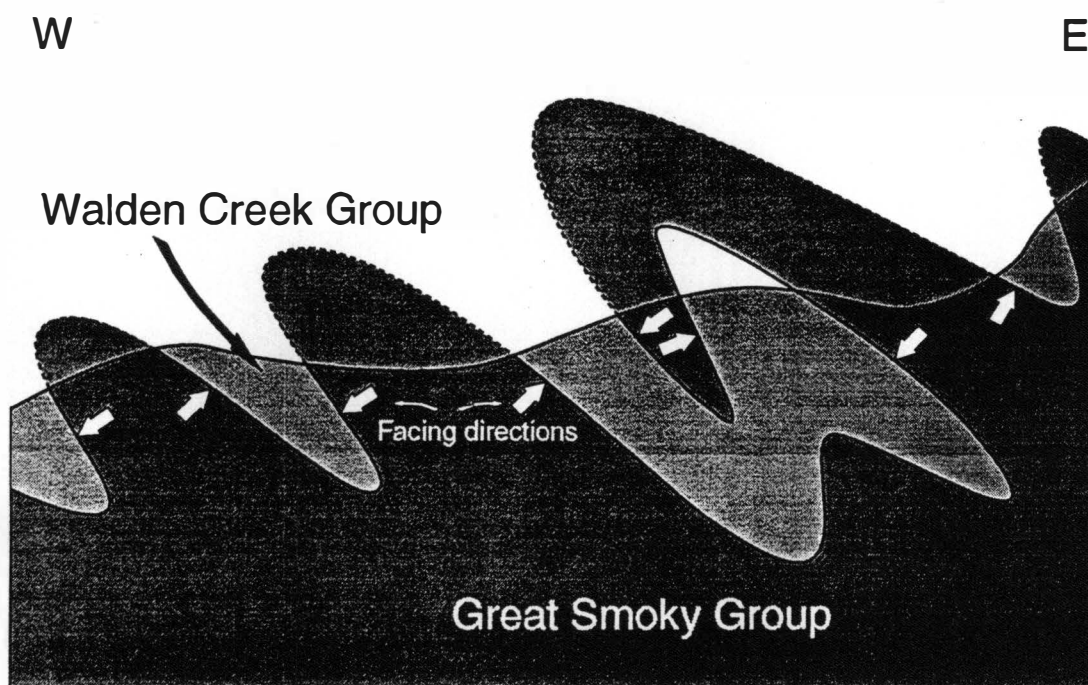
The contact between the Great Smoky and Walden Creek groups in the study area has previously been interpreted by some workers to be the southern extension of the Greenbrier fault (Merschhat and Wiener, 1973; Wiener and Merschhat, 1978, 1981; Merschhat and Hale, 1983;

Wiener and Mersch, 1992). North of the study area in the Great Smoky Mountains region (Fig. I-2), the Greenbrier fault juxtaposes Great Smoky Group rocks in the hanging wall from Walden Creek and Snowbird Group rocks in the footwall (Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965). In the study area, however, rocks of the Buck Bald Formation (Great Smoky Group) are vertically gradational and conformable with overlying rocks of the Wilhite Formation (Walden Creek Group). No evidence of a fault was observed along the contact in the study area. A similar gradational contact was previously recognized between the two groups along the Ocoee River south of the study area (Costello and Hatcher, 1986, 1991) and along the Tellico River (Figs. I-1; I-2) north of the study area (Poppelreiter, 1980).

Although the Greenbrier fault does not exist along the contact between the Great Smoky and Walden Creek groups in southeastern Tennessee, the contact does appear to be complexly folded (Carter and others, 1993) (Fig. II-7A). Detailed mapping in the study area indicates that Buck Bald Formation lithologies are exposed in the cores of map-scale anticlines along the Hiwassee River west of the main contact (Plates I; III). Similar anticlines exposing Great Smoky Group rocks were previously noted along the Ocoee River by Hurst and Schlee (1962). Graded beds indicate that the main contact between the Great Smoky and Walden Creek groups is overturned toward the northwest along the Hiwassee River (Fig. II-7B). North of the Hiwassee River near Yearling Gap, the contact is folded into a map-scale syncline that exposes Wilhite Formation rocks in its core (Plates I; III).

Good exposures of the lower lithofacies of the Buck Bald Formation are along a southwestward facing roadcut approximately 1.4 km (0.87 mi) north of the confluence of Rough Branch and the Hiwassee River, Farmer 7.5-minute quadrangle (Plate I). Fair exposures of feldspathic graywacke-granule metaconglomerate crop out in roadcuts approximately 1.4 km (0.87 mi) southwest of Yearling Gap, Farmer 7.5-minute quadrangle (Plate I). Quartz-pebble metaconglomerate is best exposed along Wolf Creek, McFarland 7.5-minute quadrangle, approximately 0.3 km (0.2 mi) upstream from the confluence of Wolf Creek and the Hiwassee

Figure II-7: Structural and lithologic characteristics along the Walden Creek Group and Great Smoky Group contact. (A) Schematic cross sectional diagram showing the complexly folded nature of the contact in southeastern Tennessee as determined by facing directions. (B) Gradational contact between the Walden Creek and Great Smoky groups. Granitoid-boulder metaconglomerate (Buck Bald Formation) and interbedded metasiltstone (Wilhite Formation). Facing directions (graded metaconglomerate beds - arrow) indicate that the contact is overturned.



(A)



(B)

River, and the only exposure of the granitoid-boulder metaconglomerate is in the Hiwassee Riverbed and along the railroad cut immediately south of the river, 0.6 km (0.4 mi) upstream from the confluence of the Hiwassee River and Wolf Creek, McFarland 7.5-minute quadrangle (Plate I).

Walden Creek Group

The Walden Creek Group is the uppermost of the three Ocoee Supergroup subdivisions and also is the most lithologically diverse (King and others, 1958). North of the Little Tennessee River in the Jones and Richardson Coves area of eastern Tennessee (Fig. I-2), the Walden Creek Group consists of an 2,500 m (8,000 ft) thick continuous succession of shale, siltstone, sandstone, conglomerate, and carbonate (King and others, 1958; Hamilton, 1961; King, 1964). Similar lithologies can be traced south of Jones and Richardson Coves throughout the Foothills belt of Tennessee and into northwestern Georgia, but the sequence is divided by faulting. South of the Little Tennessee River in the vicinity of the study area, lower Walden Creek Group strata (Wilhite Formation) are separated from upper strata (Sandsuck Formation) by the Miller Cove fault.

Wilhite Formation

Rocks assigned to the Wilhite Formation in the study area are divisible into four intertonguing lithofacies which include a dominant fine-grained metasiltstone lithofacies, and three coarser-grained metasandstone and metaconglomerate lithofacies that are informally designated and referred to collectively hereafter as the metasandstone members of the Wilhite Formation (Fig. II-4). Coarse- and fine-grained rocks that are assigned to the Wilhite Formation in this study have previously been mapped as Snowbird Group rocks by several workers (Mersch and Wiener, 1973; Wiener and Mersch, 1978, 1981; Mersch and Hale, 1983; Wiener and Mersch, 1992). Compositionally, coarse-grained rocks of the Wilhite Formation in the

study area are more quartz-rich, less feldspathic, and less micaceous than coarse-grained rocks assigned to the Snowbird Group by King and others (1958) in the Great Smoky Mountains region (Fig. II-8). Because of these compositional differences, these rocks in the study area are assigned to the Walden Creek Group (Wilhite Formation) rather than the Snowbird Group. The Wilhite Formation in the study area is equivalent to the Dixon Mountain Member of the Wilhite Formation, the Shields Formation, and Licklog Formation that have been mapped north of the Little Tennessee River (King and others, 1958; Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965). It is also equivalent to the Wilhite Formation in northwestern Georgia (McConnell and Costello, 1980, 1982, 1984). The Yellow Breeches Member of the Wilhite Formation has not been recognized in the study area and may have been faulted out.

The three, coarse-grained members of the Wilhite Formation in the study area include a feldspathic metagraywacke member, a feldspathic metasandstone member (which includes interbedded pebble to cobble metaconglomerate), and a calcareous quartzite member. All of these members form mappable but discontinuous sheets or lenses that consist predominantly of coarse-grained rocks, and generally lack finer-grained metasilstone and slate, except where associated with graded beds.

Feldspathic metagraywacke member. The feldspathic metagraywacke member consists predominantly of grayish-green fine- to coarse-grained graywacke that forms massive, characteristically ungraded beds ranging in thickness from one to ten meters. Locally, metagraywacke is interbedded with subordinate thin bedded grayish-tan feldspathic quartzite in the upper one-third of the member. Compositionally, the metagraywacke consists of moderately sorted, subangular quartz and slightly smaller feldspar (andesine and perthite) grains in a chlorite-rich micaceous matrix (Fig. II-8; Table A-II). The feldspathic metagraywacke member is exposed in the southeastern half of the Wilhite Formation outcrop belt, where it

Figure II-8: QMF diagram for coarse-grained rocks of the Wilhite Formation in the study area, and Snowbird Group in eastern Tennessee and western North Carolina. QMF diagram modified from Pettijohn (1949).

Interbedded metasandstone of the Wilhite Formation (open circles):

- 1 - Towee Creek (station MCF 126), McFarland 7.5-minute quadrangle
- 2 - Creek northwest of Towee Ridge (station MCF 1499), McFarland 7.5-minute quadrangle
- 3 - 0.3 km (0.2 mi) upstream from the confluence of the Hiwassee River and Wolf Creek (station MCF 749), McFarland 7.5-minute quadrangle
- 4 - Childers Creek Boating Site (station MCF 282), McFarland 7.5-minute quadrangle
- 5 - The Narrows along the Hiwassee River (station MCF 1650), McFarland 7.5-minute quadrangle

Feldspathic metasandstone member of the Wilhite Formation (gray circles):

- 6 - Southeast of McCulley Mountain (station MCF 916), McFarland 7.5-minute quadrangle
- 7 - Southeast of McCulley Mountain (station MCF 917), McFarland 7.5-minute quadrangle

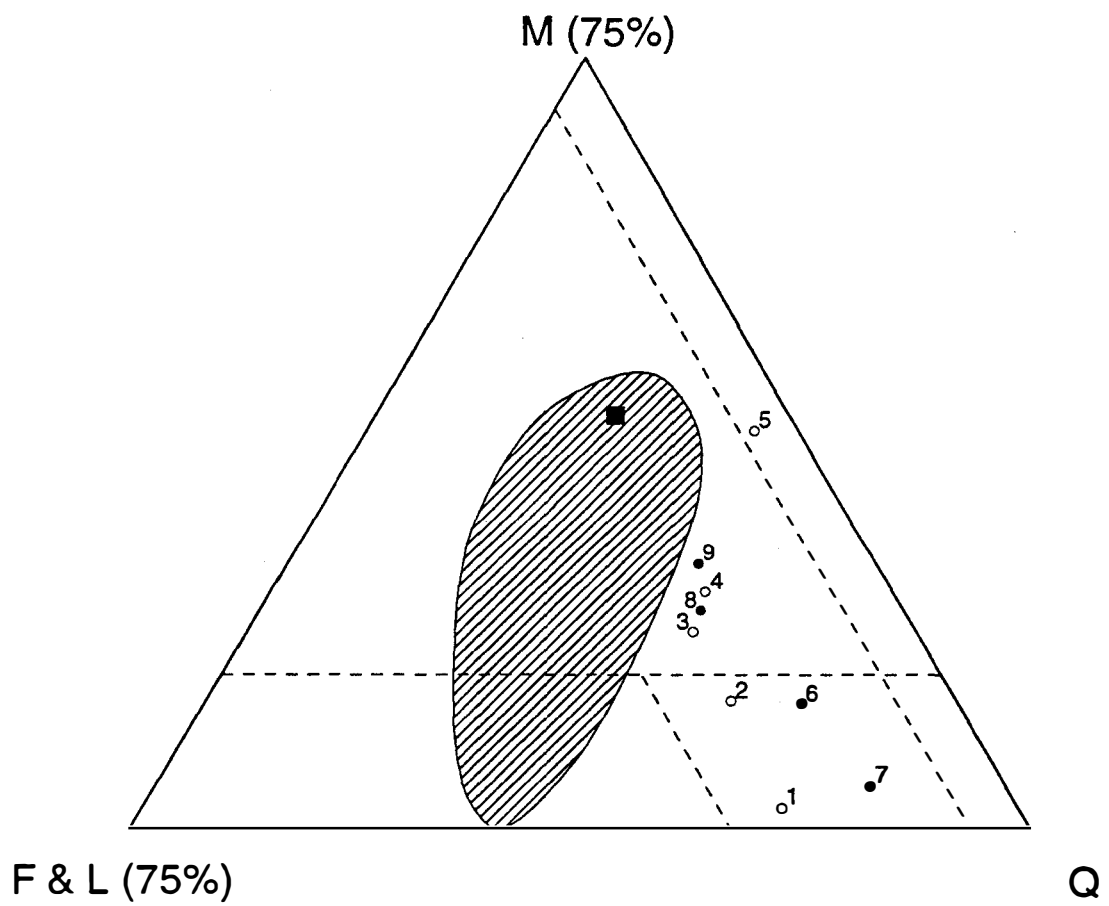
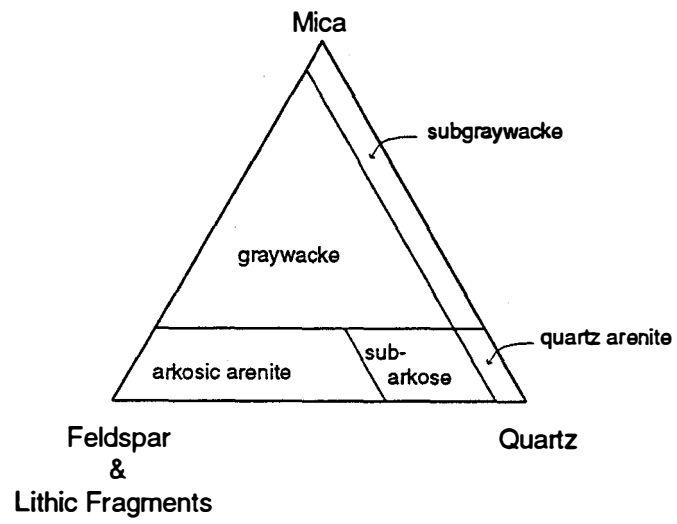
Feldspathic metagraywacke member of the Wilhite Formation (black circles):

- 8 - Coker Creek (station MCF 782), McFarland 7.5-minute quadrangle
- 9 - 0.8 km (1.3 mi) north of Hampton Cemetery (station MCF 1364), McFarland 7.5-minute quadrangle

Compositional fields, Snowbird Group:

Black square - Wading Branch Formation graywacke (Hadley and Goldsmith, 1963)

Roaring Fork Sandstone (Hadley and Goldsmith, 1963) (n = 6) 



constitutes three, irregular and discontinuous sheets. The lowest sheet rests conformably upon the Buck Bald Formation and the other two sheets intertongue with finer-grained rocks in the lower 300 m of the metasiltstone lithofacies. Map patterns suggest that all three sheets thin to the southwest. The thickest sheet is estimated to be 150 m (500 ft) thick in the vicinity of Coker Creek (Plate I), Farner 7.5-minute quadrangle, which offers the best exposures of the unit.

Feldspathic metasandstone member. The feldspathic metasandstone member consists of several lithologies that crop out in the northwestern half of the Wilhite Formation outcrop belt. These lithologies include pinkish-gray medium-grained feldspathic metasandstone (subarkose), light gray quartzite, and pebble- to cobble-sized metaconglomerate. The dominant lithology is metasandstone that forms massive beds which are 1.0 m to 3.0 m thick. Sedimentary structures such as cross bedding, graded bedding, and flute marks are rare. The metasandstone is composed of moderately sorted, subrounded quartz and feldspar (andesine and perthite) in a subordinate clay-rich matrix (Fig. II-8; Table A-II). Quartz in the metasandstone is typically white, but sandy horizons containing gray to blue quartz are also rarely observed. Gray and rare blue quartz, as well as subordinate feldspar, is also a constituent in a tightly packed, quartz-cemented, light gray quartzite, which is locally interbedded with the metasandstone in thin beds (< 1.5 m thick). Locally, but more frequently interbedded with the metasandstone is pebble- to cobble-sized metaconglomerate that occurs as thin- to thickly bedded lenses and graded channels. These lenses and channels are commonly about 1.0 m thick, and rarely exceed 3.0 meters. The metaconglomerate consists of dominantly white quartz pebbles with subordinate sandstone, quartzite, carbonate, shale (now slate), and granitoid clasts in a finer-grained subarkosic matrix. Rarely, granitoid cobbles are the dominant constituent of thin, unrythmically bedded horizons within the metasandstone. These granitoid cobbles are compositionally similar to those found in the granitoid boulder-metaconglomerate lithofacies of the Buck Bald formation, but are smaller, rarely exceeding 20.0 cm in diameter, and occur in

association with white quartz pebbles.

Rocks of the feldspathic metasandstone member constitute five irregular and discontinuous sheets that intertongue with finer-grained rocks in the lower 600 m (2,000 ft) of the metasiltstone lithofacies. The lowest sheet rests conformably above the westernmost exposures of the Buck Bald formation. The thickest exposed sheet is estimated to be between 100 m and 150 m (350 ft and 500 ft) thick. The best exposures of the feldspathic metasandstone, quartzite, and quartz-pebble-dominated metaconglomerate are in a streambed along the southeastern slope of McCulley Mountain, approximately 4.2 km (2.6 mi) southeast of Towee Church (Plate I). Only two exposures of the granitoid-cobble metaconglomerate have been located. One is approximately 0.5 km (0.3 mi) northeast of Apalachia Powerhouse along the Louisville and Nashville Railroad tracks near the confluence of Big Hopper Camp Branch and the Hiwassee River (Plate I). The other is located along Lower Jobe Patch Branch, approximately 0.3 km (0.2 mi) southwest from its confluence with the Hiwassee River (Plate I). Both exposures are in the McFarland 7.5-minute quadrangle.

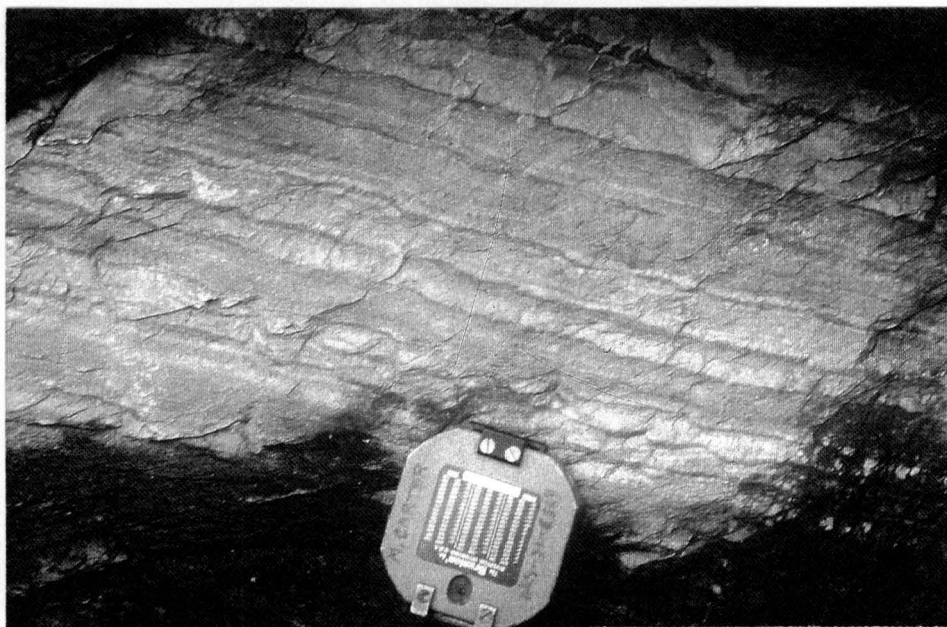
Quartzite member. A fine-grained calcareous quartzite, commonly containing up to 25 % carbonate cement is the predominant lithology of the quartzite member, which crops out along the Hiwassee River in the southwestern quarter of the Wilhite Formation outcrop belt. The quartzite is typically medium to light gray, but can also be greenish gray, pinkish gray, light tan, and white. Locally interbedded and gradational with the quartzite is finer-grained calcareous slate and metasiltstone, and macrocrystalline calcitic and dolomitic carbonate. Thin bedding is common in all lithologies and ranges in thickness from 1.0 mm to 1.0 m. Rocks of the quartzite member form several relatively thin, discontinuous lenses that pinch out to the north and east. These lenses occur within a stratigraphic horizon of the metasiltstone lithofacies approximately 270 m to 450 m above the Great Smoky Group contact and may form the northern edge of a similar, but thinner, zone of Walden Creek Group calcareous quartzite reported by Hurst and

Schlee (1962) in the Ocoee River Gorge. Calcareous quartzite in the Ocoee River Gorge forms a 15 m thick zone within Walden Creek Group phyllite, approximately 360 m stratigraphically above the contact with Great Smoky Group rocks. Bedding thickness within the quartzite zone of the Ocoee River Gorge rarely exceeds 30.0 cm, and cross bedding, scours, and graded bedding are common. In the study area, however, the thicker lenses of calcareous quartzite are about 60 m (200 ft) thick, and sedimentary structures are rare. The best exposure of rocks of the quartzite member is along Smith Creek, approximately 1.1 km (0.7 mi) southeast of Apalachia Powerhouse, McFarland 7.5-minute quadrangle (Plate I).

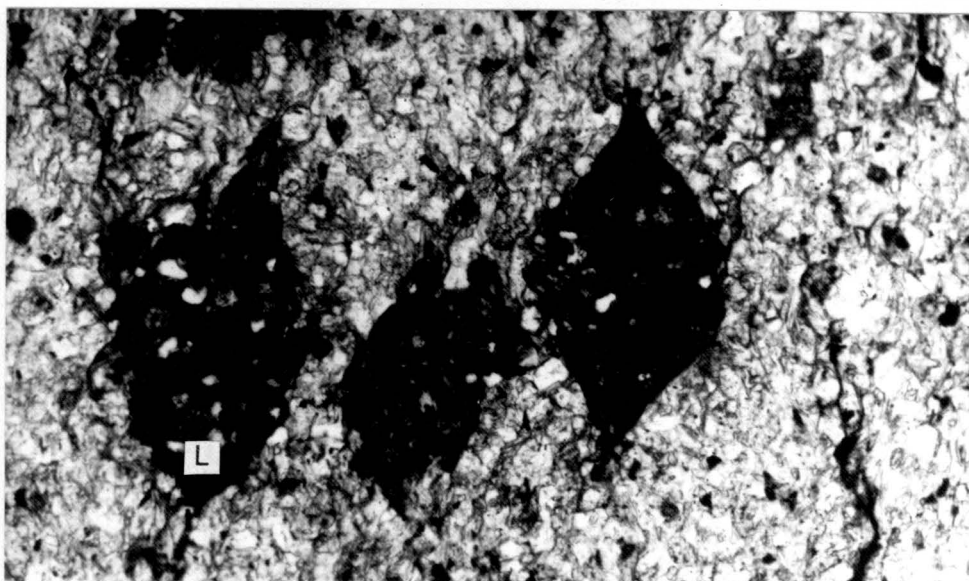
Metasiltstone lithofacies. The lithologically diverse metasiltstone lithofacies of the Wilhite Formation consists principally of metasiltstone, but locally is interbedded with thin beds of slate, phyllite, metasandstone, metaconglomerate, and carbonate. Metasiltstone dominates the lithofacies to the north and east, but laterally grades southwestward into predominantly interbedded slate, phyllite, metasandstone, and carbonate. Metasandstone throughout the lithofacies is compositionally and texturally similar to the lithologies of the metasandstone members (Fig. II-8; Table A-II), but is thinly and discontinuously interbedded with the finer-grained metasiltstone. Microcrystalline calcitic and dolomitic carbonate and calcareous quartzite are also interbedded with the metasiltstone, especially in the southwestern quarter of the Wilhite Formation outcrop belt. These lithologies form thin discontinuous beds, usually no more than 1.5 m thick, that thin and virtually pinch out to the northeast except for local lenses. Thin horizons of quartz-pebble metaconglomerate, less than 60 cm thick, are also very rarely interbedded with the thick sequence of metasiltstone to the north and east.

A medium- to coarse-grained, dark gray to grayish-green metasiltstone is the most common lithology of the metasiltstone lithofacies. Primary depositional banding ranges in thickness from 0.2 to 5 cm and is similar to, but thicker than, the banding in the metasiltstone of the Boyd Gap and Buck Bald Formations (Figure II-9A). Bedding in the metasiltstone is

Figure II-9: Characteristic lithologic features of the metasiltstone lithofacies, Wilhite Formation. (A) Primary depositional banding in metasiltstone, Apalachia Powerhouse (station MCF 211), McFarland 7.5-minute quadrangle. Brunton compass approximately 7.5 cm long. (B) Photomicrograph (plain polarized light) of limonite pseudomorphs after ankerite in a fine-grained sandstone, creek northwest of Towee Ridge (station MCF 1499), McFarland 7.5-minute quadrangle. L - Limonite pseudomorphs. Field of view is 1.5 mm.



(A)



(B)

rhythmic and generally graded, usually from finer- to coarser-grained metasiltstone, but occasionally to very fine- to fine-grained metasandstone. Thicker beds commonly preserve ripple marks and dewatering structures. Compositionally, the metasiltstone bands consist of silt- and very fine sand-size quartz and feldspar that grade upward into clay-, mica-, chlorite-, and locally, carbonate-rich horizons. Good exposures of the banded metasiltstone occur north of Big Rock Island, McFarland 7.5-minute quadrangle (Plate I).

A dark gray to light greenish gray, locally calcareous slate is also a dominant lithology of the metasiltstone lithofacies, especially in the southwestern quarter of the Wilhite Formation outcrop belt, where it occurs within the lower 150 m of the metasiltstone lithofacies. The slate is finer-grained than the metasiltstone and lacks prominent banding. Bedding is recognized by very thin laminations (< 0.5 mm) which are accentuated upon weathering. Compositionally, the slate consists primarily of clay, muscovite, and chlorite. Hurst and Schlee (1962) recognized a dark gray to black, pyritic slate above the Great Smoky Group in the Ocoee River Gorge that they correlated with the Nantahala Formation farther to the east in the Murphy belt. The slate in the study area, although lacking characteristic pyrite, is similar, and may be correlative with the slate in the Ocoee River Gorge and may be a distal western facies of the Nantahala Formation. Good exposures of the dark gray slate occur in roadcuts approximately 0.55 km (0.34 mi.) west of the confluence of Beach Bottom Branch and the Hiwassee River and in roadcuts approximately 0.2 km (0.12 mi.) west of the confluence of Towee Creek and the Hiwassee River, McFarland 7.5-minute quadrangle (Plate I).

Locally, the metasiltstone, slate, and fine grained, interbedded metasandstone contain ankerite (or more typically limonite pseudomorphs after ankerite), which weather to small (< 1 mm) voids. Similar occurrences of weathered ankerite were reported by Hurst and Schlee (1962) in phyllite along the Ocoee River. Rarely, fresh ankerite is observed as light pinkish-tan, euhedral rhombs. Ankerite commonly constitutes less than three percent of the total rock mass where observed, but rarely composes up to 30 percent of the rock mass (Fig. II-9B). North of

the study area along the Tellico River, ankerite-bearing metasiltstone and slate form mappable zones, some more than 30 m thick. Ankerite-bearing rocks in the study area, however, are present only as local, very thin (< 5 m), discontinuous lenses. Merschat and Hale (1983) also observed ankerite bearing-rocks along the eastern edge of the study area in the Farners 7.5-minute quadrangle and concluded that the ankerite is post-depositional because of the presence of well-rounded heavy mineral inclusions within the ankerite rhombs.

The true thickness of the Wilhite Formation in the study area is unknown because the top has been truncated by faulting, but a minimum estimate can be made from the preserved thicknesses of the metasiltstone lithofacies. Just east of the Miller Cove fault, only about 450 m of metasiltstone lithofacies rocks are preserved above the Buck Bald Formation, but eastward, the preserved thickness above the Buck Bald Formation increases to approximately 1,200 m. Therefore, the total thickness of the Wilhite Formation before faulting and erosion must have been greater than 1,200 m (4,000 ft).

Sandsuck Formation

The Sandsuck Formation is the uppermost unit of the Walden Creek Group, and also the most lithologically diverse in the study area. The Sandsuck Formation in the study area consists of interbedded shale, siltstone, sandstone, conglomerate, and carbonate, and is divided into lower, middle and upper members, each containing a distinctive suite of lithologies (Fig. II-4). Rocks of the Sandsuck Formation are separated from the Wilhite Formation by the Miller Cove fault. The Maggies Mill fault juxtaposes rocks of the lower member onto higher strata of the middle and upper members. Rocks of the middle and upper members of the Sandsuck Formation in the study area are equivalent to Sandsuck Formation rocks mapped north of the Little Tennessee River in the westernmost Blue Ridge fault blocks because these sequences are also stratigraphically overlain by Chilhowee Group rocks.

Rocks assigned to the lower member of the Sandsuck Formation in this study consist of several distinctive lithologies, including quartz arenite and subordinate micrite, calcareous sandstone and carbonate breccia. Similar carbonate lithologies occur north of the Little Tennessee River and have been assigned to the Yellow Breeches Member of the Wilhite Formation (King and others, 1958; Hamilton, 1961; King, 1964; Neuman and Nelson, 1965). For this reason, carbonate rocks in the study area were previously assigned to the Wilhite Formation by several workers (Merschlat and Wiener, 1973; Wiener and Merschlat, 1981, 1992).

I have chosen to assign these carbonates in the study area to the Sandsuck Formation for three reasons. First, detailed lithologic descriptions of the Yellow Breeches Member of the Wilhite Formation indicate that carbonates are enclosed by and interbedded with shale and siltstone (Hamilton, 1961; King, 1964; Neuman and Nelson, 1965; Unrug and others, 1991). Interbedded sandstone is rare (Hamilton, 1961; King, 1964; Neuman and Nelson, 1965; Unrug and others, 1991). In the study area, however, carbonates are enclosed by and interbedded with quartz arenite. Although carbonates in the study area are lithologically similar to carbonate rocks of the Yellow Breeches Member, siliclastic rocks that enclose carbonates in the study area are distinctly different and suggest that the two sequences are not equivalent. Secondly, detailed mapping in the study area indicates that quartz arenite, similar to quartz arenite in the lower member, is also present in the middle member. Quartz arenite is interpreted to lithologically tie the lower member in the hanging wall of the Maggies Mill fault to the middle member in the footwall. No lithologic similarities exist between lower member rocks in the footwall of the Miller Cove fault and Wilhite Formation rocks in the hanging wall. Lastly, other workers have assigned similar carbonates to the Sandsuck Formation south of the study area in the Ocoee River Gorge (Hurst and Schlee, 1962; Sutton, 1971; Hatcher and others, 1991), in northwestern Georgia (Salisbury, 1961), and north of the study area near English Mountain (Hamilton, 1961).

Lower member. The lower member of the Sandsuck Formation consists of massively interbedded quartz arenite, quartz-pebble conglomerate, feldspathic sandstone, and several lithologies of carbonate. The carbonate occurs as two westerly thinning sheets of variable thickness, which are interbedded with the sandstone and conglomerate near the middle of the coarse-grained clastic sequence. Shale and very fine-grained siltstone horizons are rare. The sandstone and conglomerate of the lower member are the most quartz-rich, and locally, the most feldspathic of all coarse-grained rocks in the Walden Creek Group (Fig. II-10; Table A-II).

Light brown, coarse- to very coarse-grained quartz arenite, quartz-granule to pebble conglomerate, and subordinate grayish-brown, coarse-grained feldspathic sandstone characterize the clastic rocks of the lower member of the Sandsuck Formation. Toward the southwest, the arenite is the dominant lithology and forms massive beds, commonly more than 3.0 m thick, that lack sedimentary structures, such as graded bedding and cross bedding. Locally interbedded with the arenite in the southwest is subordinate quartz-granule to cobble conglomerate, which forms weakly graded, discontinuous beds usually less than 1.5 m thick. To the northeast, however, the conglomerate is more dominant than the quartz arenite and forms graded beds, which are typically ≥ 3.0 m thick. Feldspathic sandstone is also present to the northeast and forms massive, ungraded beds commonly about 1.0 m thick.

Compositionally, the arenite consists of more than 90 % moderate to well-sorted subrounded quartz, with feldspar and matrix-forming clays minor constituents (Fig. II-10; Table A-II). Where the sandstone is locally more feldspathic, potassium-feldspar is commonly abundant. Quartz grains in the lower member of the Sandsuck Formation are typically monocrystalline, rather than the polycrystalline grains common in the coarse-grained rocks of the Wilhite Formation. Also typical of the quartz arenite is a slightly higher concentration of well-rounded zircons (compared to other coarse-grained rocks of the Walden Creek Group). The dominant constituent of the conglomerate is white quartz, with subordinate feldspar and various lithic fragments in a finer-grained quartz-rich sandy matrix (Fig. II-10; Table A-II). The

Figure II-10: QMF diagram for coarse-grained rocks of the Sandsuck and Cochran Formations in the study area. QMF diagram modified from Pettijohn (1949).

Lower member of the Sandsuck Formation (open circles):

- 1 - Sandstone, Pine Mountain (station MEC 208), Mecca 7.5-minute quadrangle
- 2 - Sandstone, Ivy Trail (station MEC 392), Mecca 7.5-minute quadrangle
- 3 - Sandstone, Childers Creek Boating Site (station MCF 338), McFarland 7.5-minute quadrangle
- 4 - Conglomerate, 0.15 km (0.75 mi) northeast of the Tennessee Highway 315 Bridge over the Hiwassee River (station MCF 377), McFarland 7.5-minute quadrangle

Feldspathic graywacke conglomerate, lower lithofacies, middle member of the Sandsuck Formation (light gray circles):

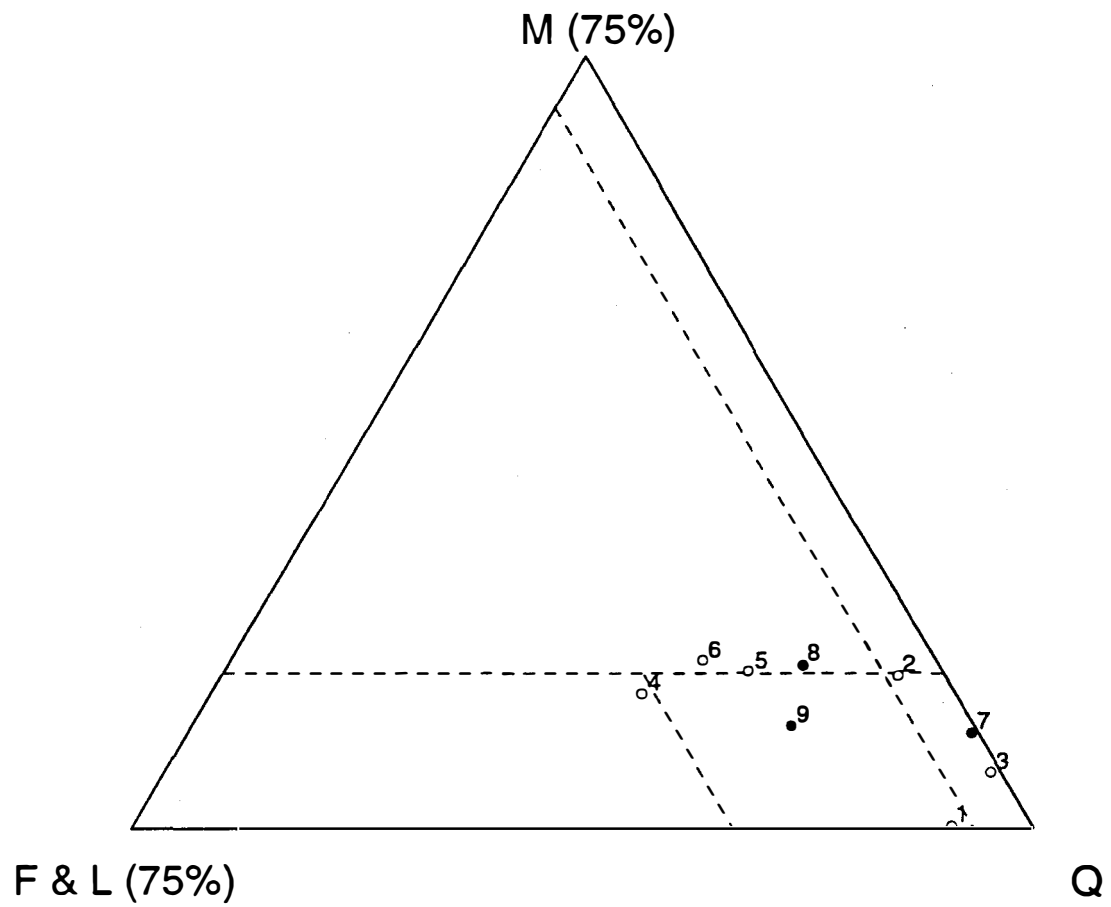
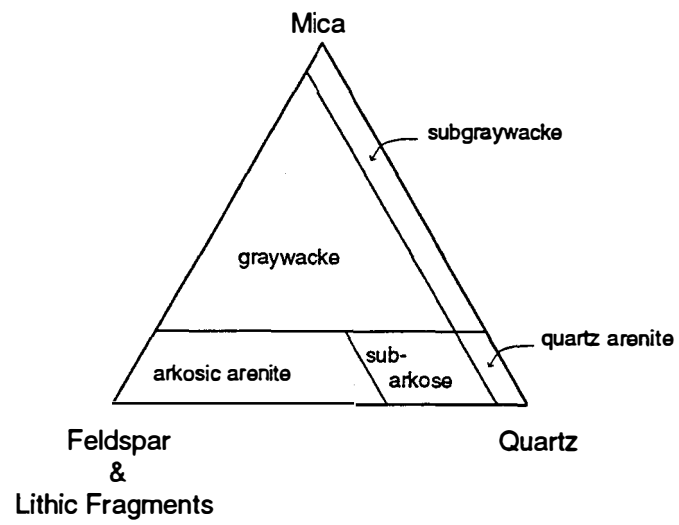
- 5 - Spring Creek (station MCF 1054), McFarland 7.5-minute quadrangle
- 6 - Reliance School (station OD 23), Oswald Dome 7.5-minute quadrangle

Sandstone, upper member of the Sandsuck Formation (dark gray circles):

- 7 - 0.7 km (0.43 mi) east of White Cliff Springs (station MEC 181), Mecca 7.5-minute quadrangle
- 8 - Spring Creek (station MCF 478), McFarland 7.5-minute quadrangle

Cochran Formation sandstone (black circle):

- 9 - Southwest slope of Locust Mountain (station MEC 240), Mecca 7.5-minute quadrangle



feldspathic sandstone consists of moderately sorted, subrounded quartz and feldspar in a clay-rich matrix (Fig. II-10; Table A-II).

Carbonate rocks of the lower member of the Sandsuck Formation comprise the most distinctive suite of lithologies in the Walden Creek Group. These carbonates consist of dark-gray fine-grained micrite, lighter-gray coarser-grained calcareous sandstone, carbonate breccia, and less common oömicrite and pisomicrite. Most common in this lithologic suite is calcareous sandstone and carbonate breccia, which form massive discontinuous beds, lenses, and locally graded channels that range in thickness from less than 30.0 cm to greater than 3.0 m. These rocks, as well as lenses and channels of noncalcareous quartz arenite are chaotically and irregularly interbedded (Fig. II-11A). Compositionally, the calcareous sandstone consists not only of 30% to 60% microcrystalline calcite, but also up to 50% moderately well-sorted, rounded, predominantly monocrystalline quartz (Table A-III). Locally, subhedral to euhedral feldspar (andesine) comprise the dominant clastic fraction of the calcareous sandstone. Accessory minerals such as tourmaline, zircon and detrital micas, also occur in the calcareous sandstone. The carbonate breccia consists of pebble- to cobble-size (rarely boulder-size) fragments and clasts of other carbonate lithologies of the lower member, especially calcareous sandstone clasts (Fig. II-11B). Clasts of oömicrite and pisomicrite, noncalcareous sandstone and shale are also constituents of the carbonate breccia. The best exposure of both carbonate and clastic rocks of the lower member of the Sandsuck Formation is in a roadcut approximately 0.3 km (0.2 mi) west of the confluence of Childers Creek and the Hiwassee River, McFarland 7.5-minute quadrangle (Plate I).

Both the upper and lower contacts of the lower member of the Sandsuck Formation are faulted, so only the minimum thickness of the unit can be estimated. Approximately 200 m of clastic rocks are exposed beneath the lower and thicker carbonate unit, and another 200 m above the carbonate. Both carbonate units irregularly thicken and thin, but the thickest part of the lower unit is estimated to be about 150 m, and the poorly exposed upper horizon is less

Figure II-11: Typical carbonate lithologies in the lower member of the Sandsuck Formation.

(A) Calcareous sandstone channelling into micrite, southwestern end of Pond Mountain (station MCF 382), McFarland 7.5-minute quadrangle. Pen is approximately 13.5 cm long. (B) Multi-clast carbonate breccia, southwestern end of Pond Mountain (station MCF 382), McFarland 7.5-minute quadrangle. Pen is approximately 13.5 cm long.



(A)



(B)

than 15.0 m thick. Therefore, the minimum thickness of the lower member before faulting and erosion must have been greater than 560 m (1,850 ft).

Middle member. Rocks of the middle member of the Sandsuck Formation comprise three lithofacies: a lower lithofacies which consists of an interbedded succession of fine- and coarser-grained rocks; and two intertonguing, upper lithofacies: a siltstone lithofacies and a micaceous sandstone lithofacies (Fig. II-4). Contacts between all lithofacies of the middle member are gradational. Very fine- to fine-grained siltstone is common in all lithofacies of the middle member. This siltstone is medium gray when fresh, and forms thin beds that range in thickness from less than 0.5 mm to rarely more than 1.0 cm. Upon weathering, the siltstone decomposes to diagnostic terra cotta brown chips. The siltstone is commonly graded from shale and very fine-grained siltstone to coarser siltstone and rarely to very fine-grained sandstone. Thin (< 6 mm thick), discontinuous lenses of very fine- to fine-grained feldspathic sandstone are also locally common in the siltstone. In the upper lithofacies, especially in the coarser-grained micaceous sandstone lithofacies, the siltstone becomes micaceous.

The lower lithofacies of the middle member consists of siltstone locally interbedded with coarser-grained sandstone, conglomerate, and very rarely, thin (< 1.0 cm thick) micritic limestone. Common to the lower lithofacies is bluish-green, unsorted, granule- to cobble-size feldspathic graywacke conglomerate that resembles the finer-grained, feldspathic graywacke conglomerate of the Buck Bald Formation. The conglomerate forms ungraded lenses within the siltstone (> 3.0 m thick) and consists of rounded quartz, feldspar, and shale and micritic limestone clasts up to 2.5 cm in diameter (Fig. II-10; Table AI-2). Quartz arenite, resembling quartz arenite in the lower member, is also common, as well as tan feldspathic, medium- to coarse-grained sandstone and white quartz-granule to pebble conglomerate. Together, these coarse-grained lithologies are interbedded with the siltstone as graded lenses and channels that range in thickness from about 1.5 m to 3.0 m.

Characteristic siltstone is also variably present in the two intertonguing, upper lithofacies of the middle member. The siltstone lithofacies is composed predominantly of siltstone, except for local interbeds of tan feldspathic, medium- to coarse-grained sandstone up to 1.5 m thick. The micaceous sandstone lithofacies, however, consists mostly of coarser-grained sandstones interbedded with micaceous siltstone. The sandstones of this lithofacies comprise two interbedded lithologies: a dominant, dark-gray fine- to medium-grained micaceous sandstone; and a light tan medium to very coarse-grained feldspathic, but locally arkosic, sandstone. Bedding in the micaceous sandstone is typically thin, rarely exceeding 30 cm, but beds in the feldspathic sandstone usually average 1.5 m thick. Pebble- to cobble-size micaceous sandstone and siltstone clasts, suspended in a coarse-grained, feldspathic sandstone matrix occur locally as interbedded horizons within the feldspathic sandstone lithology. Compositionally, the micaceous sandstone consists of coarse silt-size detrital biotite and subordinate muscovite which are well preserved along bedding surfaces, as well as moderately sorted, subangular to subrounded quartz and feldspar in a clay- and mica-rich matrix. The coarser-grained feldspathic sandstone is similar to other sandstones in the Sandsuck Formation, and lacks the abundant detrital biotite and muscovite common in the micaceous sandstone.

Soft-bodied metazoan macrofossils, originally reported by Rackley (1951) and Phillips (1952) from rocks of the Sandsuck Formation north of Spring Creek (Mecca 7.5-minute quadrangle) were recently rediscovered by Broadhead and others (1991) at a roadcut exposure of micaceous sandstone approximately 0.45 km (0.3 mi) northwest of the confluence of Ellis Branch and Spring Creek, Mecca 7.5-minute quadrangle (Plate I). Since this rediscovery, a solitary burrow(?) has also been discovered during this study from a roadcut exposure approximately 0.2 km (0.15 mi) northwest of the original fossil locality. The metazoan macrofossils are preserved as small (approximately 9.0 cm) crescent-shaped, carbonaceous impressions (Rackley, 1951). The burrow(?) is preserved as a generally circular raised cast approximately 1.0 cm (0.39 in) wide. The exposures of micaceous sandstone, which contain

these macrofossils and trace fossil, consists of interbedded micaceous sandstone and subordinate micaceous siltstone. Beds range from 1.0 to 5.0 cm thick. Other roadcut exposures consist of interbedded arkosic sandstone, micaceous sandstone and siltstone. Arkosic sandstone forms beds that range from 0.2 to 0.6 m thick.

The minimum thickness of the middle member can be reasonably estimated, although the base of the member is faulted. The thickest section of the lower lithofacies beneath the Maggies Mill fault is along the Hiwassee River, where about 300 m of rock is exposed. The siltstone lithofacies varies in thickness because of intertonguing with the micaceous sandstone lithofacies, but the thickest exposed section is approximately 450 m. The thickest exposed section of the micaceous sandstone lithofacies is approximately 180 m. Given the thickness changes in the upper two lithofacies because of intertonguing, the estimated thickness of the middle member is 750 m (2,475 ft).

Fair exposures of lower lithofacies rocks are near Reliance School, approximately 0.3 km (0.2 mi) southeast of the confluence of Presswood Branch and the Hiwassee River, Oswald Dome 7.5-minute quadrangle (Plate I). Good exposures of the siltstone lithofacies are along Ruckers Branch, McFarland 7.5-minute quadrangle (Plate I), and rocks of the micaceous sandstone lithofacies are well exposed along Ellis Branch and in roadcuts southwest of Ellis Branch, approximately 0.2 km (0.15 mi) northwest of the confluence of Ellis Branch and Spring Creek, Mecca 7.5-minute quadrangle (Plate I).

Upper member. Conformably above rocks of the middle member is a variably thick sequence of siltstone and shale interbedded with sandstone, conglomerate and minor carbonate lithologies (Fig. II-4). Lower in the sequence, sandstone and conglomerate interbeds are thin, rarely more than about 1.5 m thick, and shale and siltstone dominate. These finer-grained rocks resemble siltstone and shale that dominate the middle member of the Sandsuck Formation. Higher in the sequence rare cross bedded sandstone and conglomerate beds thicken, and finer-grained

rocks become subordinate. Near the contact with the overlying Cochran Formation (Chilhowee Group), siltstone and shale partings occur only as very thin (< 15 cm) lenses between massive sandstone beds and minor conglomerate lenses that are typically greater than 3.0 m thick.

Besides bed thickness, sandstone composition also varies upward through the member (Fig. II-10; Table A-II). Medium to light gray moderately sorted, coarse-grained feldspathic graywacke and subordinate subarkose is dominant near the base of the upper member, but vertically grades into tan well-sorted, medium- to coarse-grained quartz arenite and subarkose near the top. Quartz in all sandstone lithologies of the upper member is predominantly monocrystalline, similar to quartz in other coarse-grained rocks of the Sandsuck Formation. Potassium-feldspar (predominantly microcline), abundant in some lithologies of the lower member of the Sandsuck Formation but absent in coarse-grained rocks of the Wilhite Formation, is also a common constituent of the andesine-rich feldspar fraction of these sandstones. Fine- to very coarse-grained lithic fragments include shale, siltstone, and granitoid grains. Light brown feldspathic, but locally arkosic, quartz-pebble conglomerate, forming laterally thinning discontinuous lenses less than 3.0 m thick, is interbedded with sandstone and siltstone throughout the upper member, and consists dominantly of white quartz pebbles and subordinate feldspar granules.

Two carbonate lithologies are also present in the upper member. Light gray very fine- to coarse-grained dolomitic siltstone consists of very thin (2 mm to 1.5 cm) beds, which are typically graded and cross bedded. The dolomitic siltstone crops out to the southwest and is interbedded with similar, but noncalcareous, siltstone. The dolomitic siltstone is estimated to be 90 m (300 ft) thick. The other carbonate lithology is present only at one locality along Tinker Branch, McFarland 7.5-minute quadrangle, and consists of a chaotic mass of light gray pebble- to boulder-size, subangular, micritic limestone and dolomite clasts supported in a finer-grained carbonate-rich matrix. Only about 6 m of exposure exists beneath a massive feldspathic sandstone bed.

King (1949, 1964) interpreted the contact between the Sandsuck and Cochran formations on the northeastern slope of Chilhowee Mountain to be unconformable because he recognized a truncation of Sandsuck conglomerate beds by basal beds of the Cochran Formation. Southward from the southwestern end of Chilhowee Mountain, however, the contact has been interpreted to be conformable because no truncation of beds have been observed (Rackley, 1951; Phillips, 1952; Neuman and Nelson, 1965). Throughout the study area, the total thickness of the upper member of the Sandsuck Formation varies from about 60 m (200 ft) along Hogback Branch, Mecca 7.5-minute quadrangle (Plate I), to a maximum estimated thickness of 600 m (2,000 ft) along the southeastern slope of Chestnut Mountain, McFarland 7.5-minute quadrangle (Plate I). This thickening and thinning of the upper member, however, corresponds to an equivalent thickening and thinning of Chilhowee Group formations and may be a regional depositional feature rather than represent a truncated erosional surface at the top of the Sandsuck Formation. The contact between the Sandsuck and Cochran formations in the study area, as first inferred by Phillips (1952), is defined at the base of massive feldspathic sandstone, quartz arenite, and subordinate quartz-pebble conglomerate and is interpreted to be conformable for two reasons. First, nowhere along the contact does Cochran sandstone and conglomerate appear to channel or truncate Sandsuck beds. Secondly, Sandsuck sandstone directly below the contact resembles massive Cochran sandstone above the contact. The only difference between sandstones above and below the contact is that 3.0 m thick Sandsuck sandstone beds contain subordinate, thin (< 15 cm) interbeds of siltstone and shale. This implies that there was no appreciable lithologic break in coarse-grained sedimentation during deposition of the Sandsuck and Cochran formations.

Roadcuts northeast of Ellis Branch, approximately 1.5 km (0.9 mi) northwest of the confluence of Ellis Branch and Spring Creek, Mecca 7.5-minute quadrangle (Plate I), provides fair exposures of the interbedded fine- and coarse-grained rocks of the upper member. Other exposures are along the unnamed branch of Tinker Branch, approximately 0.2 km (0.12 mi)

north of the confluence of Tinker Branch and Spring Creek, McFarland 7.5-minute quadrangle (Plate I). The best exposures of dolomitic siltstone are located in roadcuts north of Spring Creek, approximately 0.65 km (1.3 mi) north of the confluence of Spring Creek and the Hiwassee River, Oswald Dome 7.5-minute quadrangle (Plate I). The only known exposure of the carbonate breccia is located along Tinker Branch, approximately 1.1 km (1.8 mi) north of the confluence of Tinker Branch and Spring Creek, McFarland 7.5-minute quadrangle (Plate I). A good exposure of the conformable contact between the upper member of the Sandsuck Formation and the Cochran Formation is along Tinker Branch, approximately 1.3 km (2.1 mi) northwest of the confluence of Tinker Branch and Spring Creek, McFarland 7.5-minute quadrangle (Plate I).

Chilhowee Group

Rocks of the Lower Cambrian Chilhowee Group form a linear belt of mountains in central-east and southeastern Tennessee, including Stone, English, Chilhowee, Starr, Chestnut, and Bean mountains (Figs. I-1, I-2). Correlative rocks are exposed throughout the Appalachian orogen in a discontinuous belt extending from Vermont to New York (Myrow, 1983), and from Pennsylvania to Alabama (Schwab, 1970; Mack, 1980). Chilhowee Group lithologies are similar throughout this strike belt, and range from vitreous quartz arenite in the upper formations to feldspathic sandstone, graywacke, and conglomerate in the lower formations. In east Tennessee, rocks of the Chilhowee Group cap the western Blue Ridge stratigraphic sequence, and consist of five alternating coarse- and fine-grained formations.

Cochran Formation

The lowest formation of the Chilhowee group in southeastern Tennessee is the Cochran Formation, which is well exposed along the slopes of Chestnut and Starr Mountains in the study area. Here, the Cochran Formation consists of light rose to tan moderately sorted coarse-

to very coarse-grained lithic arenite and subarkose (Fig. II-10; Table A-II), and locally, quartz-pebble conglomerate (Fig. II-4). Bedding ranges from 1.5 m to 3.0 m thick and is locally cross bedded. The thickness of the Cochran Formation varies throughout the study area, from about 60 m (200 ft) approximately 0.1 km (0.05 mi) south of Bullet Creek Falls, Mecca 7.5-minute quadrangle (Plate I), to more than 90 m (300 ft) on the slopes of Chestnut Mountain, McFarland 7.5-minute quadrangle (Plate I). Regionally, the Cochran Formation is thicker to the north, where 180 m to 350 m (600 ft to 1,150 ft) of section is preserved along the slopes of Chilhowee Mountain (Neuman and Nelson, 1964). Southward, the Cochran Formation thins to less than 75 m (250 ft) thick in Georgia and Alabama (Mack, 1980).

Nichols Shale

Stratigraphically above the Cochran Formation are finer-grained rocks of the Nichols Shale, which consists predominantly of bluish-gray shale (Fig. II-4) locally interbedded with tan feldspathic sandstone and siltstone (Phillips, 1952). The thickness of the Nichols Shale is variable in southeastern Tennessee. Neuman and Nelson (1965) reported 300 m (1,000ft) of Nichols Shale on the northwest slope of Chilhowee Mountain. Southward, Rackley (1951) and Phillips (1952) estimated the thickness of the Nichols Shale to be 90 m to 165 m (300 ft to 550 ft) on Bean and Starr Mountains, but near Bullet Creek Falls, Mecca 7.5-minute quadrangle, the Nichols Shale appears to thin to less than 60 m (200 ft) (Plate I). Fair exposures are preserved along the southeast slope of Chestnut Mountain, southwest of Tinker Branch, McFarland 7.5-minute quadrangle (Plate I).

Nebo Quartzite

A transition zone consisting of interbedded shale and sandstone marks the contact between the Nichols Shale and the overlying Nebo Quartzite (Neuman and Nelson, 1965). Rackley (1951) described the Nebo Quartzite on Bean Mountain immediately south of the study

area as consisting of thinly bedded and commonly cross-bedded buff to light tan predominantly medium-grained vitreous quartz arenite. North of the Hiwassee River on Starr Mountain near Bullet Creek Falls, the Nebo Quartzite consists of white vitreous quartz arenite that forms massive beds, commonly more than 1.5 m thick, which are characteristically cross bedded (Fig. II-4; Plate I). Also characteristic of the formation are reddish-brown nodular hematite concretions, typically no larger than 3.0 cm in diameter. Neuman and Nelson (1965) reported *Skolithos* tubes in the Nebo Quartzite on Chilhowee Mountain, but none are observed in the Nebo Quartzite on Starr Mountain at Bullet Creek Falls. No accurate thicknesses of the Nebo quartzite have been reported on Starr or Bean Mountains in the vicinity of the study area, but the formation ranges from 60 to 120 m (200 ft to 400 ft) at the type locality on the northwest slope of Chilhowee Mountain.

Murray Shale

The Murray Shale is conformable with the underlying Nebo Quartzite and consists of gray micaceous fissile silty shale and argillaceous siltstone, thinly interbedded in the upper half of the formation with greenish-gray glauconitic feldspathic fine-grained sandstone at the type locality on Chilhowee Mountain (Neuman and Nelson, 1965). A similar interbedded shale and sandstone horizon, lacking glauconite, was mapped by Rackley (1951) as part of the Nebo Quartzite on Bean Mountain, but was later reinterpreted by Rodgers (1953) to be the Murray Shale. No thicknesses are available for the Murray Shale south of the Little Tennessee River, but the formation is 100 to 170 m (350 ft to 550 ft) at the type locality (Neuman and Nelson, 1965).

Hesse Quartzite

The Hesse Quartzite is the youngest formation of the Chilhowee Group in the vicinity of the study area (Rodgers, 1953; McKinney, 1964), but no detailed descriptions of the formation exist south of the Little Tennessee River. North of the Little Tennessee River at the type locality

near the crest of Chilhowee Mountain, however, the Hesse Quartzite consists of light-gray well-sorted medium- to coarse-grained, commonly cross bedded quartz arenite that forms beds about one meter thick (Neuman and Nelson, 1965). *Skolithos* tubes are locally abundant (Neuman and Nelson, 1965), but concretion-forming authigenic hematite and barite which is common in the Nebo Quartzite is lacking in the Hesse Quartzite (Swingle, 1949). The thickness of the formation varies from 150 m to 180 m (500 ft to 600 ft) along the crest of Chilhowee Mountain.

Helenmode Formation

Neuman and Nelson (1965) recognized an interbedded succession of glauconitic and micaceous silty shale, siltstone, sandstone, and quartz arenite above the Hesse Quartzite on Chilhowee Mountain and correlated these rocks with the Helenmode Member of the Erwin Formation (the uppermost formation of the Chilhowee Group in northeastern Tennessee) (King and others, 1944; King and Ferguson, 1960). Because the term Erwin Formation is not used for naming a stratigraphic unit on Chilhowee Mountain, Neuman and Nelson (1965) raised the Helenmode to formation status in central-east Tennessee. The Helenmode Formation on Chilhowee Mountain is gradational and conformable with the underlying Hesse Quartzite, as well as the overlying Shady Dolomite, and ranges in thickness from 15 m to 50 m (50 ft to 175 ft) (Neuman and Nelson, 1965). The Helenmode Formation apparently pinches out to the southwest because it has not been recognized on Bean and Starr Mountains.

Rocks beneath the Great Smoky fault

The Great Smoky fault juxtaposes rocks of the western Blue Ridge stratigraphic sequence in the hanging wall against Cambrian and Ordovician footwall rocks of the Valley and Ridge province. Several formations, including the Shady Dolomite, Rome Formation, and rocks of the Conasauga and Knox Groups, are exposed beneath the Great Smoky fault in the

vicinity of the study area. The Shady Dolomite and the Rome Formation are also conformably present in the hanging wall sequence immediately north of the Little Tennessee River at Miller Cove (Fig. I-2). In northeastern Tennessee, a continuous stratigraphic record exists from Grenvillian basement rocks to the Cambro-Ordovician Knox Group (Rodgers, 1953), providing a regional stratigraphic link between the footwall and hanging wall sequences across the frontal Blue Ridge fault system.

Shady Dolomite

The Lower Cambrian Shady Dolomite is not exposed in the study area, but does crop out immediately northeast near Tellico Plains, Tennessee, beneath the Great Smoky fault and on the southwestern crest of Starr Mountain in the hanging wall sequence. In the Tellico Plains area, the formation is partially exposed, and consists of an alternating, medium to thickly bedded sequence of white to medium dark-gray, commonly siliceous dolomite in the lower part of the section and thin to medium interbedded, yellowish-gray to medium-gray shale, mudstone, and locally cherty dolomite in the upper part (McKinney, 1964). The true thickness of the Shady Dolomite is unknown in the vicinity of Tellico Plains, because faulting and erosion have removed the top and bottom of the formation, but maximum thicknesses of approximately 330 m (1,100 ft) have been reported for well-exposed, complete hanging wall sections in Miller Cove (Neuman and Nelson, 1965).

Rome Formation

The Lower Cambrian Rome Formation consists in the study area of maroon, red and yellowish-brown clay shale, mudstone, and silty shale interbedded with tan, red and pink siltstone and fine-grained sandstone and rare bluish-gray carbonate (McKinney, 1964). Beds range from less than 20.0 cm thick in shale and siltstone to less than 1.0 m thick in the coarser-grained rocks. Shallow-water sedimentary structures such as mudcracks and flow casts, are

locally common in silty shale and siltstone (McKinney, 1964). Detrital mica is also a common constituent of siltstone (McKinney, 1964), and thin (less than 5 mm) beds of fine-grained glauconitic sandstone are very locally interbedded with siltstone. Limestone and dolomite beds occur near the base of the formation and mark the conformable transition zone into the underlying Shady Dolomite, but poorly exposed carbonate interbeds also occur elsewhere in the sequence (McKinney, 1964). Although the top of the formation has been removed by faulting, the Rome Formation in the vicinity of Tellico Plains is estimated to be approximately 300 m (1,000 ft) thick (McKinney, 1964). Roadcut exposures of the Rome Formation are good south of Daugherty Spring, Mecca 7.5-minute quadrangle (Plate I).

Conasauga Group

Only the upper part of the Middle Cambrian Conasauga Group crops out in the study area beneath the Bullet Mountain fault and consists predominantly of yellowish-gray to light greenish-gray fissile shale, interbedded with medium dark-gray to light-gray carbonate beds near the top (McKinney, 1964). These carbonates range in thickness and lithology from thin (about 5.0 cm), shaly limestone to more massively bedded (about 30.0 cm) limestone containing silty laminae and irregular silty dolomite layers that impart a ribboned appearance to the rock (McKinney, 1964). Less than 180 m of the upper part Conasauga Group is preserved in the study area.

Knox Group

Conformably above the shales and subordinate carbonates of the Conasauga Group are carbonate rocks belonging to the Upper Cambrian to Lower Ordovician Knox Group. These carbonates consist of medium to massively interbedded dark to light-gray limestone and dolomite that are characterized by a ribboned appearance similar to the underlying carbonates of the upper Conasauga Group (McKinney, 1964). Carbonates of the Knox Group are

characteristically more cherty than the underlying Conasauga Group carbonate (McKinney, 1964) and the appearance of tan weathered chert nodules in the soil marks the contact between the two groups. This section of carbonates in the study area is correlated with the southeastern phase of the Knox Group (McKinney, 1964) which regionally consists of a limestone dominated package estimated to be more than 940 m (3,100 ft) thick (Rodgers, 1953).

Age of the Walden Creek Group – Stratigraphic and Paleontological Evidence

Recent reports of Silurian to early Mississippian fossils from the Wilhite Formation (Unrug and Unrug, 1990; Unrug and others, 1991) have rekindled a controversy concerning the age of the Walden Creek Group and the Ocoee Supergroup. This controversy has lasted more than a century (Hayes, 1891; Keith, 1895; Hayes, 1895; Keith, 1904; Stose and Stose, 1949; King, 1958; Unrug and Unrug, 1990; Unrug and others, 1991). Fundamental to understanding the age of a particular lithostratigraphic unit, however, is understanding the stratigraphic context of its occurrences. Because these fossils reported by Unrug and Unrug (1990) and Unrug and others (1991) have not been reproduced (Broadhead and others, 1993), attempts must be made to recognize the age of the Walden Creek Group using contact relationships with younger western Blue Ridge lithostratigraphic units (i.e., Chilhowee Group), as well as reexamine the existing paleontological data from these rocks.

It has been firmly established that at least the upper formations of the Chilhowee Group are Early Cambrian from the presence of the crustacean *Isoxys chilhoweana* (Walcott, 1890), and the ostracode *Indiana tennesseensis* (Laurence and Palmer, 1963) in the Murray Shale (Fig. II-3). The Cochran Formation (Chilhowee Group) stratigraphically overlies the Sandsuck Formation (Walden Creek Group) in several areas throughout the Foothills belt of eastern Tennessee. King (1949, 1964) interpreted an unconformable contact between these units along the northwestern slope of Chilhowee Mountain (Figs. I-1; I-2). A conformable contact has been recognized in several areas, including: (1) the Bean Mountain area (Rackley, 1951) and in the

present study area on Chestnut and Starr mountains (Phillips, 1951) (Figs. I-1; I-2, Plate I), (2) the southwestern slope of Chilhowee Mountain (Neuman and Nelson, 1965) (Figs. I-1; I-2), (3) the northeastern slope of English Mountain (Hamilton, 1961) (Figs. I-1; I-2), and (4) in the vicinity of Del Rio, Tennessee, north of the French Broad River (Keller, 1980) (Fig. I-1). In these areas, the Sandsuck Formation can be no younger than Early Cambrian. Only in the Del Rio District has detailed mapping shown a continuous unbroken section of the entire Walden Creek Group beneath the Chilhowee Group (Keller, 1980). Walden Creek Group rocks in this area, however, are disjunct from the main Walden Creek Group outcrop belt in the Foothills by several faults and correlations between the two sequences are tenuous. In the Foothills belt, the Sandsuck Formation is separated from the rest of the Walden Creek Group by regional faults.

Several workers have used lithologic similarities to correlate Walden Creek Group strata across these faults in the Foothills belt. In the vicinity of English Mountain where best exposures of Walden Creek Group rocks occur and constituent formations of the group were defined (King, 1958), Hamilton (1961) mapped a continuous section from the Licklog Formation to the Sandsuck Formation in the hanging wall of the Great Smoky fault. In the footwall, Hamilton (1961) recognized Sandsuck lithologies beneath Chilhowee Group rocks and cautiously correlated Sandsuck Formation strata across the fault. Walker and Rast (1991) used distinctive quartz-pebble conglomerate containing milky quartz pebbles and clasts of granitoid, aplite and black slate to correlate Sandsuck rocks mapped by Hamilton (1961) south of English Mountain to Sandsuck rocks mapped by King (1964) and Neuman and Nelson (1965) on Chilhowee Mountain. In the study area, quartz arenite is used to lithologically correlate rocks of the lower member of the Sandsuck Formation in the hanging wall of the Maggies Mill fault with rocks of the middle member which stratigraphically underlie rocks of upper Sandsuck and Cochran formations in the footwall. Unfortunately, no lithologic similarities exist between the Sandsuck Formation in the footwall of the Miller Cove fault and the Wilhite Formation in the hanging wall in the study area.

Although all of these lithologic correlations between fault blocks throughout the Foothills belt are unproven and questionable, they do suggest that rocks of the Walden Creek Group can be no younger Early Cambrian. Unrug and Unrug (1990) and Unrug and others (1991) proposed that the entire Walden Creek Group was mid Paleozoic. At least parts of the Walden Creek Group, as originally defined by King and others (1958), cannot be mid Paleozoic as proposed because of the stratigraphic continuity of the Sandsuck and Cochran formations. In the study area, rocks of the middle and upper members of the Sandsuck Formation cannot be younger than Early Cambrian.

Paleontological evidence other than data presented by Unrug and Unrug (1990) and Unrug and others (1991) also suggests a late Proterozoic to Early Cambrian age for the Walden Creek Group. Knoll and Keller (1979) reported occurrences of the late Precambrian to Paleozoic(?) acritarch *Bavlinella faueolata* (shepleva) in Walden Creek Group rocks throughout the Foothills belt (Fig. II-3). Specimens were recovered from Sandsuck Formation rocks beneath Chilhowee Group rocks in the footwall of the Miller Cove fault and from Wilhite Formation rocks in the hanging wall. Although this form ranges into the Cambrian (Knoll and Swett, 1985) and is believed to extend later into the Paleozoic (Unrug and Unrug, 1990), it is unlikely (but still possible) that the species would be present beneath Lower Cambrian rocks (that do not contain the fossil) and still represent a biostratigraphic range of Late Proterozoic to mid Paleozoic.

In addition to these acritarchs, soft-bodied metazoan macrofossils originally reported by Rackley (1951) and Phillips (1952) from the middle member of the Sandsuck Formation were rediscovered along Ellis Branch in the study area (Broadhead and others, 1991) (Fig. II-3). A trace fossil (burrow?) was also recovered from the Sandsuck Formation near the original fossil locality (Fig. II-3). These soft-bodied metazoan macrofossils and trace fossil are preserved in rocks stratigraphically related to rocks containing acritarchs discovered by Knoll and Keller (1979). These acritarchs, metazoans and trace fossil are the earliest reported occurrences of life

beneath the Nichols Shale (Neuman and Nelson, 1965). Although this assemblage does not specifically belong to the *Olenellus* zone (Walcott, 1890), it is suggested that the base of the Cambrian as defined by King (1949) may extend below the Cochran Formation in the study area to include at least the middle (and upper) members of the Sandsuck Formation from which these fossils were recovered.

Chapter III

Structure of the Western Blue Ridge Frontal Thrust Sheets, Southeastern Tennessee

Introduction

Rocks of the depositionally complex Ocoee Supergroup record an equally complex suite of structures, including several generations of folds, foliations, and regional thrust faults. Traditional interpretations suggest that these structures were produced during at least two periods of intense Paleozoic deformation, including an Ordovician (Taconian or Blountian) event in which regional folding, faulting, and the development of Barrovian-type metamorphism predominated, and a late Paleozoic (Alleghanian) event that produced major crustal faulting (Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965; Butler, 1972; Kish, 1974; Dallmeyer, 1975; Hatcher, 1978; Secor and others, 1986; Connelly and Dallmeyer, 1991; Kish, 1991; Woodward and others, 1991). With the recent hypothesis that the Walden Creek Group (Ocoee Supergroup) is middle Paleozoic (Unrug and Unrug, 1990; Unrug and others, 1991), the interpretation that some of these structures may have formed in the early Paleozoic is questioned.

Previous Structural Studies

Structures observed in the western Blue Ridge have intrigued geologists for more than a century. Safford (1869) was the first to comment on the structural complexity after studying Ocoee and Knox "formation" rocks in the vicinity of Wear, Tuckaleechee, and Cades Coves in eastern Tennessee. Safford (1869, p. 186-187) concluded that rocks of the Knox "formation" exposed in the coves were "cut off and entangled among the Ocoee rocks" during "the period of disturbance," but the kinematics of the emplacement of Ocoee rocks around the coves were not addressed until C. W. Hayes (1891) brought the fledgling notion of "overthrusts" to the

southern Appalachians. Hayes (1891, 1895) suggested that a large “overthrust” separated rocks of the western Blue Ridge from Valley and Ridge rocks in northwestern Georgia and named this thrust the Cartersville fault for exposures in the Cartersville District. Although previous workers (Safford, 1869; Keith, 1895) had identified a high-angle reverse fault separating western Blue Ridge rocks from Valley and Ridge rocks northwest of Chilhowee Mountain, Stose (1898) recognized the low-angle nature of this fault southwest of English Mountain and was the first to apply Hayes’ (1891) “overthrust” concept in eastern Tennessee.

Once this low-angle fault separating Ocoee rocks from Valley and Ridge rocks was recognized in the vicinity of the coves (Stose, 1898; Keith, 1902), several early attempts were made to understand it. Gordon (1920) concluded that two periods of deformation occurred to produce the observed structures around the coves. Gordon (1920) postulated that the first period involved the emplacement of the “great overthrust,” which faulted Ocoee rocks over rocks of the Knox Group exposed in the coves. This overthrust was later complexly deformed by a second period of folding and faulting, which also produced the faults in the Valley and Ridge province (Gordon, 1920). Keith (1927), who had earlier opposed the notion of “overthrust” faults in the region (Keith, 1895) but now supported the concept, named Gordon’s (1920) fault the Great Smoky fault and traced it more than 190 km (120 mi) through Tennessee into southwestern Virginia. Keith (1927) concluded that about 32 km (20 mi) of displacement occurred along this low-angle fault, much less than the 350 km to 500 km (217 mi to 310 mi) of displacement now speculated for the entire Blue Ridge composite thrust sheet (Hatcher, 1989; Hatcher and others, 1989b; Hatcher and Goldberg, 1991). Keith (1927) also estimated this displacement along the Great Smoky fault to have occurred between the Mississippian and the end of the Carboniferous. Further contributions were made by Wilson (1935), who described cleavage development in the Ocoee rocks surrounding the coves and recognized the lack of gouge with the fault. Wilson (1935) speculated that the Ocoee slate served as a local lubricant that prevented gouge formation. Wilson (1935) also recognized the two periods of deformation

in the coves area described earlier by Gordon (1920) and emphasized the importance of the second period in which post-thrust folding of the thrust sheet was dominant.

As studies of the Great Smoky fault progressed in the coves area of central-east Tennessee, structural work was also in progress in southeastern Tennessee, southwestern North Carolina, and northern Georgia. LaForge and Phalen (1913) described structures in the Ellijay 30-minute quadrangle in Georgia and also recognized two deformational events. The first of these events was interpreted to have occurred at the close of the Ordovician and resulted in the development of folds, schistosity, and recrystallization in the rocks (LaForge and Phalen, 1913). The second event was interpreted to have occurred near the end of the Carboniferous and included intense, northwest-vergent folding and faulting (LaForge and Phalen, 1913). Later, Crickmay (1936) challenged these interpretations by suggesting that all western Blue Ridge structures in northern Georgia and southeastern Tennessee developed during the late Paleozoic Alleghanian orogeny. Crickmay (1936) observed and described transposition of primary structures and two obliquely intersecting cleavages in the rocks east of Ducktown, but noted only one axial-planar cleavage and no transposition in the rocks immediately west of Ducktown. Unlike Hayes (1891), who interpreted this change to represent a gradual increase in metamorphism, Crickmay (1936) supported earlier regional conclusions by Jonas (1932) that a major fault separated higher-grade metamorphic rocks of the Ducktown region from lower metamorphic grade rocks farther east, and cited these differences between the two structural domains as evidence for the fault. The existence of this fault was later questioned by Stose and Stose (1944, 1947, 1949) who concluded that it was not a major structure.

Mapping in the Great Smoky Mountains National Park in Tennessee and North Carolina revealed more about the complex western Blue Ridge structures (Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965). Here, major faults, including the Greenbrier, Miller Cove, Rabbit Creek, Dunn Creek, and Line Springs faults and related folds were recognized, and the relationship between these structures and the regional

Barrovian-type metamorphism was better defined. The Greenbrier, Rabbit Creek, Line Springs, and Dunn Creek faults were interpreted to be premetamorphic because regional metamorphic isograds transect them (Hadley and Goldsmith, 1963; King, 1964). Hamilton (1961) recognized that slaty cleavage transects folds in hanging wall rocks of the Greenbrier and Dunn Creek thrust sheets and concluded that at least some folding also predated metamorphism. Farther west, the postmetamorphic Miller Cove fault transported axial-planar slaty cleaved rocks of low metamorphic grade into contact with less cleaved and metamorphosed rocks (King, 1964; Neuman and Nelson, 1965). The postmetamorphic Great Smoky fault decapitated and floored all other structures in the western Blue Ridge and was arched upward from beneath after emplacement (Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965).

At least two periods of deformation, separated by at least one episode of metamorphism, were recognized by the Park workers in the rocks of the Great Smoky Mountains region (Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965). All agreed that the emplacement of the Great Smoky and Miller Cove faults and related folding was late Paleozoic because rocks as young as early Mississippian were truncated in the footwall of the fault system (Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965). All interpreted the premetamorphic period of folding and faulting to have occurred during the Early Ordovician as well because a westerly thinning sequence of Middle Ordovician clastic rocks that crops out along the eastern edge of the Valley and Ridge in Tennessee suggests orogenesis, uplift, and erosion of western Blue Ridge rocks prior to Middle Ordovician deposition (Neuman, 1955; Kellberg and Grant, 1956; Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965).

There was disagreement among the Park workers, however, on the age of the regional metamorphic event. Hamilton (1961) suggested that metamorphism may have occurred during an early stage of the late Paleozoic deformational event, but concluded an early to middle

Paleozoic age as more reasonable. Hadley and Goldsmith (1963) interpreted predominantly Middle to Late Devonian metamorphism, because K/Ar dates (muscovite and biotite) and Rb/Sr, Pb/U, and Pb/Pb dates (uraninite, muscovite, and feldspar) from pegmatites cross-cutting basement and Ocoee rocks near the Bryson City dome in North Carolina yielded ages between 340 Ma and 375 Ma (Aldrich and others, 1958; Long and others, 1959). Neuman and Nelson (1965), however, concluded the metamorphism was Ordovician, citing a 440 Ma K/Ar date (biotite) (Eckelmann and others, 1959) from metamorphosed Ocoee rocks near Ducktown, Tennessee. More recent attempts to radiometrically date this period of metamorphism using Ar/Ar and K/Ar measurements from amphibolite-grade hornblende, chlorite-grade muscovite, and whole-rock samples have yielded only equivocal evidence that a metamorphic event occurred between 420 and 480 Ma (Kish, 1974; Dallmeyer, 1975, 1989, 1991; Connelly and Dallmeyer, 1991).

Strain analysis in the Great Smoky Mountains region has been the focus of most recent structural studies. Walters (1988) studied the relationship between the Greenbrier, Rabbit Creek, and Great Smoky faults southwest of Cades Cove and concluded that intensely strained ($R_{xz} = 1.45$ to 4.60 ; R_f/ϕ method) Cades Sandstone is exposed on the overturned forelimb of a recumbent nappe that developed in the hanging wall of the Rabbit Creek fault after the emplacement of the Greenbrier fault. These rocks were subsequently deformed by the emplacement of the Great Smoky fault and duplexing of the footwall beneath the Great Smoky thrust sheet. Lewis (1988) hypothesized that strain ellipsoid orientations represented the end result of incremental strains ($R_{xz} = 1.46$ to 3.44 ; R_f/ϕ method) associated with the initial emplacement and later deformation of the Greenbrier fault southeast of Wear Cove, reconfirming earlier conclusions that rocks of the Great Smoky Mountains were deformed twice. Lastly, Connelly (1993) and Connelly and Dunne (1993) calculated finite strains ($R_{xz} = 1.08$ to 1.83 ; R_f/ϕ method) within three premetamorphic thrust sheets south of English Mountain and attempted to model deformation along the hanging wall ramp- and-flat portions

of these sheets using strain factorization. They concluded that the majority of the internal deformation in the sandstones was coeval with the formation of regional cleavage.

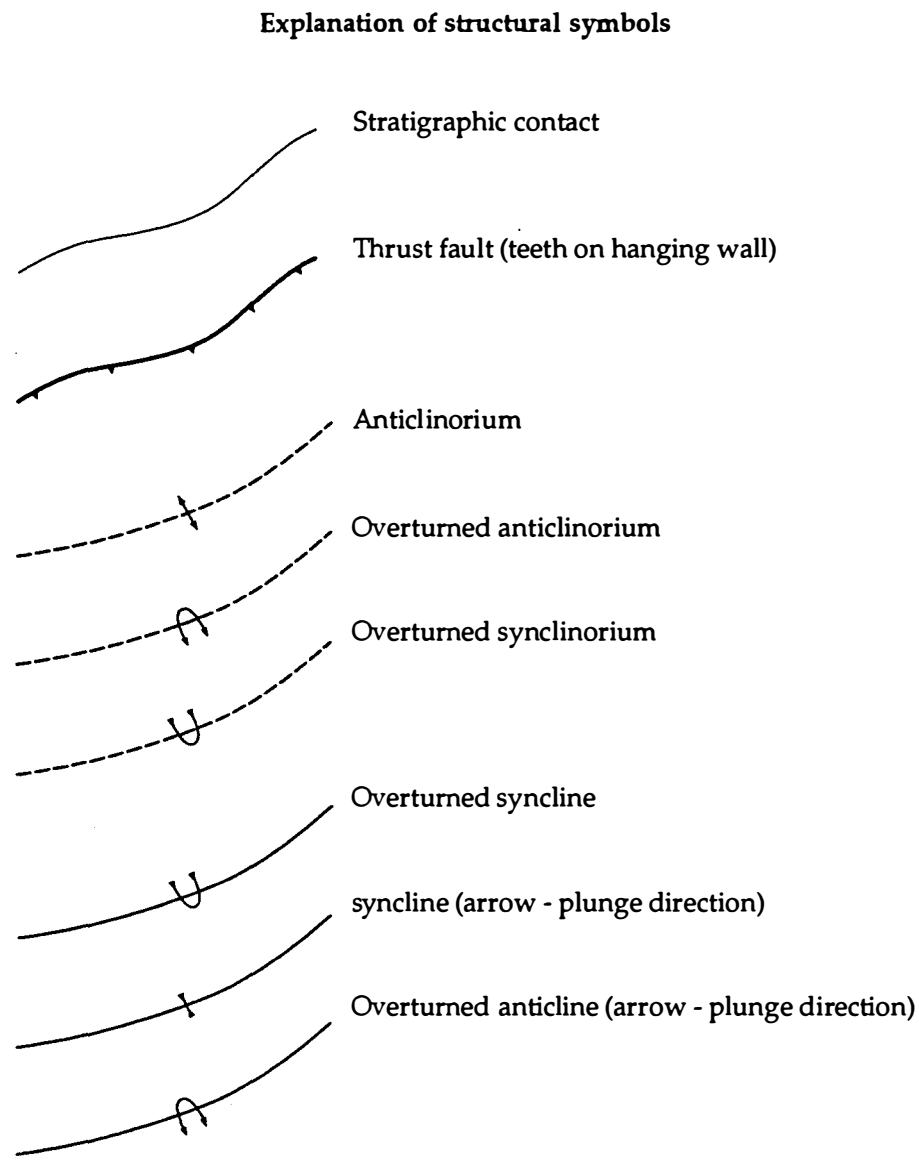
Structure in southeastern Tennessee

Meso- and macroscopic structures in the vicinity of the study area include folds, foliations, and thrust faults. These thrust faults are interpreted to be postmetamorphic brittle structures because they juxtapose rocks of different metamorphic grade, cleavage morphology, and cleavage intensity, and contain brittle structures such as gouge and slickenlines. The thrust faults separate rocks in the study area into four thrust sheets: the Great Smoky, Bullet Mountain, Maggies Mill, and Miller Cove thrust sheets (Fig. III-1). The Great Smoky thrust sheet is composed of locally slaty cleaved anchizone metamorphic rocks of the Chilhowee Group and Sandsuck Formation. East of the Great Smoky sheet is the Maggies Mill sheet which is composed of lower Sandsuck Formation rocks that have also been only mildly metamorphosed to anchizone grade and are locally slaty cleaved. The Miller Cove sheet consists of chlorite-grade, slaty cleaved rocks of the lower Walden Creek and upper Great Smoky Groups. Unmetamorphosed Paleozoic rocks in the footwall of the Great Smoky fault comprise the Bullet Mountain thrust sheet.

Folds

One syndepositional period of folding (F_0) and at least four tectonic folding events (F_{1-4}) have been recognized in the study area. Folds in the study area and throughout the western Blue Ridge in eastern Tennessee, northwestern Georgia, and southwestern North Carolina vary in size from regional 1st-order structures to 5th- and higher-order mesoscale structures (Fig. III-2; Table A-IV). The chronological order of these folding events is determined primarily from the geometric relationship between macro- and mesoscale folds to the regional axial-planar slaty cleavage (S_2). The relationship of some folds in the study area to regional faults is also an

Figure III-1: Four thrust sheets, bounding thrust faults, and major folds in the study area.



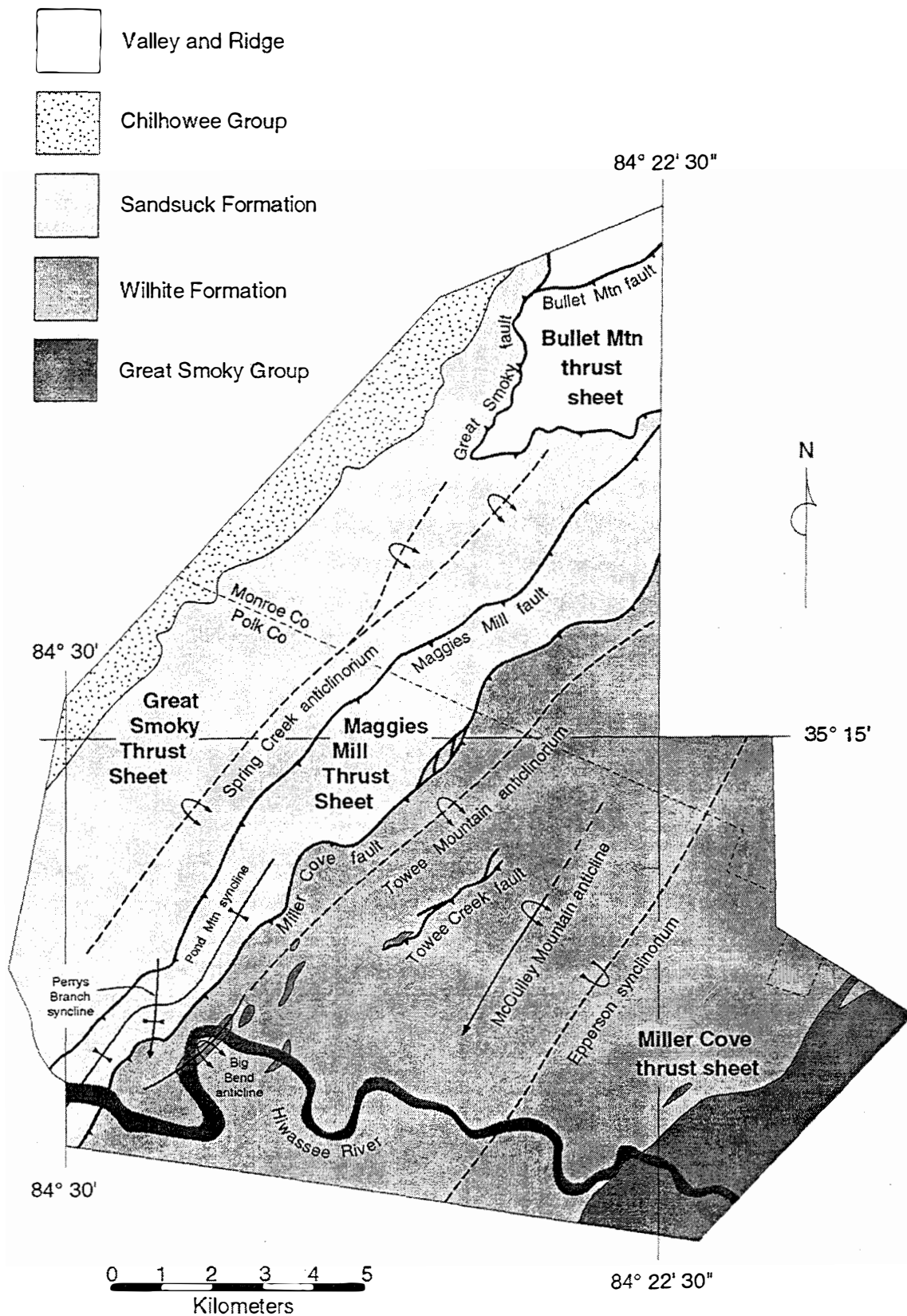
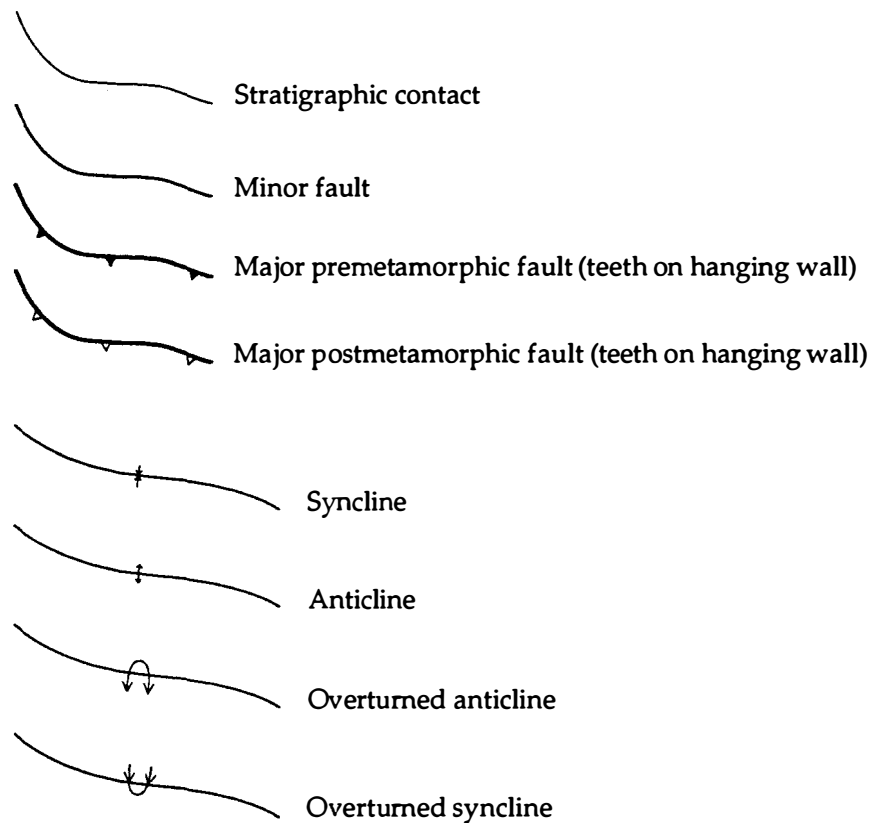


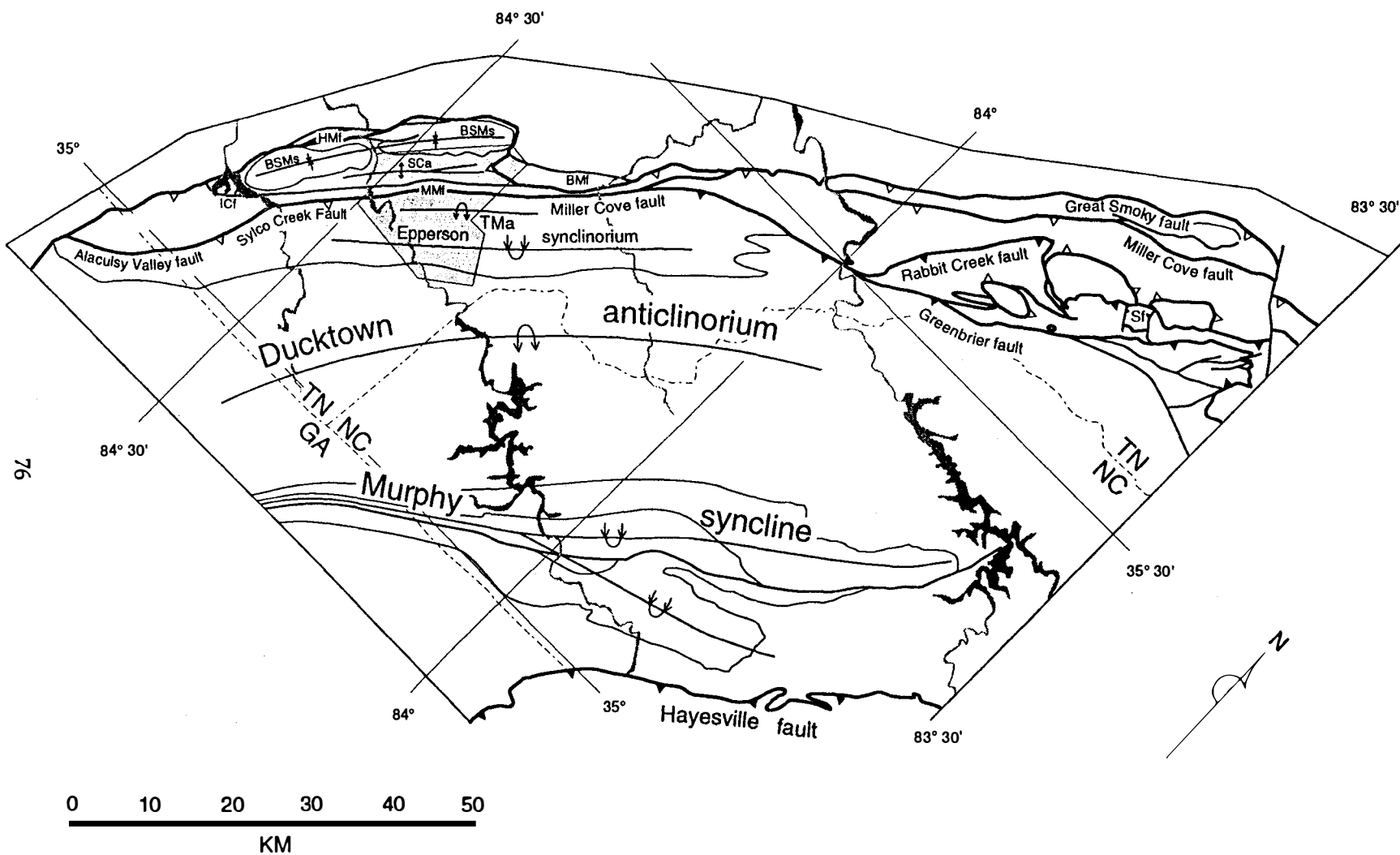
Figure III-2: Major structural elements of the western Blue Ridge in southeastern Tennessee, southwestern North Carolina, and northwestern Georgia. Study area within light-colored box.

Fault abbreviations: BMf - Bullet Mountain fault; HMf - Harrison Mill fault; ICf - Indian Creek fault; MMf - Maggie's Mill fault; Sf - Sinks fault.

Fold abbreviations: BSMs - Bean-Starr Mountain syncline; SCa - Spring Creek anticline; TMa - Towee Mountain anticlinorium.

Explanation of structural symbols



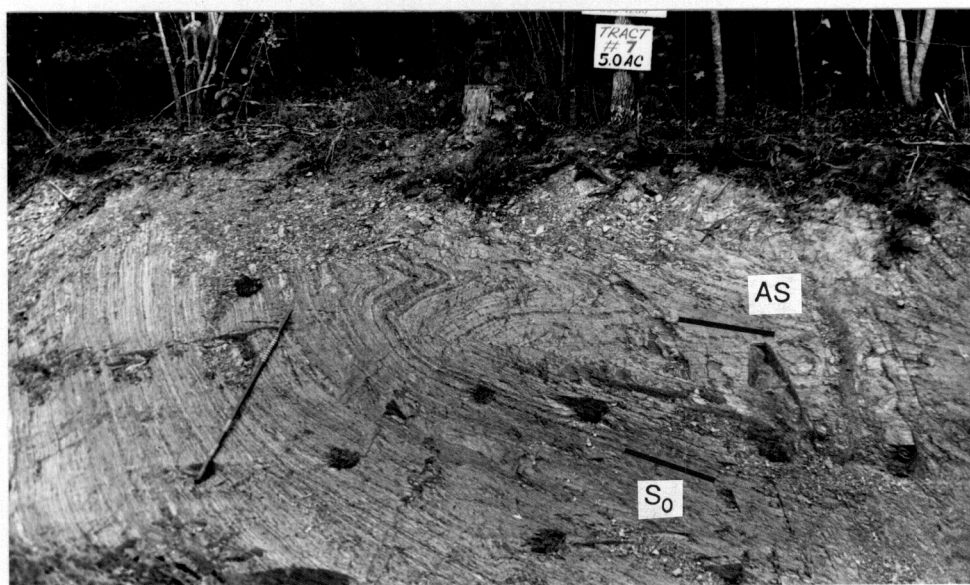


important dating criterion. 5th- and higher-order soft-sedimentary F_0 folds and tectonic F_1 folds are present in the Maggies Mill and Miller Cove thrust sheets. They are interpreted to have developed prior to regional metamorphism because slaty cleavage transects these folds (Powell, 1974; Williams, 1985). Slaty cleavage in the Miller Cove thrust sheet is axial-planar to 3rd- and higher-order F_2 folds, implying a synmetamorphic origin for these folds. 2nd- and higher-order F_3 folds in the Bullet Mountain, Great Smoky, and Maggies Mill thrust sheets are interpreted to have formed during post-metamorphic faulting, because these fold axes are oriented nearly parallel to the trends of regional, post-metamorphic faults. Other F_3 folds in the Miller Cove thrust sheet fold slaty cleavage. Lastly, 3rd-order F_4 folds overprint all preexisting structures in the Great Smoky, Maggies Mill, and Miller Cove thrust sheets.

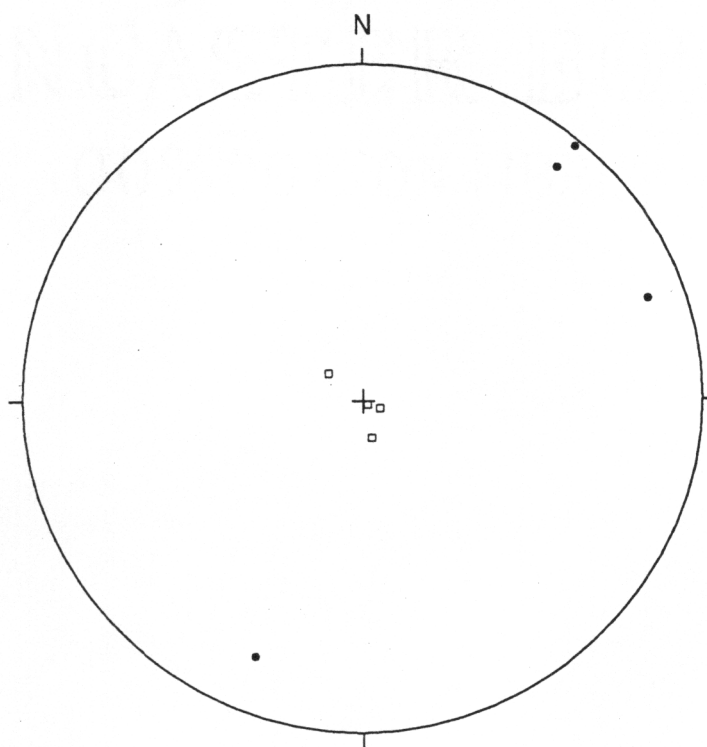
F_0 folds

Fine-grained rocks of the Sandsuck and Wilhite Formations locally preserve soft-sediment F_0 folds (Fig. III-3A). F_0 folds are typically tight to nearly isoclinal 5th- and higher-order folds that are commonly observed to have amplitudes (up to about 2.5 m) several times larger than wavelengths (about 0.5 m). Recognizable F_0 folds (not modified or obliterated by later overprinting structures) plunge gently to the northeast and southwest, and axial surfaces are moderately inclined to nearly recumbent (Fig. III-3B). These intraformational structures probably formed as water-saturated silt and clay flowed down slope in response to gravitational and overburden forces. Original vergence of these F_0 folds would have been in the down-slope direction, but later deformation has obscured the vergence direction. Transecting slaty cleavage, coupled with the shallow inclination of the axial surfaces distinguishes F_0 folds from the regionally dominant, tectonic F_2 folds.

Figure III-3: Mesoscale characteristics of soft-sedimentary F_0 folds. (A) 5th-order soft sedimentary F_0 fold on Towee Mountain (station MCF 1167), McFarland 7.5-minute quadrangle. Orientation of axial surface (AS) and bedding (S_0) noted by black lines. Note how axial surface appears oriented nearly parallel to bedding. Jacob staff is 1.5 m long. (B) Lower-hemisphere equal-area projection of 4 F_0 fold axes and poles to axial surface measurements.



(A)



(B)

- Fold axes
- ◻ Poles to axial surfaces

F₁ folds

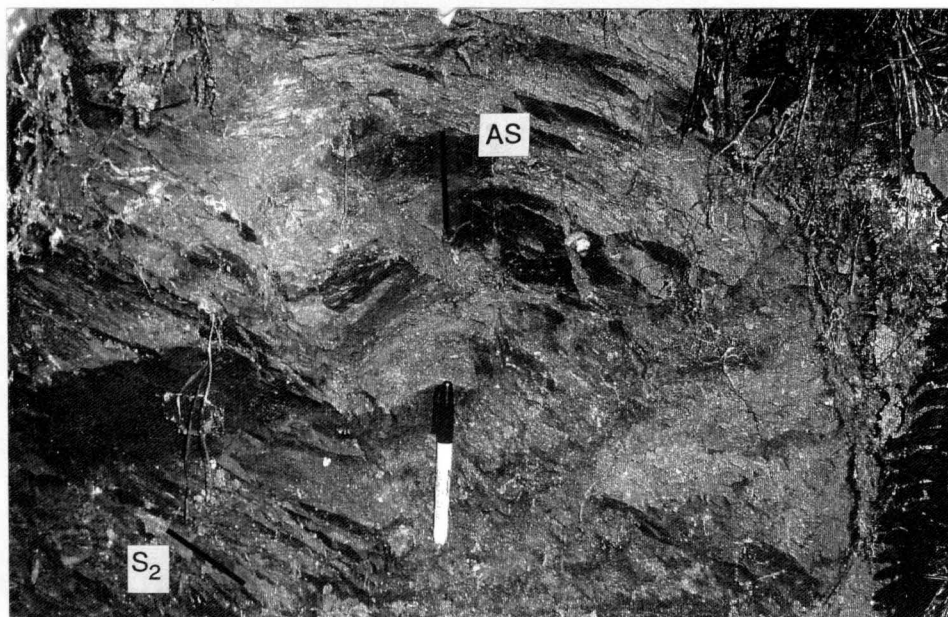
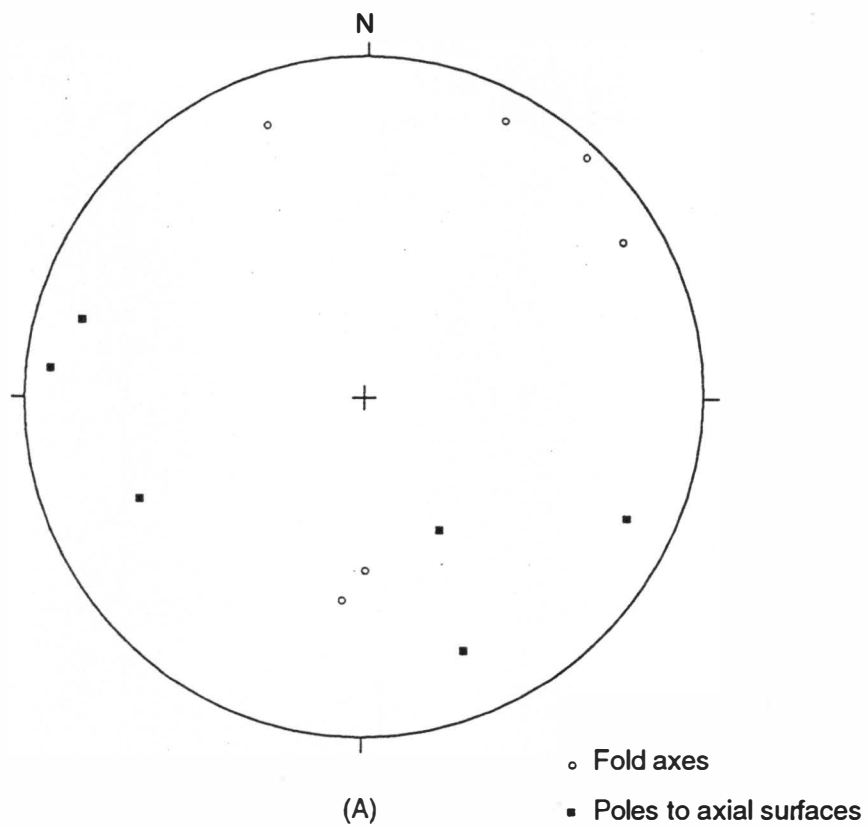
F₁ folds are the earliest recognizable tectonic structures in the study area and deform Wilhite Formation rocks in the Miller Cove thrust sheet. All F₁ folds that have been recognized are small mesoscale 5th-order structures and are gentle to open folds. F₁ folds plunge moderately to gently to the northwest, northeast, and south, and axial surfaces are steeply inclined to upright (Fig. III-4A). F₁ folds occur in all lithologies and differ in fold geometry unlike F₀ folds. Transecting slaty cleavage distinguishes these F₁ folds from later F₂ structures (Fig. III-4B). No related foliations have been recognized with F₁ folds. F₁ folds are predominantly parallel folds, suggesting that these structures possibly formed by buckling with accompanying flexural-slip, although no characteristic bedding parallel slickenlines were observed in the fold limbs.

F₂ folds

F₂ folds are distinguished from other fold generations in the study area on the basis that regional slaty cleavage is axial-planar to F₂ folds. Map- to mesoscale F₂ folds are the dominant structures in the Miller Cove thrust sheet and are also locally present in the Maggies Mill and Great Smoky thrust sheets where slaty cleavage has developed in calcareous fine-grained rocks. F₂ folds range in size from 2nd- and 3rd-order folds such as the Towee Mountain anticlinorium, Epperson synclinorium (Laaajoki, 1993), McCulley Mountain anticline, and the Big Bend anticline (Fig. III-2), to parasitic 4th- and higher-order folds that locally deform these larger structures (Fig. III-5A).

F₂ fold geometry is scale independent. Most F₂ folds are open to closed, although locally, gentle, tight, and nearly isoclinal F₂ folds also exist. Most F₂ folds plunge doubly and subhorizontally to the northeast and southwest, and axial surfaces are gently to moderately inclined predominantly to the southeast (Fig. III-5B). F₂ folds in the study area are overturned or steeply inclined to the northwest and all F₂ folds verge toward the northwest.

Figure III-4: Mesoscale characteristics of tectonic F_1 folds. (A) Lower-hemisphere equal-area projection of 6 F_1 fold axes and poles to axial surface measurements. (B) 5th-order F_1 fold, 0.95 km (0.6 mi) southwest of Towee Church (station MCF 951), McFarland 7.5-minute quadrangle. Orientation of axial surface (AS) and slaty cleavage (S_2) noted by black lines. Note transecting slaty cleavage. Pen is 13.5 cm long.

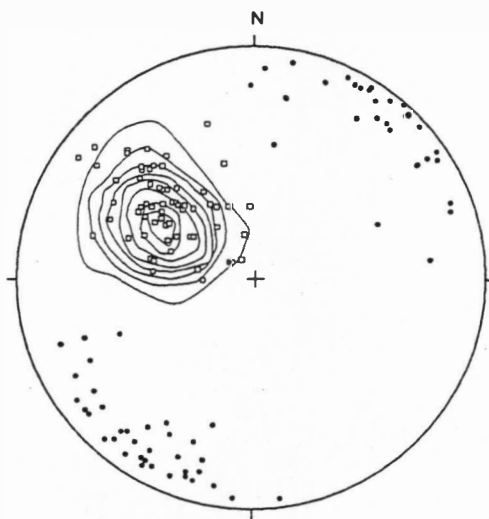


(B)

Figure III-5: Mesoscale characteristics of F_2 folds in the Miller Cove thrust sheet. (A) 5th-order F_2 fold, Hiwassee River (station MCF 257), McFarland 7.5-minute quadrangle. (B) Lower-hemisphere equal-area projection of 67 F_2 fold axes and poles to axial surface measurements. Note axial-planar relationship between F_2 fold axial surfaces and contoured poles to slaty cleavage (S_2). S_2 contours represent 2, 4, 6, 8, 10, 12, 14, 16% per 1% area. (C) Lower-hemisphere equal-area projection of intersection lineation measurements. Note close correspondence between L_{Ox2} intersection lineations and trend of F_2 fold axes.

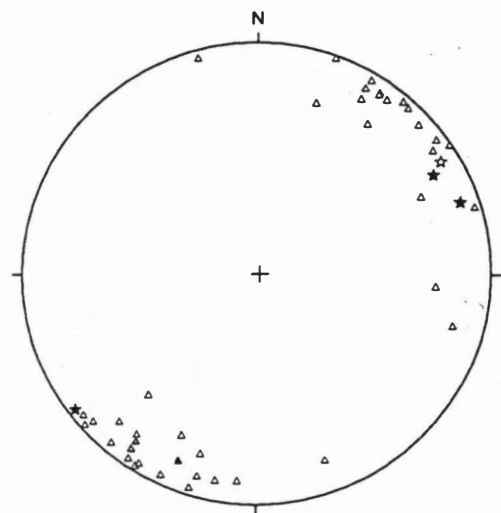


(A)



- Fold axes
- Poles to axial surfaces

(B)



- △ L_{0x2} ★ L_{2x2a}
- △ L_{0x2a} ★ L_{2x3}
- △ L_{0x3}

(C)

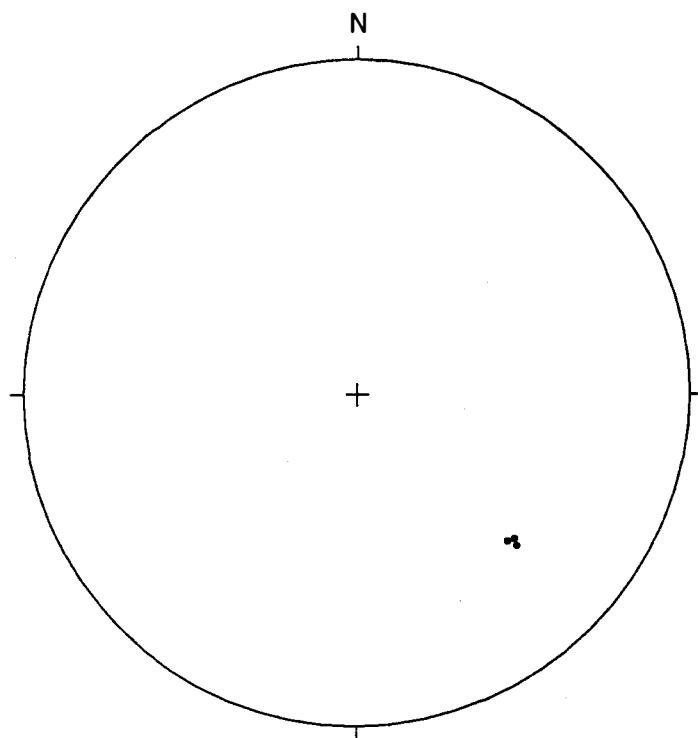
Slaty cleavage in the Miller Cove thrust sheet (and where developed in the Maggie's Mill and Great Smoky thrust sheets) is axial-planar to F_2 folds, and bedding-slaty cleavage intersection lineations ($L_{0\alpha}$) are subparallel to F_2 fold axes (Fig. III-5C). This axial-planar relationship between regional slaty cleavage and F_2 folds is the most distinguishing characteristic of these structures, and suggests that F_2 folding and regional metamorphism were coeval.

F_2 folds in the study area are predominantly parallel folds which suggests that these folds formed by buckling. Whether buckling was accompanied by flexural flow, flexural slip, or some other mechanism, depends on the lithology of the deforming medium and also on the metamorphic temperatures and pressures to produce variations in ductility between layers (Donath and Parker, 1964). F_2 folds that deformed interlayered sequences (such as interbedded fine- and coarser-grained rocks) with a ductility contrast evolved by buckling with flexural flow. F_2 folds formed in this manner are recognized on the basis that bedding thickness in the less competent layers change from limb to hinge. F_2 folds that deformed more homogeneously competent, predominantly coarse-grained sequences, however, formed by buckling with flexural slip, as indicated by generally constant bedding thickness throughout the fold and bedding-parallel slickenlines in the fold limbs.

F_3 folds in the Miller Cove thrust sheet

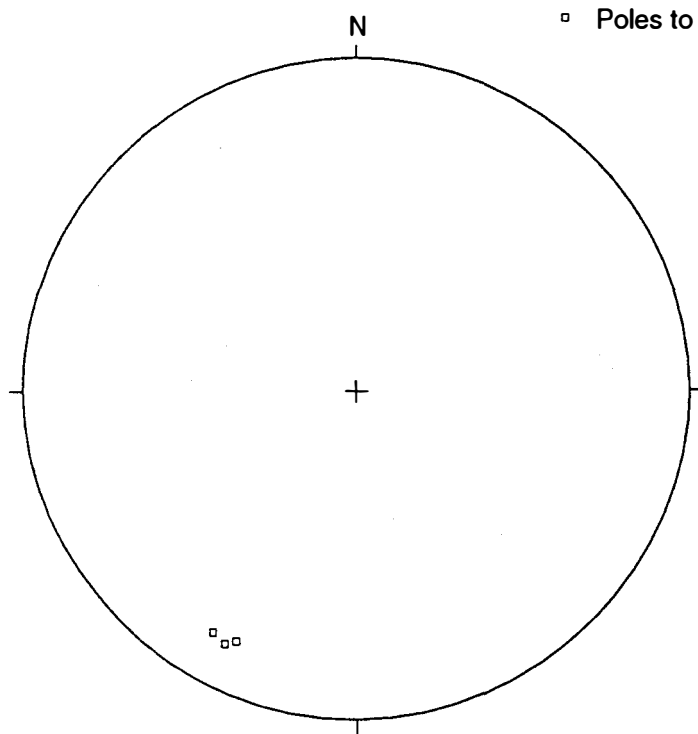
Approximately 0.95 km (0.55 mi) southeast of Towee Church (station MCF 1299) (Plates I; II), slaty cleavage (S_2) in a dark gray slate was observed to be folded by three 6th-order F_3 folds. Fold wavelengths range from approximately 1 cm to 7 cm. Two smaller folds are kink folds and one fold is concentric, suggesting these F_3 folds formed by buckling. All three folds plunge gently to the northeast and their axial surfaces are moderately inclined to the northwest (Fig. III-6). F_3 axial surfaces are oriented similar to axial surfaces of crenulation cleavage (S_3) deforming slate in the Miller Cove and Great Smoky thrust sheets (compare figs. III-6 and III-13A), but the relationship between these F_3 folds and crenulation

Figure III-6: Lower-hemisphere equal-area projection of 3 F_3 folds in the Miller Cove thrust sheet. (A) Fold axes. (B) Poles to axial surface measurements.



(A)

- Fold axes
- Poles to axial surfaces



(B)

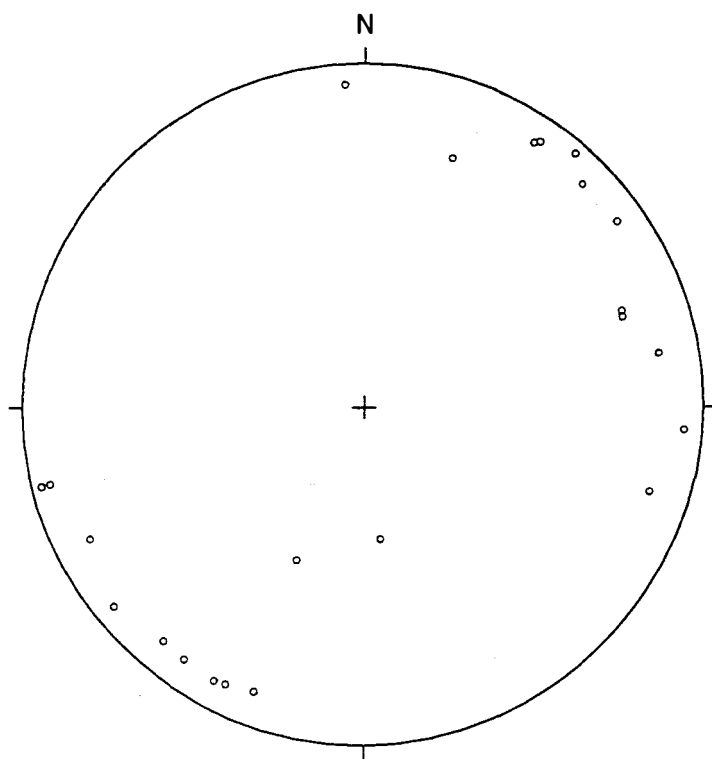
cleavage is uncertain. These F_3 folds were found approximately 150 m west of the Towee Creek fault (Plate I) and may be related to faulting. Because these F_3 folds were observed only at one locality, they are probably regionally insignificant.

F_3 folds west of the Miller Cove fault

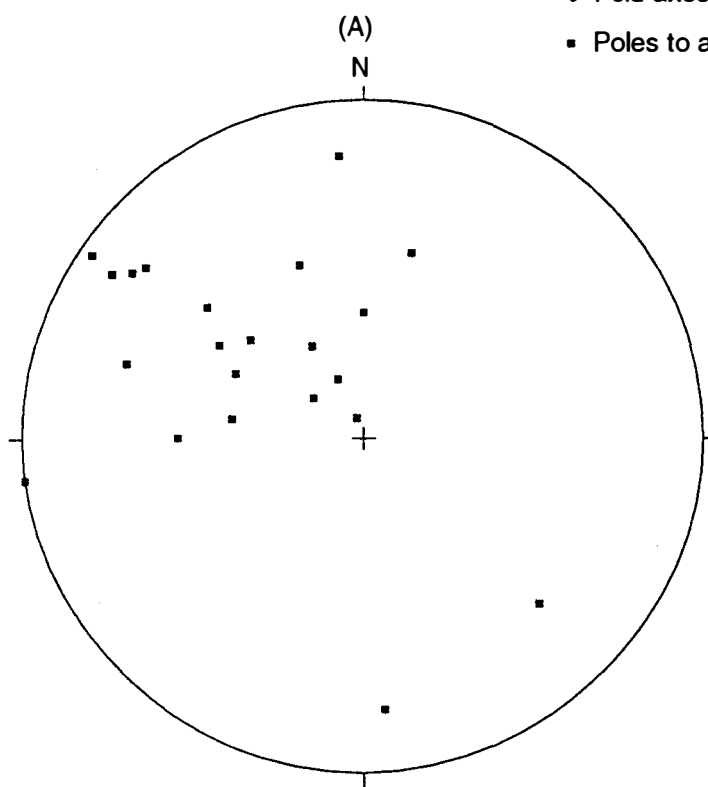
2nd- and higher-order folds are developed in rocks not deformed by regional slaty cleavage in the Maggies Mill, Great Smoky, and Bullet Mountain thrust sheets. These folds, which include the Spring Creek anticlinorium and the Pond Mountain syncline (Fig. III-1), and many 4th- and higher-order parasitic folds, do not have axial-planar slaty cleavage. The relationship between these structures and F_2 folds with axial-planar slaty cleavage and F_3 folds that deform slaty cleavage is uncertain. Detailed mapping, however, has revealed that bedding is locally overturned beneath the postmetamorphic Miller Cove and Maggies Mill faults (Plate I). The formation of footwall synclines beneath these faults suggests that folds in the Maggies Mill and Great Smoky thrust sheets are related to faulting. 5th-order hanging wall anticlines and footwall synclines are also present in the Bullet Mountain thrust sheet (Plate I). Near the Bullet Mountain fault, fold axes of hanging wall anticlines are oriented parallel to the Bullet Mountain fault and similarly oriented fold axes of footwall synclines are present beneath the Great Smoky fault. Because these folds in the Maggies Mill, Great Smoky, and Bullet Mountain thrust sheets appear to be related to postmetamorphic faulting rather than synmetamorphic S_2 cleavage development, they are interpreted to be F_3 folds.

Most F_3 folds are gentle to open, although locally, closed folds also exist. 17 of 21 F_3 folds plunge subhorizontally to moderately to the northeast and southwest, but 4 of 21 F_3 fold axes plunge to the east and southeast (Fig. III-7A). 17 of 21 F_3 axial surfaces are subhorizontally to steeply inclined to the southeast, but 4 of 21 F_3 axial surfaces are inclined to the northeast, northwest, and southwest (Fig. III-7B). F_3 folds are parallel folds and bedding-parallel slickenlines were found in the fold limbs of some F_3 folds, suggesting these structures possibly

Figure III-7: Lower-hemisphere equal-area projection of 21 F_3 fold measurements from the Maggies Mill, Great Smoky, and Bullet Mountain thrust sheets. (A) Fold axes. (B) Poles to axial surfaces.



- Fold axes
- Poles to axial surfaces



(B)

formed by buckling with accompanying flexural-slip.

F₄ folds in the western Blue Ridge thrust sheets

F₄ folds are the youngest structures present in the study area and deform rocks in all three western Blue Ridge thrust sheets. All F₄ folds are 3rd-order structures. No mesoscale F₄ folds were recognized. Characteristic F₄ fold geometry can be derived from well exposed structures such as the Perrys Branch syncline, which deforms the southwestern end of the Maggies Mill thrust sheet (Fig. III-1). Map patterns suggest that north-south trending F₄ folds are predominantly gentle upright structures that plunge gently southward. F₄ folds overprint preexisting structures. F₄ structures clearly fold the postmetamorphic Maggies Mill and Miller Cove thrust faults and earlier folds such as the Pond Mountain syncline. Because these folds apparently developed in the hanging wall of the Miller Cove and Maggies Mill thrust sheets after emplacement, the F₄ folding event may represent deformation from imbrication of the Valley and Ridge footwall sequence. Footwall deformation has been well documented beneath the frontal western Blue Ridge thrust sheets north of the study area in the vicinity of the Great Smoky Mountains National Park (Neuman, 1951; King, 1964; Neuman and Nelson, 1965; Livingston, 1978; Hatcher and others, 1989a; Hatcher and others, 1989b). Here, windows that expose anticlinal imbricated footwall rocks provide evidence that duplexing in the footwall arched these higher thrust sheets after emplacement. F₄ folds in the study area may have formed by a bending mechanism similar to that which arched these northern frontal thrust sheets. No foliations were recognized to be related to the F₄ folding event.

S-surfaces

Five dominant S-surfaces were recognized in the study area, including sedimentary bedding, (S₀), continuous (slaty) cleavage (S₂) (Powell, 1979), stylolitic disjunctive spaced (pressure-solution) cleavage (S_{2a}) (Powell, 1979), zonal crenulation cleavage (S₃) (Gray, 1977),

and weak to strong spaced cleavage (S_{3a}) (Alvarez and others, 1978). S_0 (bedding) is unequivocally the most significant of these S-surfaces because bedding properties, particularly lithology, influence the development of all other S-surfaces. Rocks in each thrust sheet in the study area are deformed by different combinations of cleavage morphologies and cleavage intensities (Fig. III-8). In the Miller Cove thrust sheet, S_2 (slaty cleavage) is the most pervasive of the four tectonic S-surfaces and is developed in all finer-grained (metasiltstone and slate) lithologies. Microstructures suggest that the intensity of S_2 increases eastward across the Miller Cove thrust sheet. S_{2a} (pressure-solution cleavage) and S_3 (zonal crenulation cleavage) are also locally developed in the fine-grained rocks of the Miller Cove thrust sheet. Cleavage in the Maggies Mill thrust sheet is characterized by locally developed S_2 only in calcareous very fine-grained (shale) lithologies. Elsewhere in the Maggies Mill thrust sheet, a weak to strong spaced cleavage (S_{3a}) is developed. S_2 is also locally developed in similar lithologies in the eastern part of the Great Smoky thrust sheet. Farther west in the Great Smoky thrust sheet, spaced cleavage (S_{3a}) in siltstone forms pencil structures. Along the western edge of the Great Smoky thrust sheet in the study area, only a weak to moderate spaced cleavage (S_{3a}) (without pencil structures) deforms shale. S_3 (zonal crenulation cleavage) also locally deforms fine-grained rocks in the Great Smoky thrust sheet. Lastly, weak to strong spaced cleavage (S_{3a}) deforms siltstone and shale in the Bullet Mountain thrust sheet.

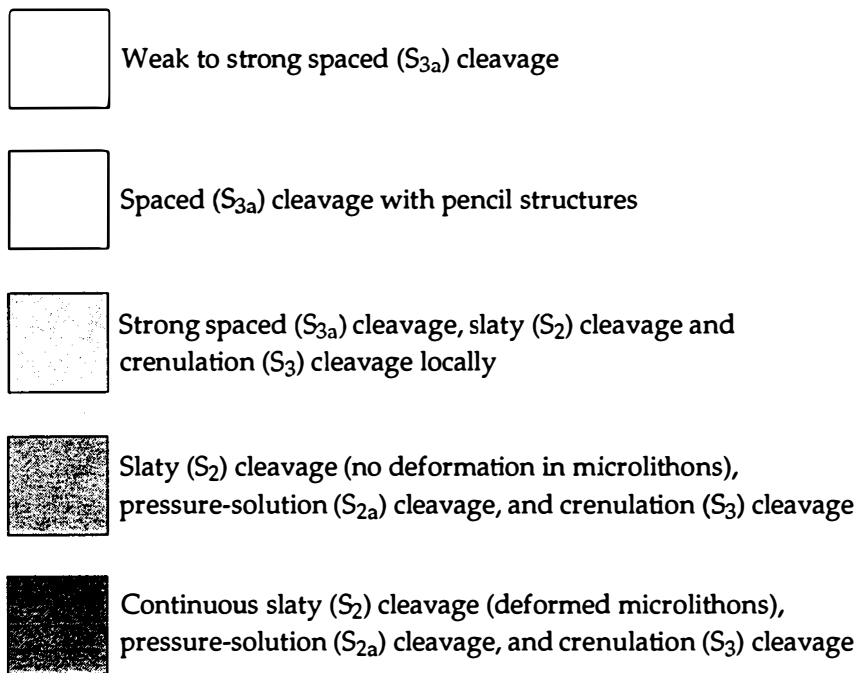
S_0 (bedding)

The character of S_0 depends principally on lithology. S_0 in shale and slate typically consists of thin (< 1 mm) laminations. These laminations consist of usually very fine-grained quartz and feldspar silt that is slightly coarser grained than the surrounding clay-rich horizons. Cohesion across these laminations is strong, even after intense weathering. S_0 in siltstone is characterized by primary depositional bands that consist of alternating, thin deposits of silt and clay. These bands range from 2.0 mm to 5.0 cm thick, and are rhythmically uniform in

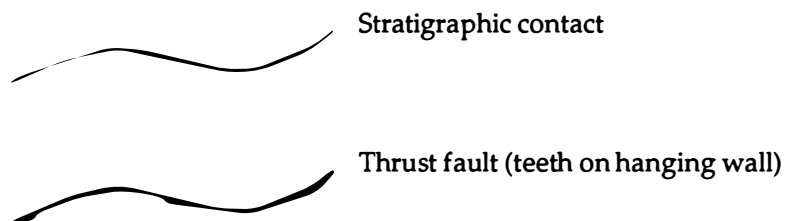
Figure III-8: Constituent cleavage morphologies of five cleavage zones in the study area.

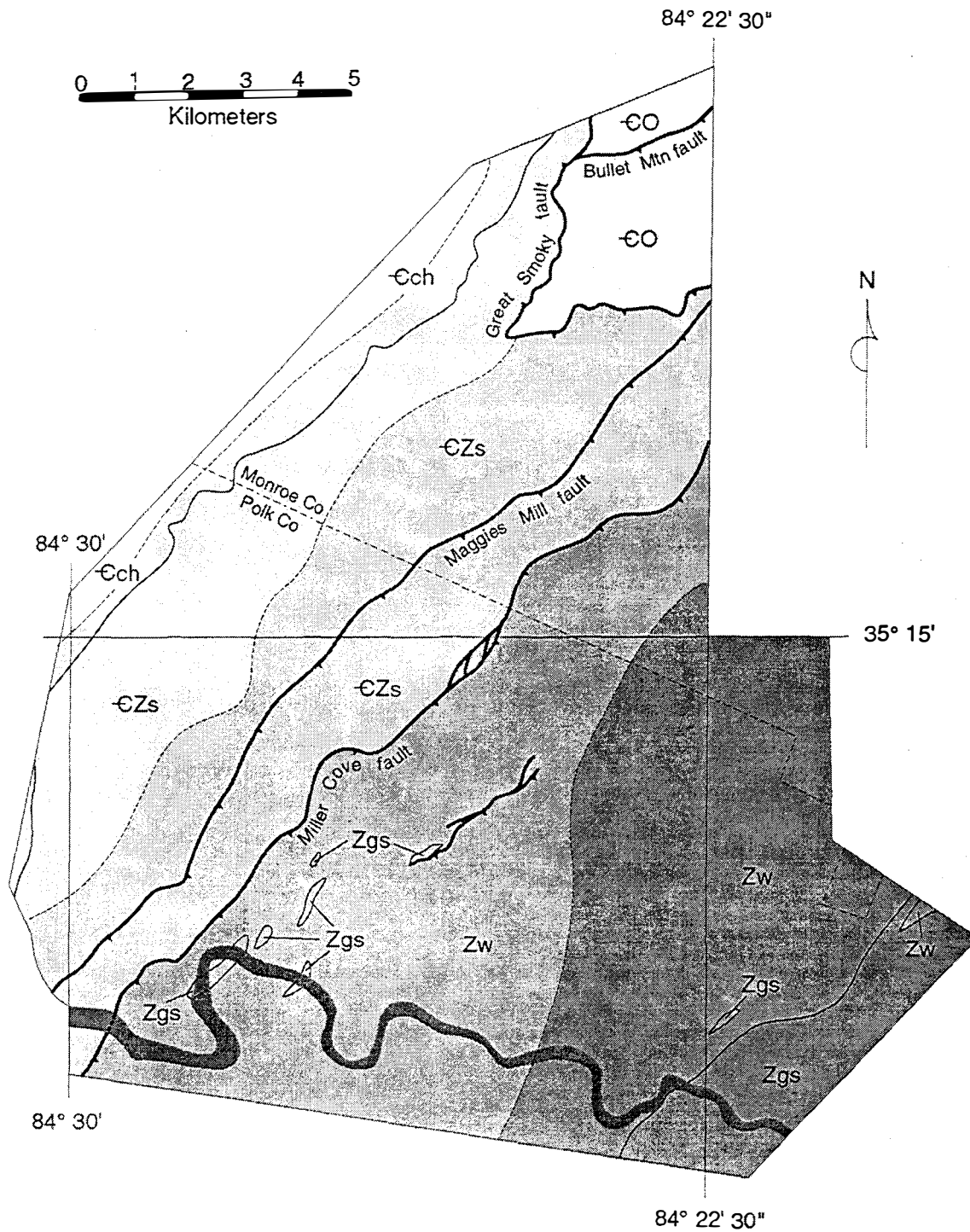
Stratigraphic abbreviations: CO - includes Shady Dolomite, Rome Formation, Conasauga Group, and Knox Group; Ech - Chilhowee Group; CZs - Sandsuck Formation; Zw - Wilhite Formation; Zgs - Great Smoky Group.

Explanation of cleavage zones



Explanation of contacts

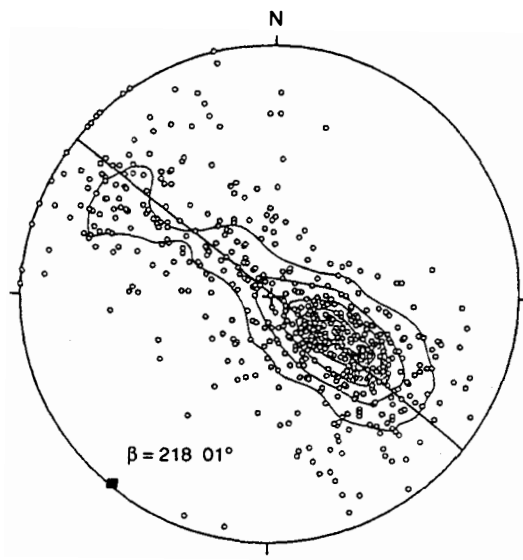




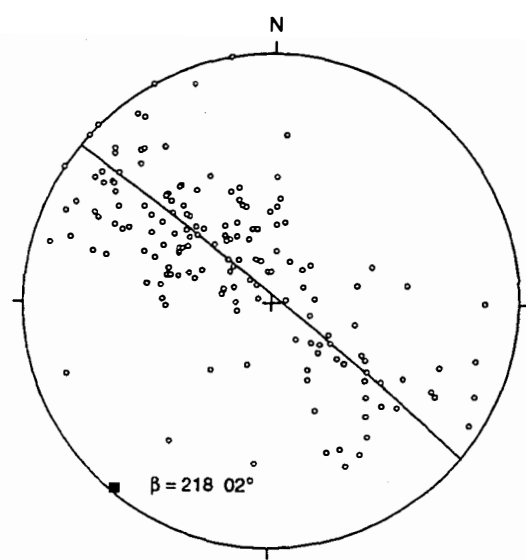
thickness or distorted by other sedimentary structures (i.e., ripples, dewatering structures, scour marks, and cross beds). Siltstone in the Great Smoky and Maggies Mill sheets typically parts along these bands even when fresh, particularly where the bedding surfaces contain abundant detrital micas. These bands are coherent in the metasiltstone of the Miller Cove sheet. S_0 in all coarse-grained rocks in the study area is typically much more widely spaced than bedding in the finer-grained rocks. Sandstone beds are commonly 1.0 m to 3.0 m thick, whereas conglomerate beds generally range from 3.0 m to less than 10 m thick. S_0 spacing in quartzite is closer, and ranges from about 1.0 cm to less than 1.0 m. Graded bedding and channeling are common sedimentary structures in these coarse-grained rocks and reduce cohesion across bedding surfaces. Massive sandstone and conglomerate beds are more cohesive, but bedding surfaces locally part along joints. Bedding in quartzite is the most cohesive, even where extremely weathered.

Bedding in the Great Smoky thrust sheet generally dips gently to the northwest and southeast. Bedding here defines the southeastern limb of the 2nd-order Bean-Starr Mountain syncline and the Spring Creek anticlinorium (Figs. III-1; III-2), but higher-order parasitic folds also deform bedding. Poles to bedding in the Great Smoky thrust sheet define a great circle (318, 89°N) and the corresponding β pole (Diggle and Fisher, 1985; Press, 1989) plunges gently southwest (218, 01°) (Fig. III-9A). Poles to bedding in the Maggies Mill thrust sheet delineate a similar great circle (309, 88°N) and β pole (218, 02°) (Fig. III-9B). These beds in the Maggies Mill thrust sheet, however, are distributed about the axes of the 3rd-order Pond Mountain and Perrys Branch synclines (Fig. III-1), and higher-order parasitic folds. Bedding in the Miller Cove thrust sheet is deformed by 2nd- and higher-order folds such as the Towee Creek anticlinorium, Epperson synclinorium, McCulley Mountain anticline, and Big Bend anticline (Figs. III-1; III-2). Poles to bedding in the Miller Cove thrust sheet delineate a great circle (129, 88°S) and corresponding β pole (039, 02°) (Fig. III-9C). 4th- and higher-order folds deform bedding in the Bullet Mountain thrust sheet, and poles to these beds define a great circle (322,

Figure III-9: Lower-hemisphere equal-area projections of S_0 (bedding) data. (A) 598 poles to bedding measurements from the Great Smoky thrust sheet. Contours represent 2, 4, 6, 8, 10% per 1% area. (B) 163 poles to bedding measurements from the Maggies Mill thrust sheet. (C) 1100 poles to bedding measurements from the Miller Cove thrust sheet. Contours represent 2, 4, 6, 8, 10% per 1% area. (D) 47 poles to bedding measurements from the Bullet Mountain thrust sheet.

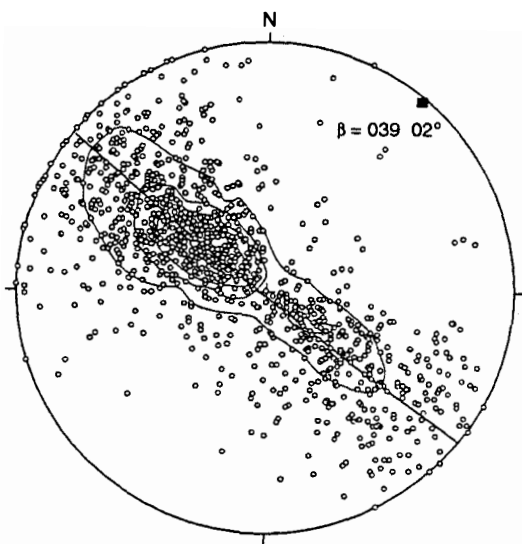


(A)

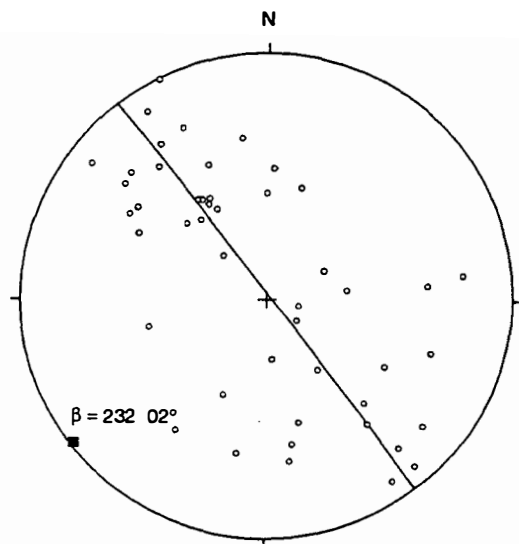


(B)

◦ Poles to bedding
■ β pole



(C)



(D)

88°E) and corresponding β pole (232, 02°) (Fig. III-9D).

Cleavage in the Miller Cove thrust sheet

S_2 (*Slaty Cleavage*). S_2 is the dominant S-surface in the Miller Cove thrust sheet. Mesoscopically, S_2 appears continuous in fine-grained lithologies throughout the thrust sheet (Fig. III-10A). S_2 dips predominantly southeast (031, 40°S) (Fig. III-10B) and is axial-planar to F_2 folds. Cohesion across S_2 is weak and upon weathering, cleaved rocks tend to part along the cleavage surface into flat chips less than 0.5 mm thick but up to 25 cm² in surface area.

Although mesoscopic examination suggests S_2 is continuous, microscopic observation reveals that S_2 records an easterly intensification across the Miller Cove thrust sheet. This is typical of the evolution of S-surfaces long recognized in orogenic belts (Tobish and Patterson, 1988). The microstructures that record this intensification, although partially lithologically dependent, are primarily the product of cleavage-forming mechanisms active during metamorphism and ductile deformation.

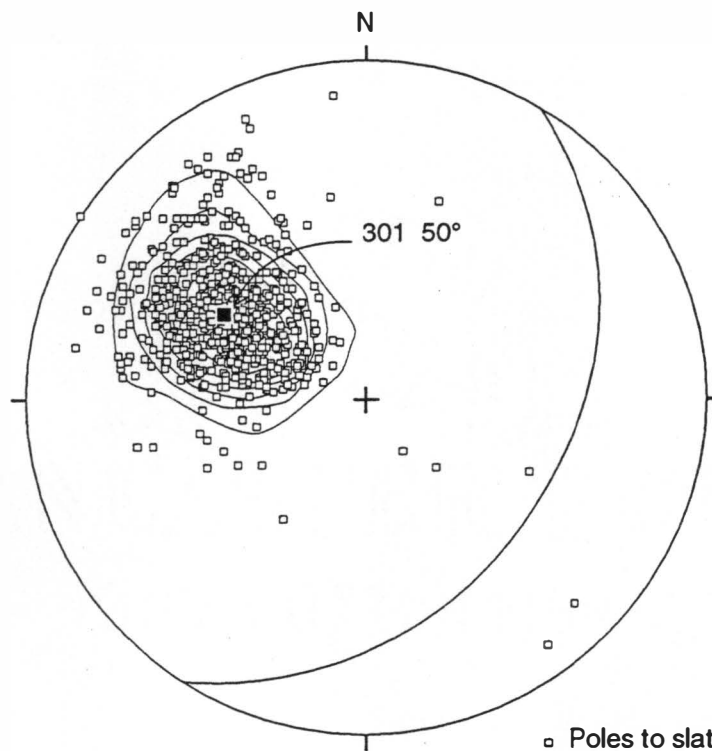
In the western half of the Miller Cove thrust sheet (Fig. III-8), microscopic examination indicates that S_2 consists of spaced pressure-solution selvages. In carbonate-rich rocks, dominant 0.01 mm- to 0.05 mm-thick selvages are oriented suborthogonal to bedding and contain residues of iron oxides and completely aligned clay minerals (Fig. III-11A). These selvages separate 0.1 mm- to 0.5 mm-thick, undeformed microlithons. Bedding-parallel, pressure-solution selvages containing insoluble residues (mostly iron oxides) exist, but are deformed and overprinted by the dominant S_2 selvages. In rocks containing less carbonate, no bedding-parallel, pressure-solution selvages exist, and strongly aligned recrystallized clays define 0.01 mm- to 0.5 mm-thick cleavage selvages that separate 0.02 mm- to 0.2 mm-thick microlithons. Accumulations of insoluble iron oxide locally occur along these clay-dominated cleavage selvages. Some clays within the microlithons are weakly oriented parallel to the selvages, but most are randomly oriented. Pressure-solution appears to dominate the formation of S_2 in

Figure III-10: Mesoscopic characteristics of slaty cleavage (S_2) in the Miller Cove thrust sheet.

(A) Slaty cleavage, 0.35 km (0.2mi) southeast of the confluence of Childers Creek and the Hiwassee River (station MCF 285), McFarland 7.5-minute quadrangle. Orientation of S_2 noted by black line. Hammer is 30 cm long. (B) Lower-hemisphere equal-area projection of 647 poles to slaty cleavage measurements. Contours represent 2, 4, 6, 8, 10, 12, 14, 16% per 1% area.

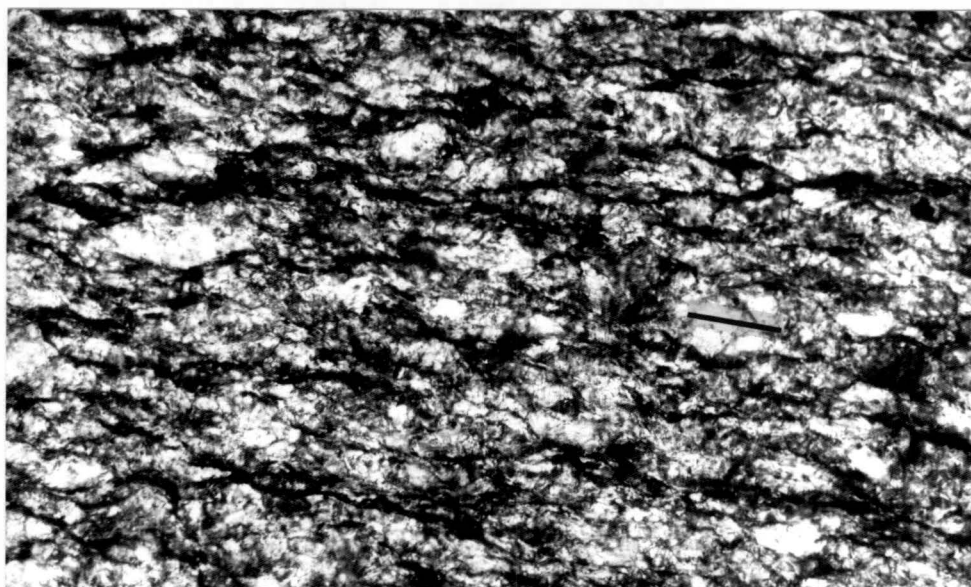


(A)

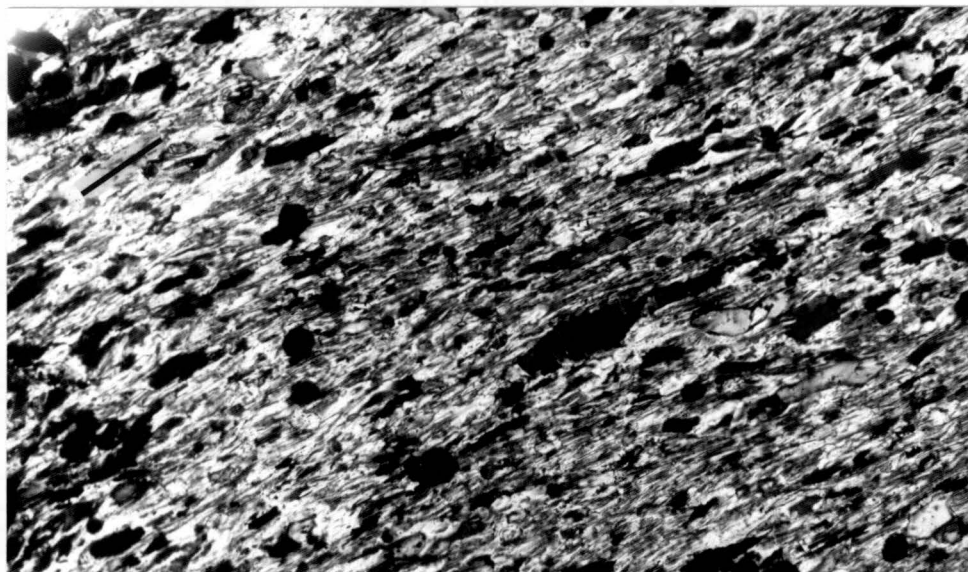


(B)

Figure III-11: Characteristic slaty cleavage (S_2) microstructures. (A) Photomicrograph (plane polarized light) of cleavage selvages separating less deformed microlithons in a calcareous siltstone, 150 m south of Towee Church (station MCF 1174), McFarland 7.5-minute quadrangle. Orientation of S_2 noted by black line. Field of view is 1 mm. (B) Photomicrograph (crossed nicols) of continuous slaty cleavage in Wilhite metasiltstone, Towee Creek (station MCF 1528), McFarland 7.5-minute quadrangle. Orientation of S_2 noted by black line. Field of view is 1 mm.



(A)



(B)

carbonate-rich rocks in the eastern half of the Miller Cove thrust sheet, but recrystallization of new micas as a cleavage-forming mechanism is apparently important in rocks lacking abundant carbonate.

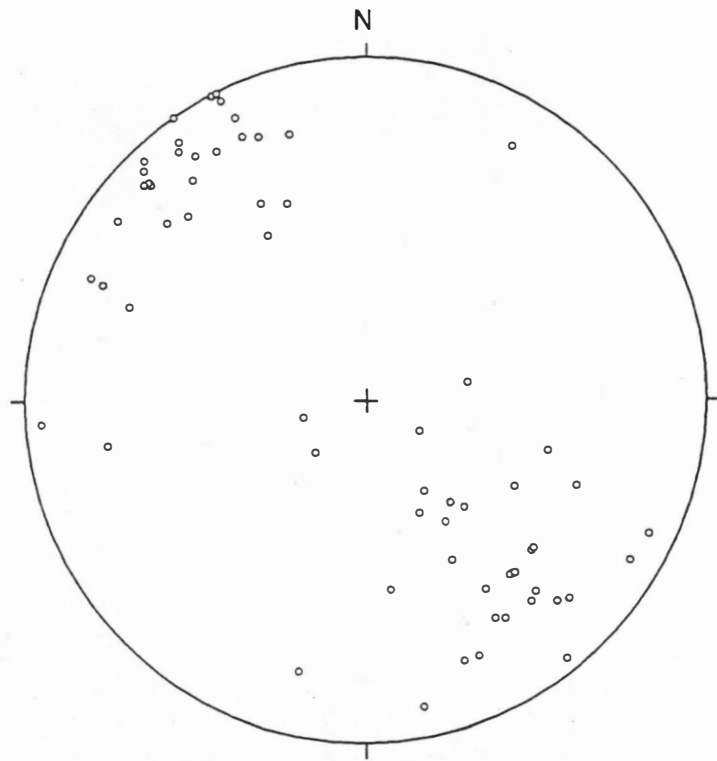
In the eastern half of the Miller Cove thrust sheet (Fig. III-8), S_2 intensifies and is continuous at all scales. Microscopic examination reveals that 0.02 mm- to 0.05 mm-thick cleavage selvages consist of uniformly aligned recrystallized clays. Recrystallized clays within 0.05 mm- to 0.5 mm-thick microlithons are also so very strongly oriented parallel to the cleavage selvages, obliterating microlithon boundaries (Fig. III-11B). Partially recrystallized quartz grains in siltier horizons are strongly oriented parallel to S_2 and may represent incipient transposition in these rocks. Recrystallized chlorite and pressure shadows around pyrite grains, consisting of face-controlled quartz and chlorite fibers, are developed locally and are also oriented parallel to S_2 . All vestiges of early pressure-solution (such as insoluble residues along cleavage selvages) are absent in rocks in the eastern half of the thrust sheet and recrystallization of new grains appears to be the predominant cleavage-forming mechanism.

Coarse-grained rocks of the Miller Cove thrust sheet were deformed by a mesoscopic spaced cleavage (Fig. III-8) that is interpreted to be related to S_2 . This spaced cleavage is well developed in clay-rich sandstone and granule conglomerate. The spaced cleavage appears as thin (< 1 mm-thick) clay-rich seams that anastomose around grains in coarser-grained lithologies. The grain-size dependent microlithons defined by these seams typically range from 1.0 cm to 1.0 dm thick. In outcrops where slaty cleaved fine-grained rocks are interbedded with coarser-grained lithologies, S_2 in the finer-grained rocks appear to be refracted through the coarser-grained lithologies along these spaced cleavage selvages. For this reason it is assumed that the spaced cleavage found in coarse-grained rocks of the Miller Cove thrust sheet is related to S_2 developed in finer-grained lithologies.

S_{2a} (Pressure-solution cleavage). Fine-grained rocks in the Miller Cove thrust sheet were deformed by secondary stylolitic disjunctive spaced cleavage (Fig. III-8). Where locally well preserved, this domainal *S_{2a}* cleavage mesoscopically appears as very thin (< 0.5 mm) dark bands that are spaced approximately 1.0 mm apart. *S_{2a}* generally dips southeast and northwest at moderate to high angles (Fig. III-12A). *S_{2a}* is strongly coherent, and rocks do not part along the cleavage surfaces. Microscopically, *S_{2a}* forms thin (0.1 mm to 0.3 mm) zones spaced 0.5 mm to 0.8 mm apart, and consists entirely of iron and titanium oxides and other insoluble heavy minerals (Fig. III-12B). The presence of these insoluble minerals along the cleavage selvages suggests that *S_{2a}* formed by pressure-solution mechanisms. Very commonly, *S_{2a}* is suborthogonal to *S₀* and appears not to be related to diagenesis. *S_{2a}* also overprints *S₂*. Commonly, the planarity of aligned clays within *S₂* selvages is disrupted by overprinting *S_{2a}* selvages, which locally anastomoses into domains up to 0.5 mm thick. Recrystallized clay minerals within these domains are reoriented parallel to the *S_{2a}* selvages. Locally, however, *S₂* selvages appear to deform *S_{2a}* selvages. These observations suggest that *S_{2a}* may have formed late in the development of *S₂* and continued after *S₂* formation ceased.

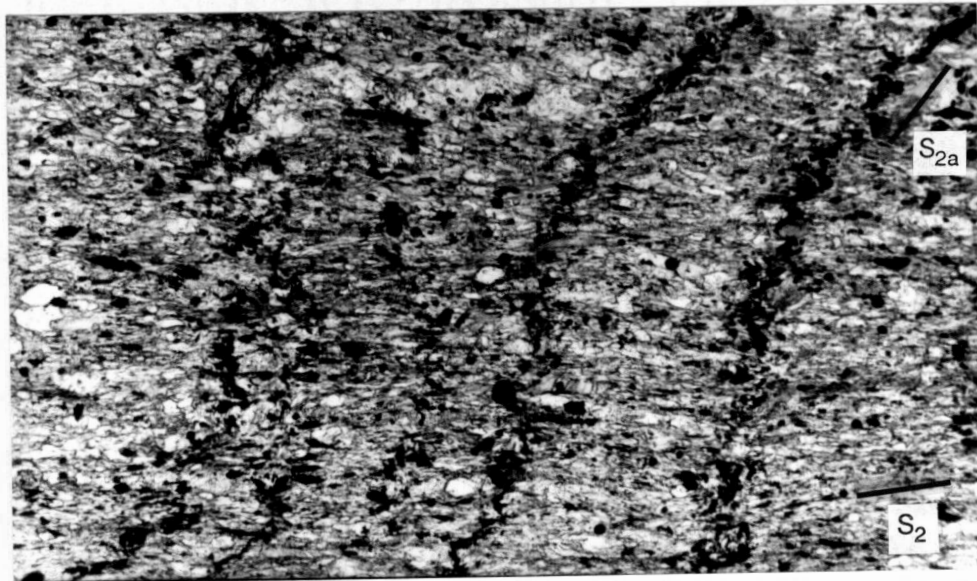
S₃ (crenulation cleavage). *S₃* is a zonal crenulation cleavage that is developed in fine-grained rocks of both the Miller Cove thrust sheet (Fig. III-8). *S₃* is also very locally present in two outcrops (stations MCF 419 and 420) (Plate II) approximately 300 m east of Ruckers Branch in the southeastern half of the Great Smoky thrust sheet (Fig. III-8). This zonal crenulation cleavage mesoscopically appears as widely spaced, thin (0.9 mm to 0.5 cm) zones or bands deforming *S₂*. Cohesion across these crenulation zones is strong and only after intense weathering do rocks preferentially part along cleavage surfaces. Axial surfaces of crenulations dip northwest at shallow to moderate angles (Fig. III-13A). Livingston (1978) recognized similarly oriented crenulations in Ocoee rocks along the Little Tennessee River to the north of the study area. Microscopically, these crenulations appear as buckled microfolds (Fig. III-13B)

Figure III-12: Meso- and microstructural characteristics of pressure-solution cleavage (S_{2a}) in the Miller Cove thrust sheet. (A) Lower-hemisphere equal-area projection of 63 poles to pressure-solution cleavage measurements. (B) Photomicrograph (plane polarized light) of S_{2a} defined by accumulation of heavy minerals in Wilhite Formation metasiltstone, Towee Creek (station MCF 1528), McFarland 7.5-minute quadrangle. Orientation of S_2 and S_{2a} noted by black lines. Field of view is 1.5 mm.



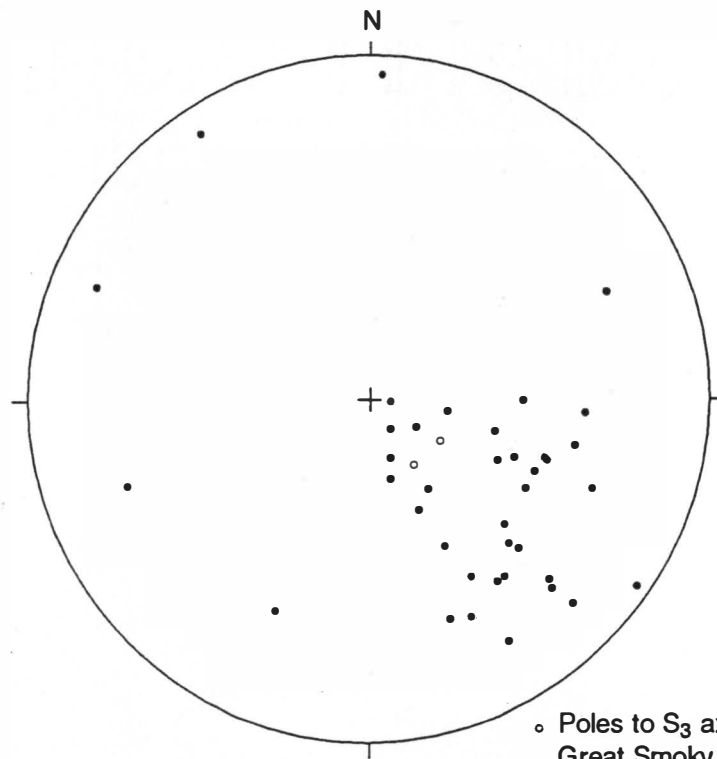
◦ Poles to pressure-solution cleavage

(A)



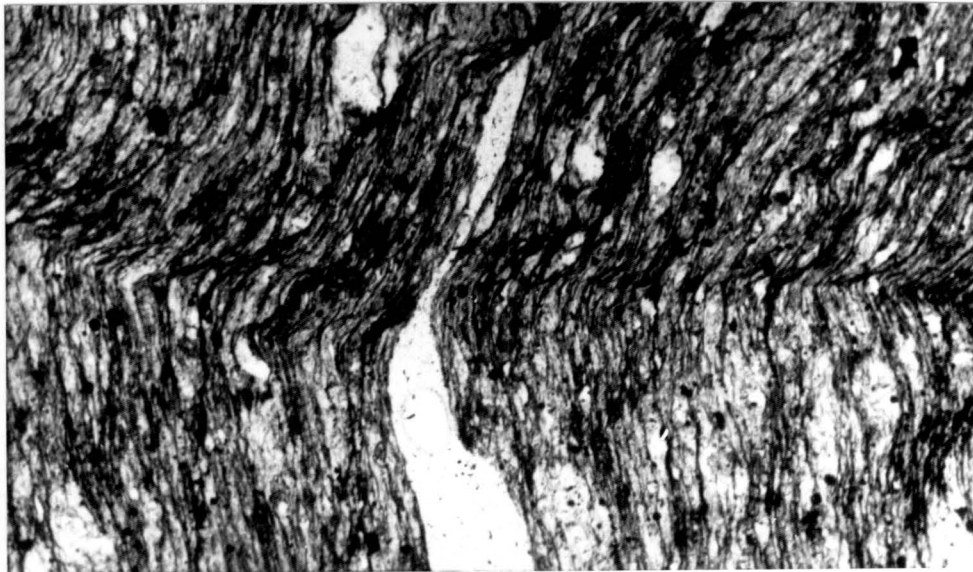
(B)

Figure III-13: Meso- and microscopic characteristics of crenulation cleavage (S_3) in the Miller Cove and Great Smoky thrust sheets. (A) Lower-hemisphere equal-area projection of 42 poles to S_3 axial surface measurements. (B) Photomicrograph (plane polarized light) of crenulation cleavage in Wilhite metasiltstone, Childers Creek (station MCF 1017), McFarland 7.5-minute quadrangle. Field of view is 1.5 mm.



(A)

- Poles to S_3 axial surfaces in the Great Smoky thrust sheet
- Poles to S_3 axial surfaces in the Maggie's Mill thrust sheet



(B)

(Gray, 1977; Gray and Durney, 1979). Clay minerals and micas forming S_2 selvages may have been mechanically rotated (folded) into the crenulation zone. Pressure-solution selvages (recognized by insoluble residues) within the short limb of the crenulations suggest pressure-solution may have also been important in the formation of S_3 .

Although S_3 clearly deforms preexisting S_2 , the relationship between S_{2a} and S_3 is less constrained because these two cleavages are rarely present in the same outcrop. Mesoscopic examination of outcrops approximately 120 m west of Witt Cemetery, McFarland 7.5-minute quadrangle (Plate I), reveals S_3 crenulations that overprint S_{2a} selvages, suggesting that at least locally, S_3 postdates S_{2a} . It is possible, however, that the regional formation of S_3 may have been at least partially coeval with S_{2a} development (see Tobish and Patterson, 1988). The relationship between S_3 and F_3 in the Miller Cove thrust sheet is not demonstrable, but it is reasonable to assume that S_3 and F_3 may have been coeval because of similar fold style (kinking) and orientation (northwest dipping) (compare figs. III-13A and III-6B).

Cleavage in the Great Smoky and Maggies Mill thrust sheets

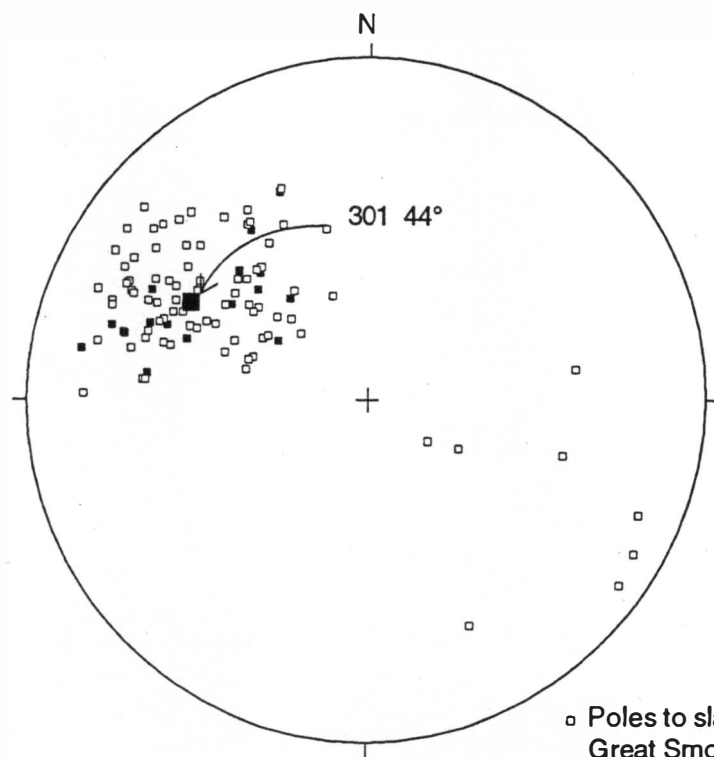
S_2 (*slaty cleavage*). S_2 is very locally developed in the Maggies Mill thrust sheet and in the southeastern half of the Great Smoky thrust sheet (Fig. III-8). S_2 development in these sheets is primarily a function of lithology; S_2 deforms only carbonate-rich shale and very fine-grained siltstone. In the Maggies Mill thrust sheet, micrite and calcareous shale is slaty cleaved, but siltier carbonates exhibit only a widely spaced (4.0 cm to 10.0 cm) cleavage. In the southeastern half of the Great Smoky thrust sheet, S_2 is very locally developed in carbonate-rich shale and very fine-grained siltstone. Elsewhere in the southeastern half of the thrust sheet, fine-grained rocks are deformed by a moderate to strong (Alvarez and others, 1978) spaced cleavage. S_2 is axial-planar to F_2 folds in this area. Spaced cleavage is also axial-planar to some (F_2 ?) folds, suggesting it may be related (a lower metamorphic grade equivalent?) to S_2 .

S_2 in the Maggie's Mill and Great Smoky thrust sheets is mesoscopically similar to slaty cleavage (S_2) in the Miller Cove thrust sheet. Cohesion is weak across S_2 and weathering produces flat chips that are thicker (about 1.0 cm) and larger in surface area (about 100 cm²) than chips in the Miller Cove thrust sheet. S_2 generally dips toward the southeast (031, 46°S) (Fig. III-14A), but minor dispersion of this orientation may have been produced by rotation accompanying later faulting. Microscopically, S_2 consists of spaced pressure-solution selvages (Fig. III-14B). These 0.02 mm-thick selvages contain residues of iron oxide and weakly aligned clay minerals, but no deformation is recorded within 0.3 mm- to 0.5 mm-thick microlithons. The primary mechanism of cleavage formation in this area appears to be pressure-solution.

Spaced cleavage (S_{3a}) in the Great Smoky thrust sheet. Spaced cleavage deforms rocks in the western half of the Great Smoky thrust sheet (Fig. III-8). Siltstone fissility of roughly similar intensity along both bedding and spaced cleavage selvages produces pencil structures (Engelder and Geiser, 1979; Reks and Gray, 1982; Ramsay and Huber, 1983) (Fig. III-15A). Pencil dimensions are proportional to bed thickness and microlithons between the spaced cleavage selvages. These pencils are typically about 2 cm wide and 15 cm to 20 cm long, but strongly coherent siltstone can produce pencil structures up to 1.0 m long. The spaced cleavage that influences the development of pencil structures dips predominantly southeast (Fig. III-15B).

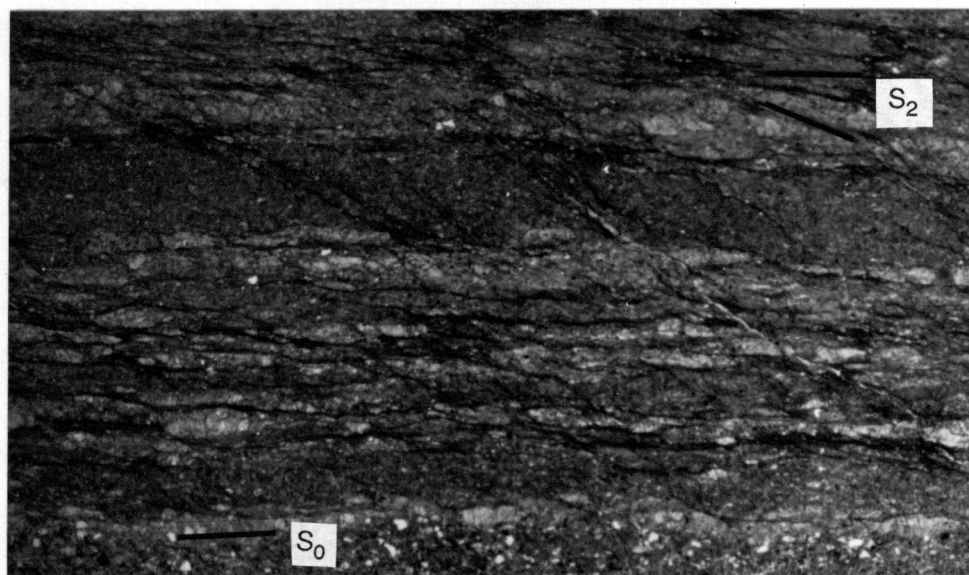
Pencils are nonexistent along the western edge of the study area (Fig. III-8). This apparent easterly intensification may be dependent primarily upon lithology. Where pencils are well developed in the Great Smoky thrust sheet, a thick section of thinly bedded siltstone dominates, yielding a region conducive to the formation of pencils. Along the western edge of the study area, however, thickly bedded sandstone and conglomerate inhibit pencil development. Where thick sections of finer-grained shale occur in this area (such as the Nichols Shale), a weak spaced cleavage is locally present.

Figure III-14: Meso- and microstructural characteristics of slaty cleavage (S_2) in the Great Smoky and Maggie's Mill thrust sheets. (A) Lower-hemisphere equal-area projection of 104 poles to slaty cleavage measurements. (B) Photomicrograph (plane polarized light) of two orientations of pressure-solution selvages in calcareous siltstone, 0.12 km southeast of Maggie's Mill (station MCF 1078), McFarland 7.5-minute quadrangle. Orientations of bedding (S_0) and pressure-solution selvages (S_2) noted by black lines. Field of view is 12 mm.



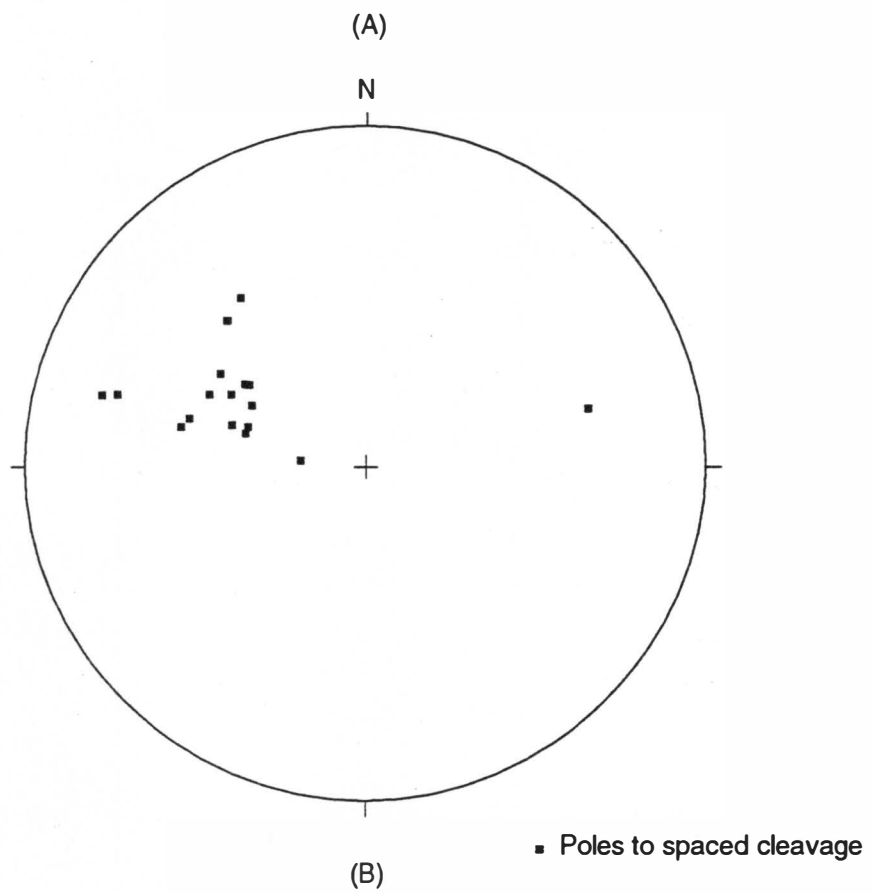
(A)

- Poles to slaty cleavage in the Great Smoky thrust sheet
- Poles to slaty cleavage in the Maggies Mill thrust sheet
- Mean vector to slaty cleavage



(B)

Figure III-15: Characteristic mesoscopic spaced cleavage (S_{3a}) structures in the Great Smoky thrust sheet. (A) Pencil structures, Long Ford (station MCF 1031), McFarland 7.5-minute quadrangle. Hammer is 30 cm long. (B) Lower-hemisphere equal-area projection of 17 poles to pencil forming spaced cleavage measurements.



The relationship between spaced cleavage in the western half of the Great Smoky thrust sheet and cleavage to the east is uncertain. This spaced cleavage is oriented similar to S_2 farther east, but Williams (1970) concluded that orientation should not be used to correlate generations of structures. The relationship between spaced cleavage and fold axial surfaces in this area was not observed. Spaced cleavage may be related to S_2 (a lower metamorphic grade equivalent?), but it is probably related to regional postmetamorphic faulting and F_3 folds which dominate the thrust sheet.

Spaced cleavage (S_{3a}) in the Bullet Mountain thrust sheet

Weak to strong spaced cleavage (Alvarez and others, 1978) also deforms siltstone and shale of the Rome Formation in the Bullet Mountain thrust sheet (Fig. III-8). Spacing is dependent on bed thickness and lithology. In thin shale horizons, cleavage selvages are spaced about 1.0 cm to 3.0 cm apart, but in thicker, siltier beds, cleavage spacing is more than 20.0 cm. Rocks deformed by this cleavage preferentially part along these surfaces, and poorly developed pencil structures (measuring less than 3.0 cm X 1.0 cm X 1.0 cm) are locally common in fissile shale (Fig. III-16A). Mesoscopic fabric analysis (Fig. III-16B) reveals no significant trends in orientation.

The relationship between spaced cleavage in the Bullet Mountain thrust sheet to cleavage in the western Blue Ridge thrust sheets is uncertain. The Bullet Mountain thrust sheet is dominated by F_3 folds formed possibly during regional thrusting, but spaced cleavage transects these structures. Spaced cleavage may have formed during the waning stages of thrusting, after the development of fault related folds.

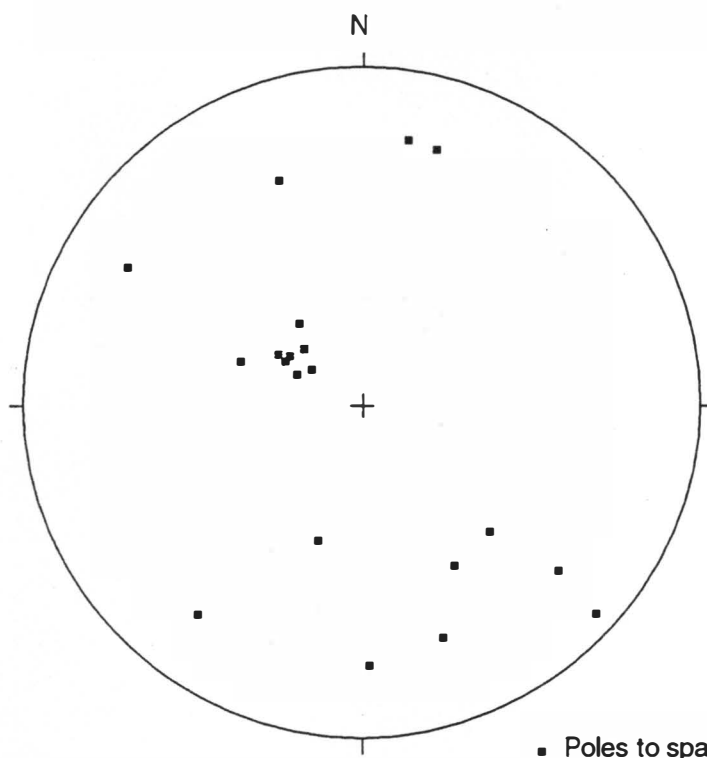
Faults

Four major faults are exposed in the study area and juxtapose rocks of different age and metamorphic grade: the Great Smoky, Bullet Mountain, Miller Cove, and Maggies Mill faults

Figure III-16: Mesoscopic characteristics of spaced cleavage (S_{3a}) in the Bullet Mountain thrust sheet. (A) Spaced cleavage in Rome Formation shale, Rural Vale (station MEC 123), Mecca 7.5-minute quadrangle. Orientation of bedding (S_0) and spaced cleavage (S_{3a}) noted by black lines. Hammer is 30 cm long. (B) Lower-hemisphere equal-area projection of 20 poles to spaced cleavage measurements.



(A)



(B)

(Figure III-1; Plate I). The Great Smoky fault is the most regionally significant of these structures because it emplaced metamorphosed Lower Cambrian and Precambrian rocks of the western Blue Ridge over unmetamorphosed Paleozoic rocks of the Valley and Ridge. It is locally the frontal Blue Ridge fault. North of and beneath the Great Smoky fault, the Bullet Mountain fault juxtaposes unmetamorphosed Lower Cambrian rocks (Shady Dolomite and Rome Formation) against younger Paleozoic rocks. The Bullet Mountain fault may be the floor fault of the southern continuation of the Foothills duplex, first recognized in the coves region of the Great Smoky Mountains National Park (Hatcher and others, 1989a), the floor of a different duplex, or may be an exposed slice of the frontal Blue Ridge fault system (McKinney, 1964). The Miller Cove fault is also regionally important because it juxtaposes chlorite grade Wilhite Formation rocks against lower grade (anchizone) rocks of the Sandsuck Formation. The Maggies Mill fault, previously mapped as the Sylco Creek and Miller Cove faults (Rodgers, 1953; Wiener and Merschat, 1992), separates the lower Sandsuck Formation from the upper members Sandsuck Formation and the Chilhowee Group sequence.

Great Smoky Fault

Throughout the southern Appalachians, rocks of the Blue Ridge province are separated from those in the Valley and Ridge province by the Blue Ridge frontal fault system (King, 1955; Hatcher and Butler, 1979). In southeastern Tennessee, the frontal Blue Ridge fault is the Great Smoky fault, which extends southwards about 116 km (78 mi) from Chilhowee Mountain to Bean Mountain (Rodgers, 1953; Hardeman, 1966) (Figs. I-1; I-2). The Great Smoky fault juxtaposes anchizone rocks of the Sandsuck Formation and Chilhowee Group against unmetamorphosed rocks of the Shady Dolomite, Rome Formation, Conasauga and Knox Groups, and Athens Shale (Rodgers, 1953; McKinney, 1964; Hardeman, 1966).

The Great Smoky fault is traceable throughout the northeastern part of the study area where it rims a broad valley (Plate I). Exposures of the fault are poor to nonexistent, but the

trace is easily mapped by the juxtaposition of light brown siltstone and coarser-grained rocks of the Sandsuck Formation against maroon red siltstone of the Rome Formation or Knox Group carbonates that floor the valley. These Paleozoic rocks crop out beneath the Great Smoky fault in a reentrant (referred to hereafter as the Conasauga reentrant) into the gently arched Great Smoky thrust sheet. On the northwest side of this reentrant, the fault dips about 8° to 10° to the northwest. Along the southern end of the Conasauga reentrant, the fault dips about 25° southeast.

The Great Smoky fault is interpreted as a thin-skinned, postmetamorphic brittle structure from several lines of evidence: 1) The low-angle nature of the Great Smoky fault in the vicinity of the Conasauga reentrant in southeastern Tennessee, and in the Coves region north of the Little Tennessee River. 2) No basement rocks are presently exposed at the surface within the frontal Great Smoky thrust sheet. 3) Metamorphosed rocks in the hanging wall are juxtaposed against unmetamorphosed rocks in the footwall, indicating faulting and transport of the Great Smoky thrust sheet took place after the regional metamorphic event. 4) Exposures of the Great Smoky fault and adjacent country rocks throughout the region show only brittle deformation (Neuman, 1951; Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; McKinney, 1964; Neuman and Nelson, 1965; Wiener and Mersch, 1978).

Estimates of the amount of displacement along the Great Smoky fault vary widely, from 32 km (20 mi) (Keith, 1927; King, 1964) to 500 km (310 mi) (Hatcher, 1989; Hatcher and others, 1989b; Hatcher and Goldberg, 1991). In the vicinity of the study area, stratigraphic comparison between footwall and hanging wall sequences and direct field evidence (i.e. Calderwood window) provide minimum estimates of 5,400 m (17,750 ft) of stratigraphic throw and approximately 10 km (6 mi) of dip-slip displacement along the fault. The Great Smoky fault probably utilized shale beds in the Sandsuck Formation as flats while ramping through stronger sandstone and conglomerate units as it propagated out of the Ocoee basin into carbonate platform strata on the continental margin (Hatcher and others, 1989b) (Plate III).

Although the Great Smoky fault is nowhere well exposed in the study area, exposures of the fault are present in roadcuts approximately 0.8 km (0.5 mi) southeast of White Cliff, Mecca 7.5-minute quadrangle. Other exposures of the Great Smoky fault in the study area are located in a small stream valley south of Webb Branch, approximately 1.0 km (0.6 mi) southwest of Rural Vale Church, and along an unnamed tributary of Dry Creek, approximately 1.9 km (1.1 mi) west of Black Mountain, Mecca 7.5-minute quadrangle.

Structure beneath the Great Smoky thrust sheet. Structure beneath the Great Smoky thrust sheet is interpreted from seismic data (Cook and others, 1983). Seismic data suggests that a major structure, probably the Saltville fault, ramps from a deeper detachment level above Grenville basement beneath the western Blue Ridge frontal thrust sheets in southeastern Tennessee (Plate III). The basal detachment of this fault is interpreted to be the base of the Rome Formation. The fault may have ramped from the Rome Formation through the stronger carbonates of the Conasauga and Knox groups into weaker shale and siltstone of the Sevier Shale [Chickamauga Group]. Seismic profiling also indicates northwest dipping structures at depth near the eastern edge of the study area. These structures are interpreted to be the southern continuation of the Foothills duplex which is exposed to the northeast in the coves region of the Great Smoky mountains. Horse blocks of the Foothills duplex in southeastern Tennessee may consist of stronger carbonates of the Conasauga and Knox groups as well as a thin veneer of Sevier Shale [Chickamauga Group]. Imbricated rocks of the Knox Group and Sevier Shale are exposed in the coves beneath the folded Great Smoky fault (King, 1964; Neuman and Nelson, 1965; Livingston, 1978; Hatcher and others, 1989a). The western Blue Ridge thrust sheets in southeastern Tennessee may also have been gently folded and arched upward during imbrication and duplexing of the footwall strata (Plate III).

Bullet Mountain fault

The Bullet Mountain fault extends approximately 27 km (16.5 mi) south from the vicinity of Tariffville, Tennessee (approximately 18 km northeast of Tellico Plains, Tennessee) into the Conasauga reentrant in the study area where it is truncated by the Great Smoky fault 0.7 km (0.4 mi) southeast of White Cliff, Mecca 7.5-minute quadrangle (Plate I). Rocks of the Rome Formation are thrust over upper Conasauga and Knox Group rocks along the trace of the Bullet Mountain fault (Rodgers, 1953; McKinney, 1964; Hardeman, 1966). Although exposures of the fault in the study area are poor, the trace can be mapped on the basis of juxtaposing maroon red siltstone of the Rome Formation against tan to light brown shale of the upper Conasauga Group. The trace of the fault through the Conasauga reentrant suggests that it dips approximately 30° southeast. McKinney (1964) estimated a dip of 30° to 40° to the southeast on the fault immediately north of the study area. The Bullet Mountain fault is also interpreted as a brittle structure because both the footwall or hanging wall rocks lack ductile deformation features.

McKinney (1964) suggested that the Bullet Mountain fault is a splay of the Great Smoky fault system. McKinney (1964) concluded that the Bullet Mountain fault bounds an intermediate slice of footwall rocks that were transported westward beneath the overriding Great Smoky fault. This interpretation is supported by the observation that the Bullet Mountain fault is truncated by the Great Smoky fault along the northwestern side of the Conasauga reentrant.

The Bullet Mountain thrust sheet may have been duplexed as it was transported beneath the Great Smoky thrust sheet. The Bullet Mountain fault may be the floor fault to this subthrust duplexed slice (Plate III). In the vicinity of the study area, rocks of the Shady Dolomite and Rome Formation are exposed beneath the Great Smoky fault within the northern part of the Bullet Mountain thrust sheet. South of the Hiwassee River, imbricate slices of the Shady Dolomite, Rome Formation, and Conasauga Group reappear from beneath the Great

Smoky thrust sheet in front of Bean Mountain as part of the Harrison Mill fault system (Rodgers, 1953) (Fig. III-2). These faults are interpreted to be the southern continuation of the Bullet Mountain duplex. The amount of displacement along the Bullet Mountain fault is unknown.

Miller Cove fault

The Miller Cove fault has been recognized for many years as a major structure in the western Blue Ridge (King, 1964, Neuman and Nelson, 1965). The Miller Cove fault is distinguished from other prominent western Blue Ridge faults because it is the westernmost fault to emplace chlorite and higher-grade cleaved rocks at the surface. For this reason, the Miller Cove fault is interpreted to be a basement fault (Hatcher and others, 1989b) which decapitates regional synmetamorphic folds in cross section (Plate III). The system of faults that comprise the Miller Cove fault family extends discontinuously approximately 250 km (167 mi) from northwest of English Mountain to the Cartersville District in northwestern Georgia (Costello, 1984; Hatcher and others, 1989b) (Fig. I-1).

The Miller Cove fault in and near the study area was previously mapped as the northern continuation of Salisbury's (1961) Alaculsy Valley fault (Wiener and Mersch, 1992) (Figs. I-1; III-2). In northern Georgia, the Alaculsy Valley fault clearly separates deformed rocks in the hanging wall from less deformed rocks in the footwall (Salisbury, 1961). In the study area, a similar structural relationship is observed across the Miller Cove fault. Footwall rocks (e.g., rocks in the Maggie's Mill and Great Smoky thrust sheets) are metamorphosed to anchizone and the dominant S-surface is spaced cleavage (S_{3a}), although fine-grained calcareous rocks are locally deformed by continuous (slaty) cleavage (S_2) and crenulation cleavage (S_3). In the hanging wall of the Miller Cove fault, however, rocks are metamorphosed to chlorite grade and the dominant S-surface is continuous (slaty) cleavage (S_2) which deforms all fine-grained lithologies. Spaced (pressure-solution) cleavage (S_{2a}) and crenulation cleavage

(S₃) also deforms hanging wall rocks. Similar metamorphic and structural discontinuities were noted by Neuman and Nelson (1965) across the Miller Cove fault in Miller Cove north of the study area.

The Miller Cove fault is well exposed in several places along its trace within the study area, but where not well preserved, the fault is easily mapped on the basis of contrasting lithologies and rock fabrics (i.e., slaty cleaved rocks in the hanging wall versus comparatively uncleaved rocks in the footwall). The fault trace generally occupies the floor of Childers and Steer creeks, except where post-thrust folding or imbricating has contorted the fault surface. Observation of this fault surface as well as the topographic expression of the fault trace indicates the Miller Cove fault variably dips 15° to 30° southeast. Shallow and steeper angles are locally observed where the fault is imbricated or folded.

Wiener and Mersch (1978) tenuously suggested that the Alaculsy Valley fault in southeastern Tennessee and northwestern Georgia is a premetamorphic structure analogous to the Dunn Creek and Line Springs faults in the Great Smoky Mountains region, but cited no conclusive evidence. Woodward and others (1991) interpreted axial-planar cleavage, folds, and minor ductile thrust faults within the Miller Cove thrust sheet in the Great Smoky Mountains region to be related to ductile body deformation within a moving thrust sheet after Mitra and Elliot (1980) and concluded that the Miller Cove fault is a multiphase structure with both a ductile pre- to synmetamorphic and brittle post-metamorphic history of movement. Although cleavage development within a moving thrust sheet has been well documented (Mitra and Elliot, 1980; Marshak and Engelder, 1985), observations of well-exposed sections of the Miller Cove fault in the study area suggest that the fault is a postmetamorphic brittle structure.

Mesoscopically, several lines of evidence suggest that the Miller Cove fault is a postmetamorphic brittle structure in the study area: 1) structural and metamorphic discontinuities as previously described exist across the fault. 2) Direct mesoscopic observation of imbricates approximately 0.65 km (0.4 mi) west of Hankins Mountain, McFarland 7.5-minute

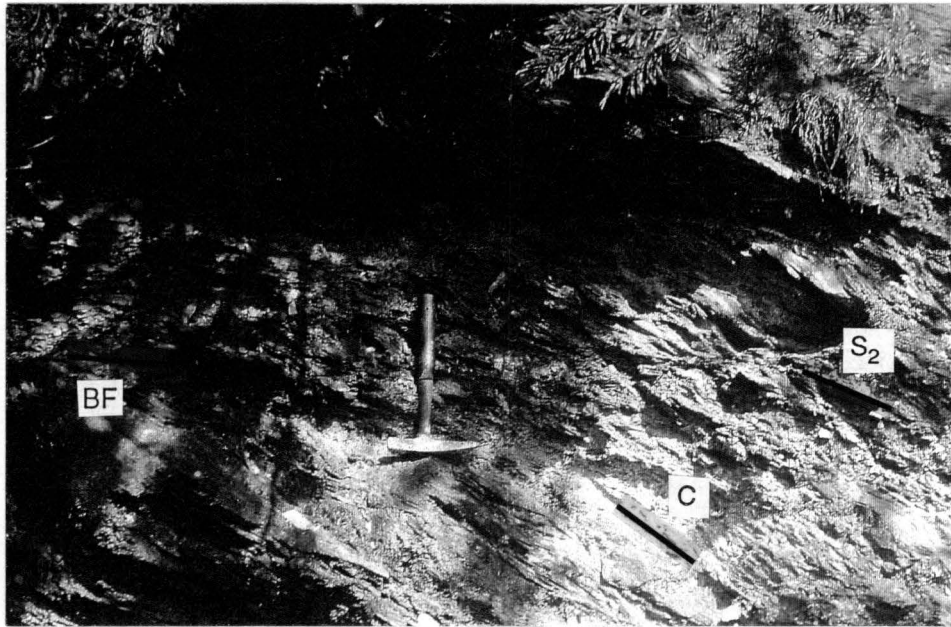
quadrangle (Plate I) reveals gouge zones and discrete crenulations (Gray, 1977; 1979) (oriented suborthogonal to gouge zones) that clearly transect preexisting continuous (slaty) cleavage (S_2) (Fig. III-17A). 3) Slickenlines are observed on minor fault surfaces within the Miller Cove fault zone approximately 0.7 km (0.42 mi) northeast of the confluence of Childers Creek and the Hiwassee River, McFarland 7.5-minute quadrangle (Plate I).

Microstructures within the Miller Cove imbricate zone west of Hankins Mountain (McFarland 7.5-minute quadrangle) include highly strained and partially recrystallized quartz within folded quartz veins and discrete and zonal crenulations that are axial-planar to these microfolds (Fig. III-17B). Meso- and microstructural crosscutting relationships suggest that slaty cleavage developed prior to veining, microfolding, and axial-planar crenulations. Gouge zones crosscut all preexisting structures.

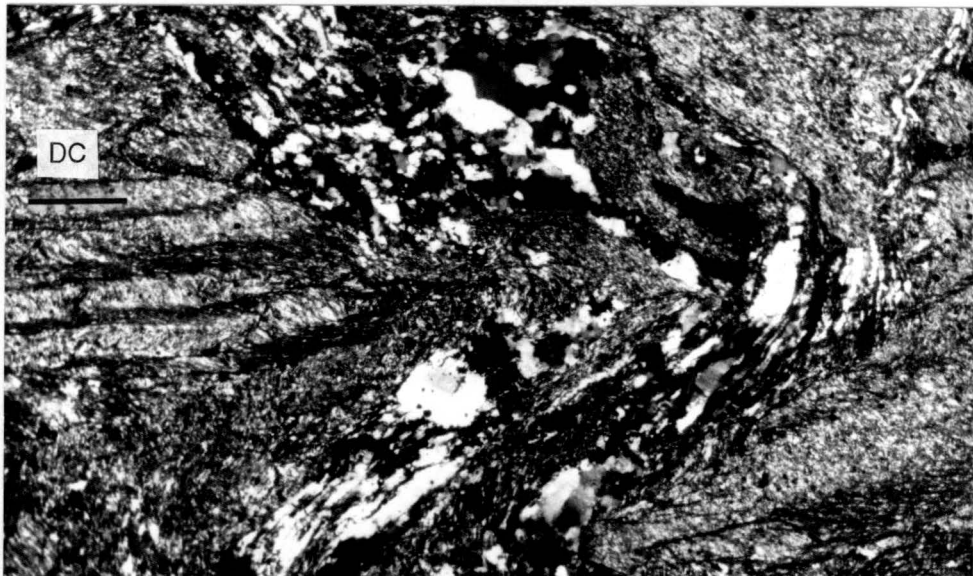
The highly strained nature of the quartz and discrete crenulations within the fault zone may be interpreted as the result of ductile deformation during thrusting. In this interpretation, ductile thrusting was coeval to cleavage development within the Miller Cove thrust sheet (Woodward and others, 1991) (Fig. III-18A). Overprinting gouge zones may represent later reactivation along the preexisting ductile fault.

Alternatively, the Miller Cove fault may be wholly a younger brittle structure that propagated through predeformed strata rather than a reactivated ductile fault. Slaty cleavage in the Miller Cove thrust sheet probably did not form above a ductile fault. Cleaved rocks at the surface are interpreted to be transposed and metamorphosed to higher metamorphic grades at depth. The premetamorphosed and deformed terrane was subsequently brittlely deformed and transported to the surface along the Miller Cove fault (Fig. III-18B). This interpretation implies that microfolds and discrete crenulations may have formed by buckling with flexural-slip and pressure-solution mechanisms in response to increased strain within the zone of failure prior to brittle faulting. Meso- and microstructural crosscutting relationships previously described lend some support for this alternative hypothesis.

Figure III-17: Miller Cove fault fabrics. (A) Brittle faults and discrete crenulations transecting slaty cleavage (S_2) in the Miller Cove fault zone, Hicks Branch (station MCF 1231), McFarland 7.5-minute quadrangle. Orientation of brittle faults (BF), crenulations (C) and S_2 noted by black lines. Jacob staff is 1.5 m long. (B) Photomicrograph (crossed nichols) of microfolds and discrete crenulations (DC - noted by black line) in the Miller Cove fault zone, Hicks Branch (station MCF 1223), McFarland 7.5-minute quadrangle. Field of view is 4 mm.



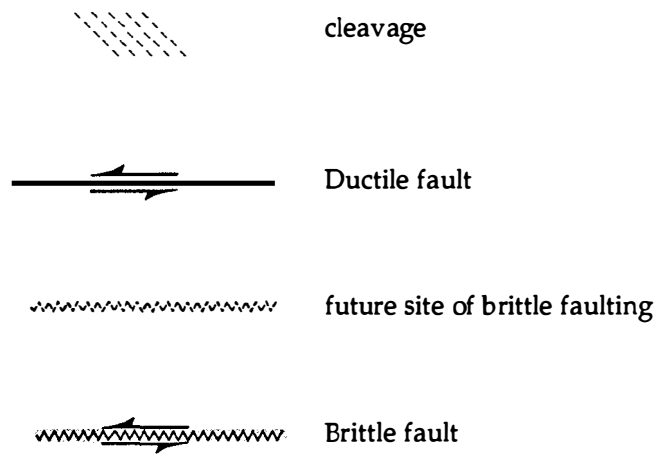
(A)

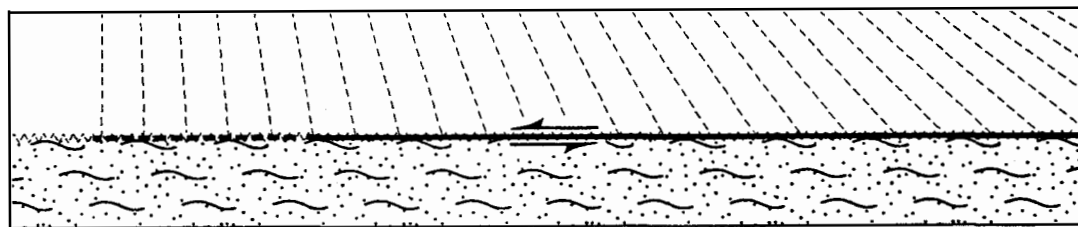


(B)

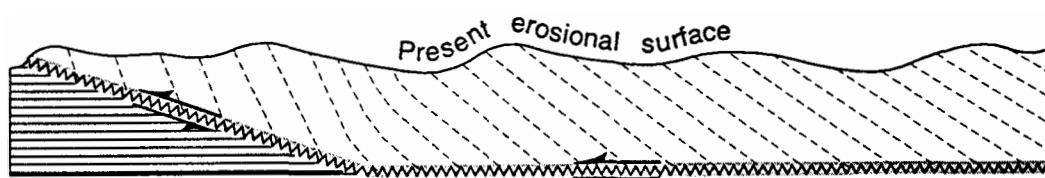
Figure III-18: Alternative interpretations for the development of the Miller Cove fault. (A) Ductile thrusting and coeval cleavage development within the "early" Miller Cove thrust sheet (T1) followed by later brittle reactivation (T2). (B) A premetamorphosed and deformed terrane (T1) was brittily deformed and transported along the Miller Cove fault (T2).

Explanation



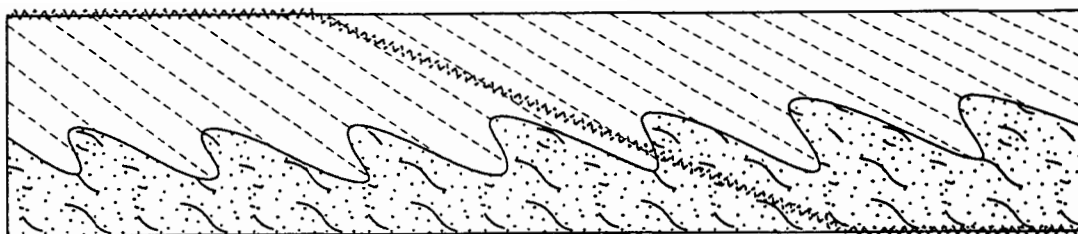


T_1

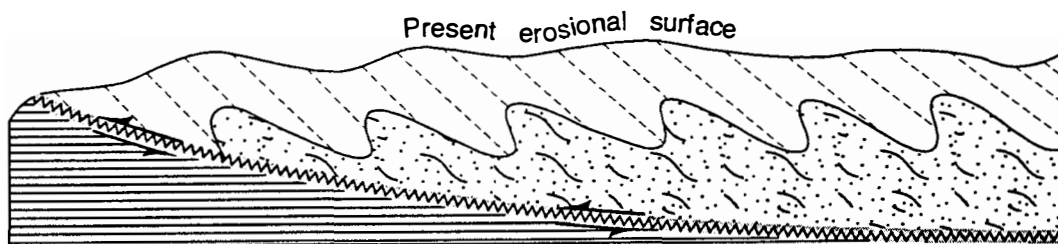


T_2

(A)



T_1



T_2

(B)

The lack of correlative lithologic markers across the Miller Cove fault prevents the determination of the amount of stratigraphic throw in the study area. The amount of horizontal displacement is also difficult to estimate. The observation that the Miller Cove fault juxtaposes slaty cleaved chlorite grade rocks in the hanging wall from less cleaved anchizone rocks in the footwall suggests at least 5.0 km of vertical displacement along the fault to account for these differences in metamorphic grade. Lateral displacement along the Miller Cove fault in the study area, therefore, is interpreted to be more than 10.0 km.

Maggies Mill fault

The Maggies Mill fault, previously mapped as the Sylco Creek fault (Rodgers, 1953) and the Miller Cove fault (Wiener and Mersch, 1992), juxtaposes anchizone rocks of the lower and middle members of the Sandsuck Formation. The Maggies Mill fault enters the Mecca 7.5-minute quadrangle 0.67 km (0.4 mi) northeast of Webb Branch and has been mapped for approximately 17 km (10.5 mi) southwest to the Hiwassee River, 0.5 km (0.3 mi) northwest of Reliance, Tennessee, Oswald Dome 7.5-minute quadrangle (Plate I). Reconnaissance mapping by Wiener and Mersch (1992) suggests that the Maggies Mill fault may continue southward and join with Sutton's (1971) Indian Creek fault southeast of Bean Mountain south of the Ocoee River (Fig. III-2).

Detailed mapping revealed two important lithologic and structural characteristics of the Maggies Mill fault in the study area. First, lithologic similarities exist between the footwall and hanging wall. Quartz arenite, dominant in the lower member of the Sandsuck Formation in the hanging wall, is also present in the footwall as lenses and channels interbedded with siltstone of the middle member. Secondly, no structural or metamorphic discontinuities exist across the fault. Anchizone rocks with similar cleavage morphology and intensity occur in both the hanging wall and footwall.

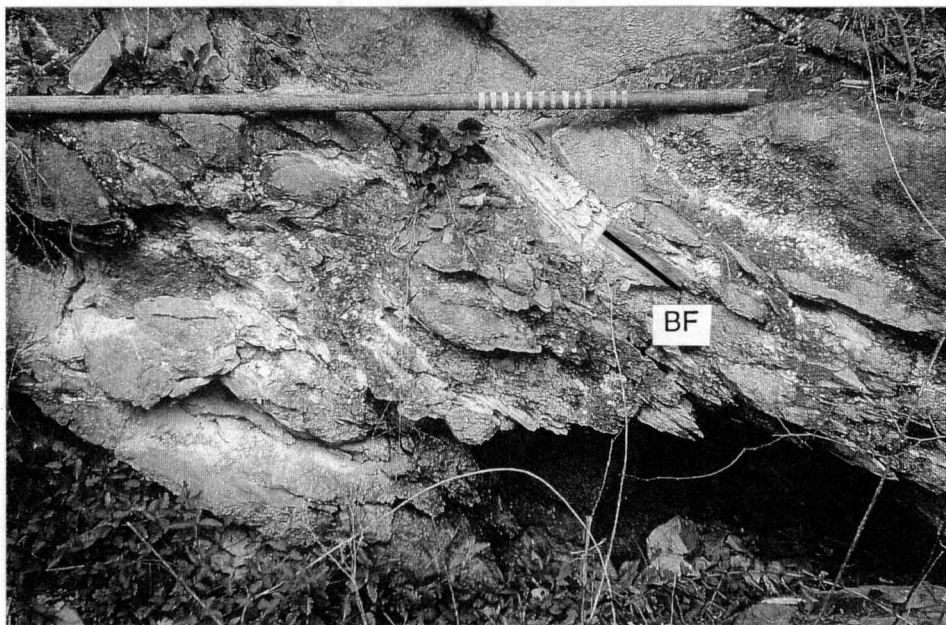
Meso- and microstructures suggest that the Maggies Mill fault is a postmetamorphic brittle fault. Although metamorphic grade is continuous across the structure, minor brittle faults delineate the fault zone on the northeastern bank of the Hiwassee River, 0.3 km (0.2 mi) northwest of Reliance, Tennessee, Oswald Dome 7.5-minute quadrangle (Plate I; Fig. III-19A). Approximately 3 km (1.9 mi) to the northeast, microscopic examination reveals that the fault zone consists of a well preserved brittle cataclasite (Fig. III-19B) northwest of Perrys Branch (station MCF 4) (Plate II).

Exposures of the fault are generally poor, especially in the northeastern half of the study area, but the fault is mapped on the basis of differing footwall and hanging wall stratigraphy. To the north, siltstone and shale of the middle member of the Sandsuck Formation in the footwall contrasts with coarser-grained sandstone and conglomerate of the lower member in the hanging wall. Southward, the fault is recognized by a prominent sandstone and conglomerate horizon in the hanging wall that is juxtaposed against shale in the footwall. Fault exposures and topographic expression of the fault trace reveal a 25° southeastern dip along the southern portion of the Maggies Mill fault, but northern portions of the fault may dip up to 40° southeast.

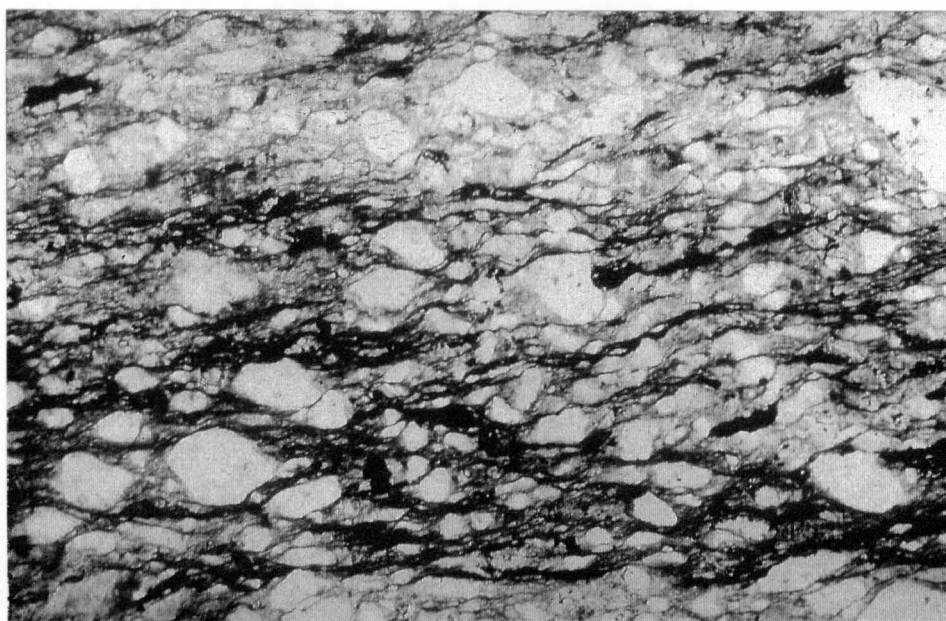
Three interpretations are possible for the formation of the Maggies Mill fault and the amount of displacement along the structure in the study area. The Maggies Mill fault may be an imbricate of the Miller Cove fault, a slice of the Miller Cove fault, or an imbricate of the Great Smoky fault. Both imbricate models negate the possibility of large lateral displacements along the Maggies Mill fault. The slice hypothesis, however, suggests that the Maggies Mill fault may have as large a lateral displacement as the Miller Cove fault.

For the Maggies Mill fault to be an imbricate of the Miller Cove fault, one would assume lithologic and structural similarities between the footwall and hanging wall of the Miller Cove fault, but none exist in the study area. The Miller Cove fault juxtaposes chlorite grade slaty cleaved rocks in the hanging wall against anchizone rocks that are less cleaved in

Figure III-19: Maggies Mill fault fabrics. (A) Brittle faults in the Maggies Mill fault zone, 0.3 km (0.2 mi) northwest of Reliance, Tennessee (station OD 17), Oswald Dome 7.5-minute quadrangle. Orientation of brittle faults (BF) noted by black line. Jacob staff is 1.5 m long. (B) Photomicrograph (plane polarized light) of Maggies Mill fault zone cataclasite, Perrys Branch (station MCF 4), McFarland 7.5-minute quadrangle. Field of view is 4 mm.



(A)



(B)

the footwall (e.g., the Maggies Mill thrust sheet). There are also no lithologic similarities between the footwall and hanging wall of the Miller Cove fault.

The hypothesis that the Maggies Mill thrust sheet is a slice beneath the Miller Cove fault is also problematic. This interpretation assumes that lenses and channels of quartz arenite in the footwall of the Maggies Mill fault are laterally equivalent to massive beds of quartz arenite in the hanging wall, rather than vertically gradational as previously interpreted in this thesis. Supporting evidence for this assumption is lacking. Furthermore, the Maggies Mill thrust sheet is laterally extensive (>17 km), consists of easily discernible stratigraphy, and preserves broad, map-scale structures such as the Pond Mountain syncline. This is unlike other recognized slices along the frontal fault zone in the region which are smaller and usually consist of indistinguishable and complexly deformed stratigraphy (Wiener and Merschat, 1978).

Field evidence supports the third interpretation that the Maggies Mill fault is an imbricate of the Great Smoky fault. Quartz arenite is present in both the footwall and hanging wall of the Maggies Mill fault, suggesting that the footwall is lithologically similar to the hanging wall. Rocks in the Maggies Mill thrust sheet are also similar to footwall rocks in metamorphic grade (anchizone), cleavage morphology, and cleavage intensity. These lithologic and structural relationships would be expected if the Maggies Mill fault is an imbricate of the Great Smoky fault. Other imbricates of the Great Smoky fault such as the Gee Creek fault (Rodgers, 1953; Hardeman, 1966) deform Chilhowee Group rocks on Starr Mountain in the vicinity of the study area (Plate III).

Minor faults

Other faults of local significance deform rocks in all three western Blue Ridge thrust sheets. The Towee Creek fault, largest of these structures, deforms Wilhite and Buck Bald Formation rocks 0.3 km (0.2 mi) west of Witt Cemetery, McFarland 7.5-minute quadrangle (Plate I). The Towee Creek fault and related splays extend approximately 3 km (1.9 mi) and are

recognized because they contain fault fabrics identical to those in the Miller Cove fault zone to the northeast. Coarse fault gouge is preserved where the Towee Creek fault deforms metaconglomerate of the Buck Bald Formation. The fault generally dips steeper (about 30° to 40° southeast) than the major faults exposed in the study area, suggesting that the Towee Creek fault may have formed as a minor backward-breaking thrust to the main fault system, or it could be part of a fault propagation fold. Displacement along the Towee Creek fault is estimated to be less than 100 m (328 ft). Good exposures of the Towee Creek fault are located in roadcuts approximately 1.45 km (0.9 mi) northeast of Witt Cemetery, McFarland 7.5-minute quadrangle, and along Towee Creek, 1.25 km (0.75 mi) southwest of Witt Cemetery, McFarland 7.5-minute quadrangle. Other minor brittle faults are exposed throughout the study area, such as 0.7 km (0.45 mi) west of Servilla on the north bank of Spring Creek (station MCF 1083), McFarland 7.5-minute quadrangle, and in roadcuts immediately west of Hogback Branch (station MEC 266), Mecca 7.5-minute quadrangle (Plate II). Direct observation indicates that displacement along these faults is less than several meters.

Strain analysis

Strain is a measure of the amount of internal deformation preserved in a rock mass. Macro-, meso-, and microstructures in a terrane such as the western Blue Ridge are the direct result of regional strain produced during deformation. The purpose of recent strain analyses of clastic rocks from the western Blue Ridge in Tennessee and North Carolina has been to quantify the amount of internal deformation, or strain, preserved in this terrane, and to geometrically relate this strain to regional western Blue Ridge structure and deformational history. Studies in the vicinity of the Great Smoky Mountains National Park have been generally successful in accomplishing these goals (Lewis, 1988; Walters, 1988; Connelly, 1993).

Lewis (1988) and Walters (1988) were the first to quantify western Blue Ridge strain in eastern Tennessee using the R_f/ϕ method (Ramsay, 1967; Dunnet, 1969; Dunnet and Siddans,

1971; Lisle, 1977; Lisle, 1985). Lewis (1988) reported R_{xy} , R_{xz} , and R_{yz} ($X \geq Y \geq Z$) values (using quartz grains as strain markers) between 1.11 and 3.44 with means and standard deviations of 1.62 ± 0.34 , 2.32 ± 0.54 , and 1.44 ± 0.26 , respectively, from 17 samples of the Thunderhead Sandstone (Great Smoky Group) near Wear Cove. Lewis (1988) recognized that some strain ellipsoids with these strain values were oriented subparallel to the Greenbrier fault and concluded that these ellipsoids were produced during the initial transport and emplacement of the Greenbrier thrust sheet. Lewis (1988) recognized that other ellipsoids within the Greenbrier thrust sheet may have been the result of later thrusting along the Sinks fault (Fig. III-2). This high-angle thrust displaced the Greenbrier thrust sheet in the vicinity of Wear Cove and Lewis (1988) concluded that these ellipsoids recorded superimposed strain from movement along both faults.

Southward, Walters (1988) analyzed 8 samples of Cades and Elkmont Sandstones (Great Smoky Group) from the vicinity of Cades Cove and recorded R_{xz} and R_{yz} ($X \geq Y \geq Z$) values (using quartz grains as strain markers) between 1.20 and 4.60 with means and standard deviations of 2.56 ± 1.09 and 2.24 ± 0.82 , respectively. An R_{xy} value of 1.05 was also obtained from one sample. Walters (1988) concluded that these strains and associated ellipsoids were the final product of superimposed incremental strains related to a complex deformational history in the Cades Cove region. This history included initial westward transport of the Cades and Elkmont sandstones along the Greenbrier fault, followed by shearing along the Rabbit Creek fault, and the emplacement of a recumbent nappe cored by these lithostratigraphic units. The Elkmont Sandstone, occurring on the upright backlimb of this nappe, records strains comparatively low (R_{xz} of 1.57 ± 0.13) relative to strains within the Cades Sandstone (R_{xz} of 2.94 ± 1.16), which is located in the overturned forelimb of the structure.

The largest amount of strain data that has been collected from western Blue Ridge rocks was by Connelly (1993), who measured strain in 69 sandstone samples from various Ocoee Supergroup lithostratigraphic units within three premetamorphic thrust sheets south of

English Mountain. Connelly (1993) used both the R_f/ϕ and normalized Fry methods (Fry, 1979; Erslev, 1988). One purpose of Connelly's (1993) study was to kinematically model deformational events along the hanging-wall flat-and-ramp portions of these thrust sheets using a strain factorization technique (Ramsay and Huber, 1983; Kligfield and others, 1984), which has proven a viable modeling technique in the Appalachian foreland (Couzens and others, 1993). Connelly (1993) recorded R_{xy} , R_{xz} , and R_{yz} ($X \geq Y \geq Z$) values between 1.01 and 1.79 using the R_f/ϕ method with means and standard deviations of 1.14 ± 0.11 , 1.33 ± 0.16 , and 1.17 ± 0.08 , respectively. The normalized Fry method yielded R_{xy} , R_{xz} , and R_{yz} ($X \geq Y \geq Z$) values between 1.03 and 3.24 with means and standard deviations of 1.25 ± 0.24 , 1.53 ± 0.28 , and 1.23 ± 0.11 , respectively (Connelly, 1993). Results of Connelly's (1993) study indicated strain ratios determined by the Fry method were typically 5 to 20 percent greater than those determined by the R_f/ϕ method, suggesting at least some strain was inhomogeneously concentrated in the matrix. Strain values from both methods were also found to generally increase toward the south into the hinterland. Although strain factorization failed to produce a single conclusive deformational model for observed finite strains in these western Blue Ridge thrust sheets, Connelly's (1993) study provided additional and significant finite strain data for the western Blue Ridge.

The purpose of this strain analysis study in southeastern Tennessee is to reconnoiter strain magnitude south of the Little Tennessee River and compare results with the previously published works in the vicinity of the Great Smoky Mountains National Park. The importance of this work is twofold. First, strain measurements have only been collected east of the Miller Cove fault in the Great Smoky Mountains National Park region. This current study is the first to provide both R_f/ϕ and normalized Fry data from the westernmost Blue Ridge thrust sheets west of the Miller Cove fault. Secondly, this study provides an opportunity to compare strain data collected from thrust sheets with differing tectonic histories. Lewis (1988), Walters (1988) and Connelly (1993) collected strain data from the premetamorphic Greenbrier, Dunn Creek,

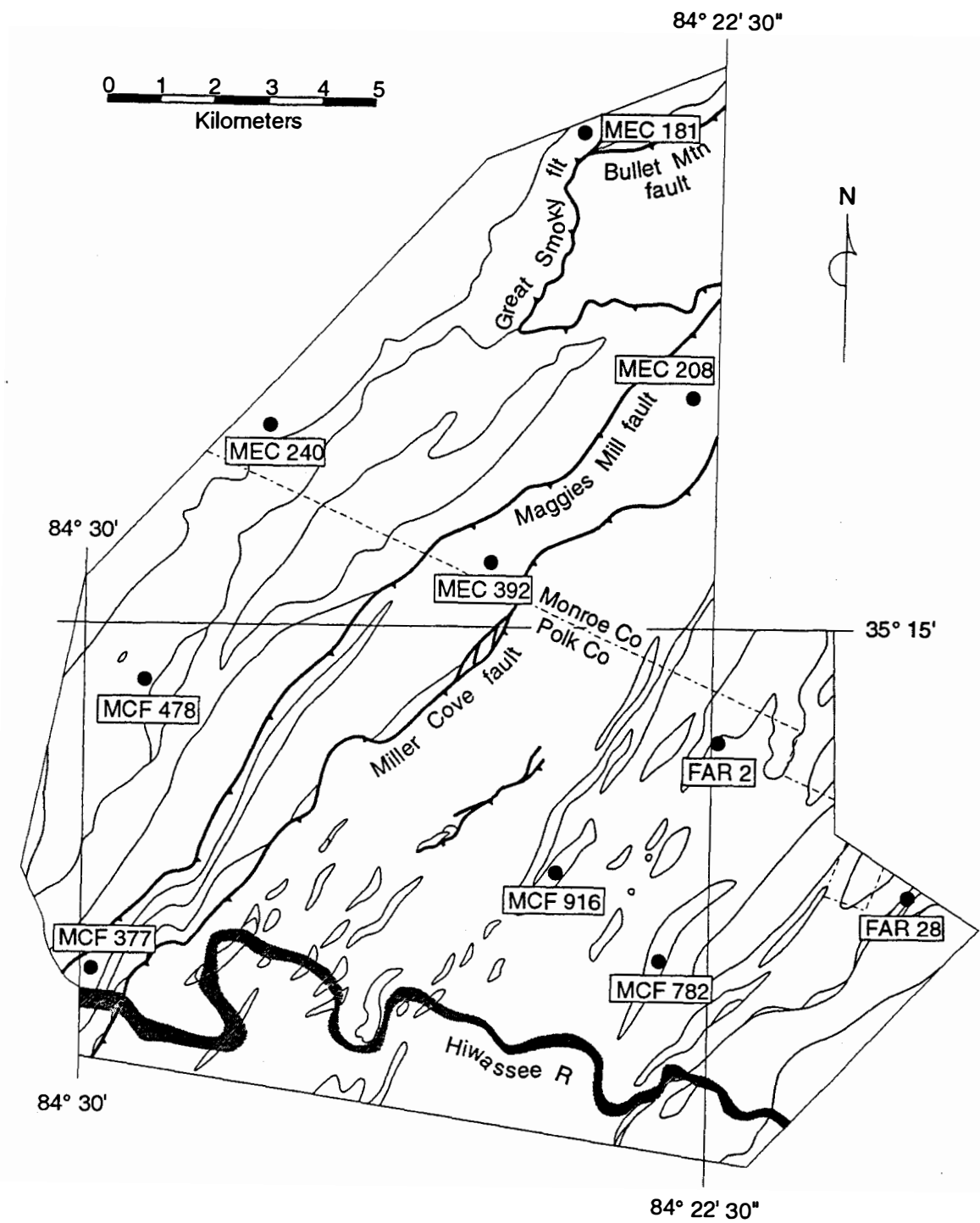
Line Springs, and Rabbit Creek thrust sheets, as well as the Miller Cove thrust sheet. Strain data collected in southeastern Tennessee, however, are derived from postmetamorphic thrust sheets, and comparison with strain data from demonstrably premetamorphic thrust sheets may provide new insight into the polyphase strain history of the western Blue Ridge.

Methodology

Nine oriented samples of coarse-grained sandstone and granule conglomerate from the Great Smoky, Maggies Mill, and Miller Cove thrust sheets were collected for strain analysis (Fig. III-20). These samples were oriented in the field with respect to bedding and then three mutually perpendicular thin sections (parallel to bedding, perpendicular to bedding, and perpendicular to strike) were made from these samples in the laboratory. Modal analyses were performed to estimate the amount of quartz, matrix, and other constituents within each sample (Table A-II). Black and white photomicrographs were then taken of these sections using a Leitz Orthoplan Pol™ polarizing microscope and Wild mounted camera assemblage. Next, quartz grain boundaries within these samples were digitized using a Kurta® Model 12X17 digitizing tablet and associated Penworks® software for the Apple® Macintosh™ computer, and the digitized boundaries were input into strain software developed by A. Yonkee (University of Utah) for the Macintosh™ computer. Fry plots utilizing Fry's (1979) and Erslev's (1988) methods, and R_f/ϕ plots using methods described by Dunnet (1969) and Peach and Lisle (1979) were generated with Yonkee's programs. The orientation and magnitude of the strain ellipse for each thin section (three per sample) was determined for both the normalized Fry and R_f/ϕ data set. For each method, the three ellipses for a sample were used to calculate the orientation and magnitude of the strain ellipsoid using a method described by Owens (1984).

In addition to computer-generated strain measurements derived from these sandstone and conglomerate samples, 52 quartz pebbles and 14 granitoid pebbles and cobbles were collected from an exposure 1.3 km (0.8 mi) west of Black Mountain (FAR 2), Farner 7.5-minute

Figure III-20: Location of samples used for strain analysis.



quadrangle, for plotting on a Flinn diagram (Flinn, 1962). These pebbles were oriented with their long and intermediate axes parallel to slaty cleavage in the outcrop, suggesting that the observed shapes were the result of tectonic strain modifying original depositional shape. The three principal axes of each pebble were measured (in millimeters), and the ratios of the principal axes were calculated (Tables A-V; A-VI) to determine Flinn's (1962) k . Lastly, these ratios were plotted on a Flinn diagram for graphical analysis.

Results of study

The nine sandstone and conglomerate samples produced results consistent with other measurements of strain farther north in the Great Smoky Mountains. R_{xy} , R_{xz} , and R_{yz} ($X \geq Y \geq Z$) from the R_f/ϕ technique range between 1.05 and 1.63 with means and standard deviations of 1.12 ± 0.05 , 1.22 ± 0.14 , and 1.37 ± 0.18 , respectively (Table A-VII). R_{xy} values increase weakly to the southeast, parallel to the increase in Barrovian metamorphic grade (Fig. III-21). Mean R_{xy} in the Great Smoky thrust sheet is 1.08 ± 0.02 , but east of the Maggies Mill fault, the mean R_{xy} increases to 1.15 ± 0.04 (Fig. III-21). The orientation of X/Y planes is not parallel to regional slaty cleavage (Fig. III-21). No trends are observed in either the X or Y axes orientations, but Z axes lie in a subvertical east-west girdle (Fig. III-22). 7 of 9 R_f/ϕ values fall within the field of apparent flattening on a Flinn diagram (Fig. III-23A).

R_{xy} , R_{xz} , and R_{yz} ($X \geq Y \geq Z$) values from the normalized Fry technique range between 1.03 and 1.78 with means and standard deviations of 1.23 ± 0.13 , 1.24 ± 0.12 , and 1.52 ± 0.17 , respectively (Table A-VIII). R_{xy} values obtained using the normalized Fry method also increase to the southeast, except for sample FAR 28 (Fig. III-24). The increase in normalized Fry R_{xy} values across the Maggies Mill fault is more pronounced than in R_{xy} values from the R_f/ϕ method. Mean R_{xy} from the normalized Fry method in the Great Smoky thrust sheet is 1.15 ± 0.06 , but east of the Maggies Mill fault, the mean R_{xy} increases to 1.27 ± 0.14 (Fig. III-24). X/Y planes are not parallel to regional slaty cleavage (Fig. III-24). Similar to the orientations of X

Figure III-21: X/Y axial ratios as determined by the R_f/ϕ method. Trend of the X axis is indicated for each ellipse. 9 poles to X/Y planes are plotted on the contour diagram of 647 poles to slaty cleavage (contours represent 2, 4, 6, 8, 10, 12, 14, 16% per 1% area).

Fault abbreviations: GSF - Great Smoky fault; MMF - Maggies Mill fault; MCF - Miller Cove fault.

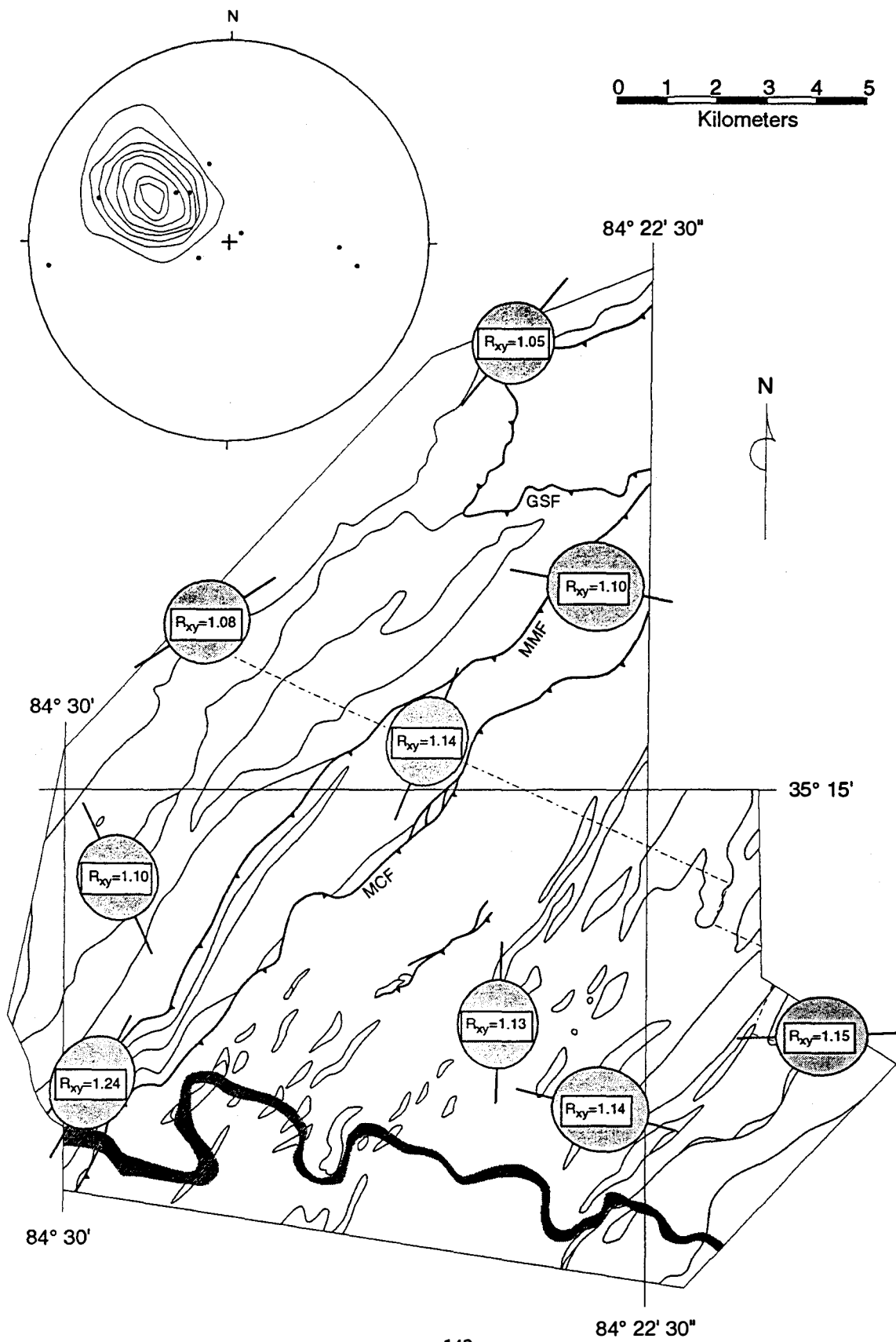
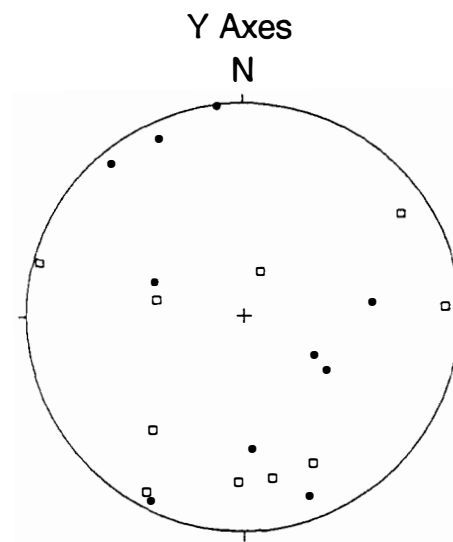
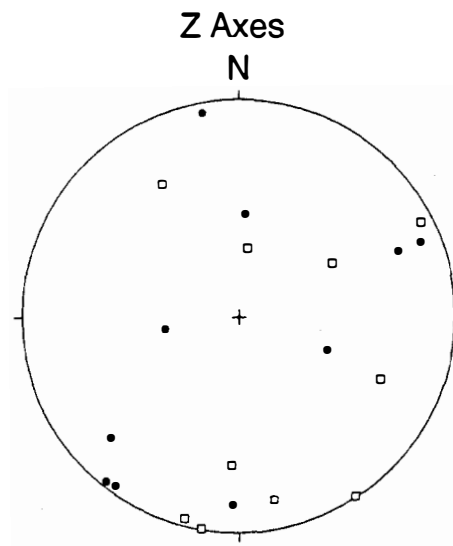
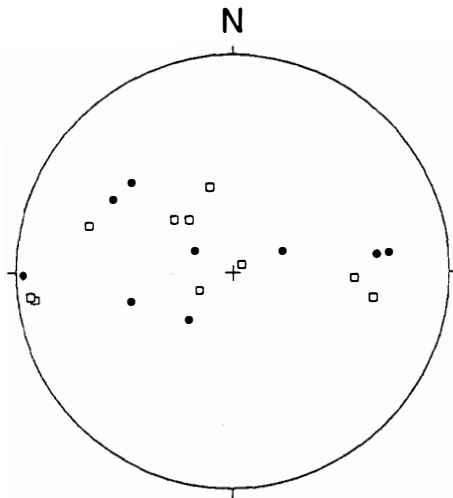


Figure III-22: Lower-hemisphere equal-area projections of strain ellipsoid axes.

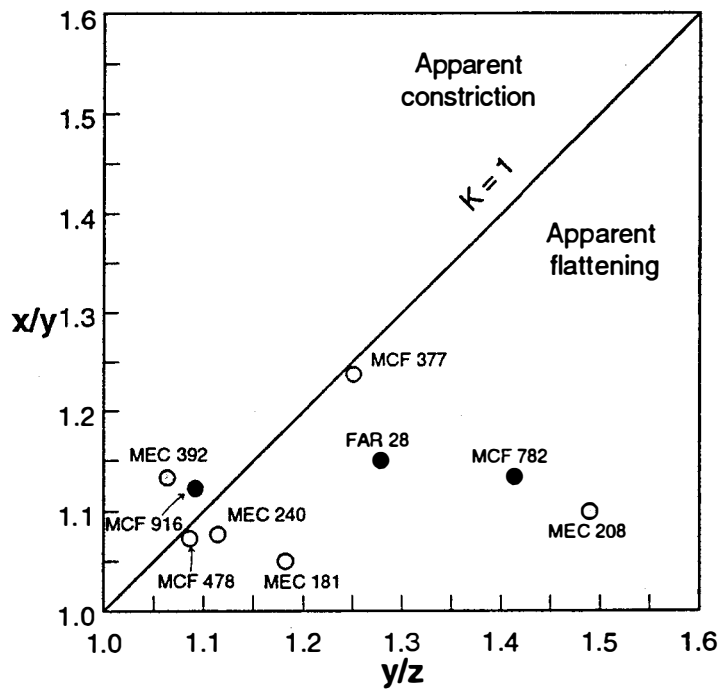


• Fry Axes
□ Rf/φ Axes

X Axes

Figure III-23: Flinn diagram of normalized Fry and R_f/ϕ strain values in each thrust sheet. (A) R_f/ϕ values. (B) normalized Fry values.

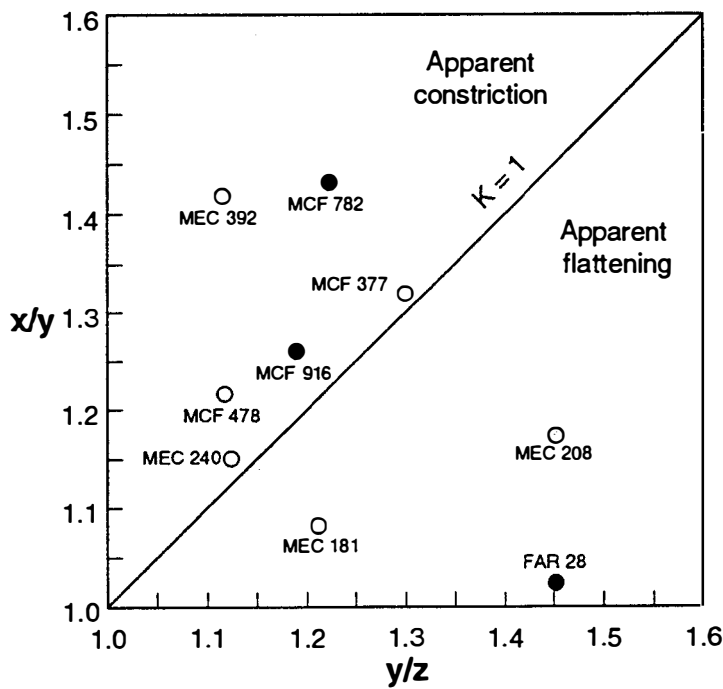
R_f/ϕ values



(A)

- Great Smoky thrust sheet
- Maggies Mill thrust sheet
- Miller Cove thrust sheet

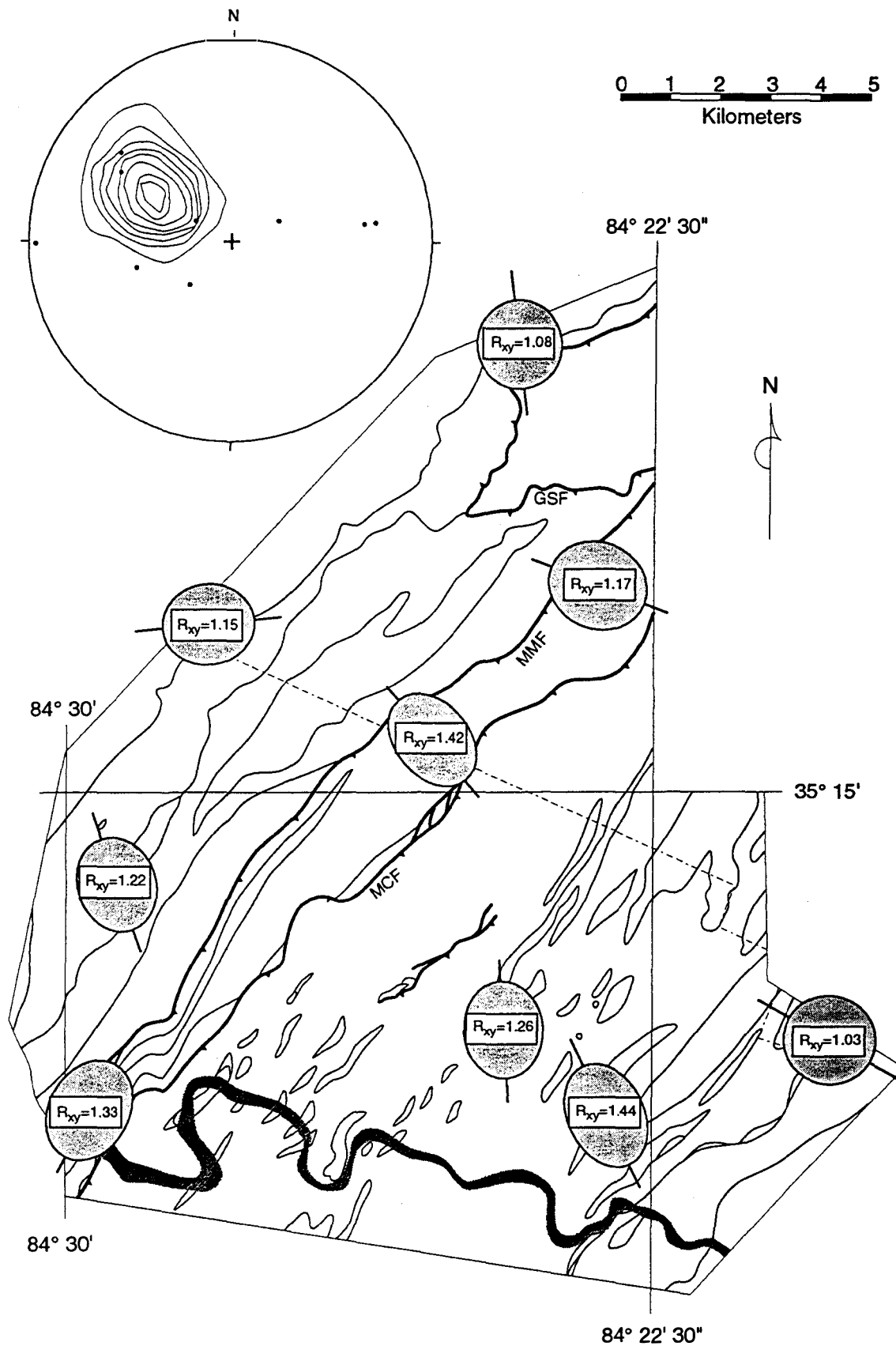
Normalized Fry values



(B)

Figure III-24: X/Y axial ratios as determined by the normalized Fry method. Trend of the X axis is indicated for each ellipse. 9 poles to X/Y planes are plotted on the contour diagram of 647 poles to slaty cleavage (contours represent 2, 4, 6, 8, 10, 12, 14, 16% per 1% area).

Fault abbreviations: GSF - Great Smoky fault; MMF - Maggies Mill fault; MCF - Miller Cove fault.

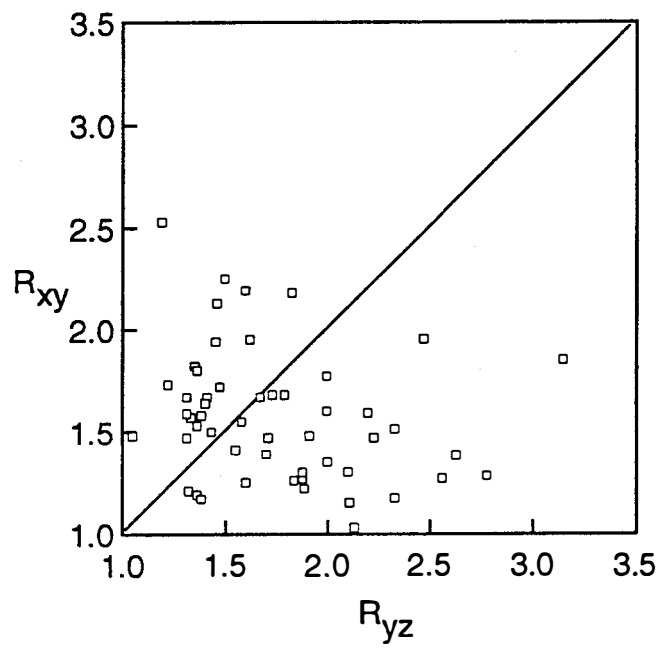


and Y axes from the R_f/ϕ method, no trends were observed in the orientations of the X or Y axes from the normalized Fry method, but Z axes also lie in a subvertical east-west trending girdle (Fig. III-22). Unlike R_f/ϕ values, 6 of 9 normalized Fry values fall within the field of apparent constriction on a Flinn diagram (Fig. III-23B). Normalized Fry values in southeastern Tennessee are 2% to 22% greater than corresponding R_f/ϕ values, supporting a similar conclusion by Connelly for strain values determined in rocks north of the Little Tennessee River.

Two basic assumptions must be met for measurements of flattened pebbles to yield simple finite strain ratios. First, the original shape of the measured pebbles had to be nearly spherical (relative to the amount of tectonic strain) before deformation. Some relatively undeformed pebbles from the feldspathic metasandstone member of the Wilhite Formation in the study area consist of nearly spherical clasts, and many unstrained, monocrystalline quartz grains within carbonate in the lower member of the Sandsuck Formation are also spherical. These observations suggest rocks in the study area may meet the first assumption. Secondly, volume loss due to pressure-solution of the original quartz pebble must have remained minimal during deformation. Although most pebbles from station FAR 2 have been deformed by pressure-solution, the original shape of the clasts before pressure-solution deformation can be visually estimated and measured, thus negating some of the effect of pressure-solution.

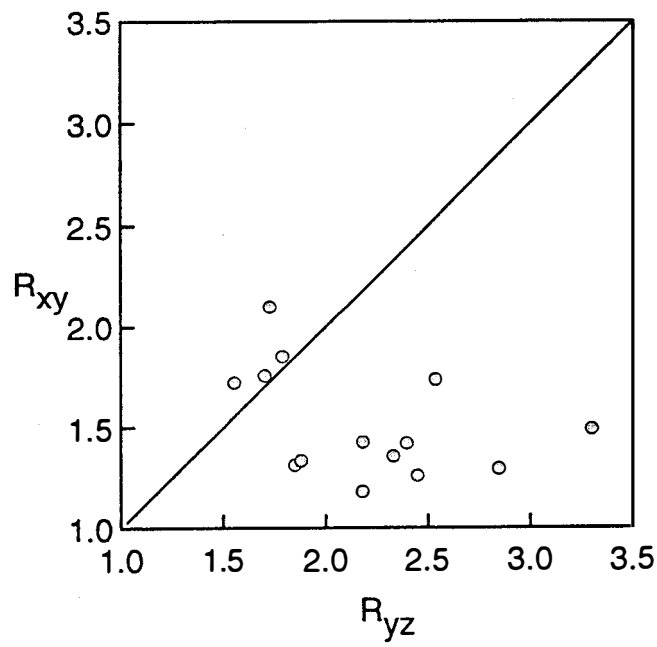
The principal axes of 52 quartz pebbles oriented parallel to regional slaty cleavage record mean R_{xy} , R_{xz} , and R_{yz} ($X \geq Y \geq Z$) values of 1.57 ± 0.31 , 1.75 ± 0.45 , and 2.71 ± 0.8 , respectively (Table A-V). The principle axes of 14 granitoid pebbles, though not as accurate as quartz pebbles for recording strain because of the variable rheologies of the constituent minerals, record mean R_{xy} , R_{xz} , and R_{yz} ($X \geq Y \geq Z$) values of 1.51 ± 0.26 , 2.20 ± 0.47 , and 3.28 ± 0.69 , respectively (Table A-V). When graphed on a Flinn plot, 60% of quartz pebbles and 71% of granitoid pebbles and clasts fall within the field of apparent flattening (Fig. III-25).

Figure III-25: Flinn diagrams of flattened quartz pebbles and granitoid pebbles from Black Mountain, (station number FAR 2), Farner 7.5-minute quadrangle. (A) Flinn diagram of values obtained from 52 quartz pebbles. (B) Flinn diagram of values obtained from 14 granitoid pebbles.



(A)

□ Quartz pebbles
 ○ Granitoid pebbles



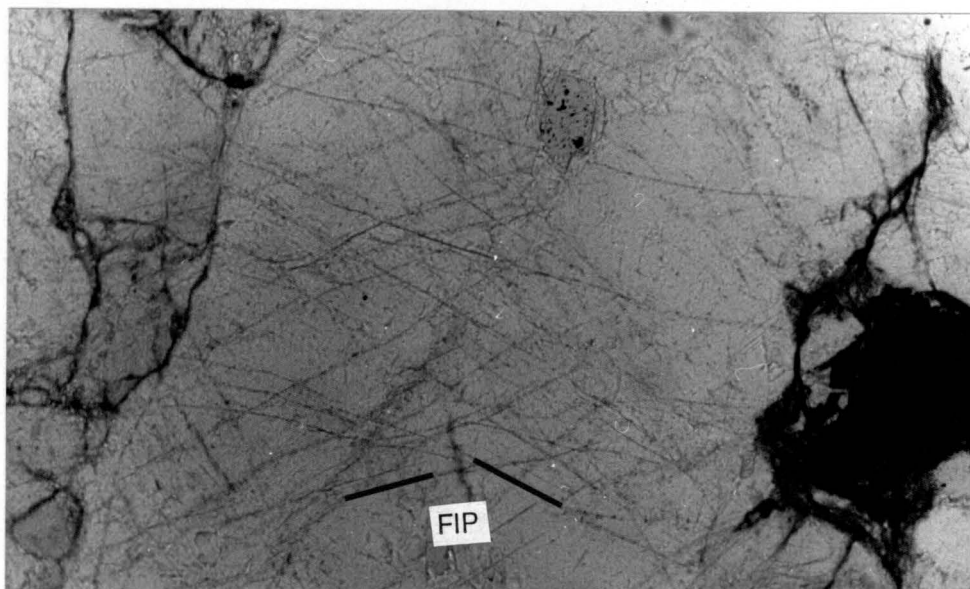
(B)

Discussion of results

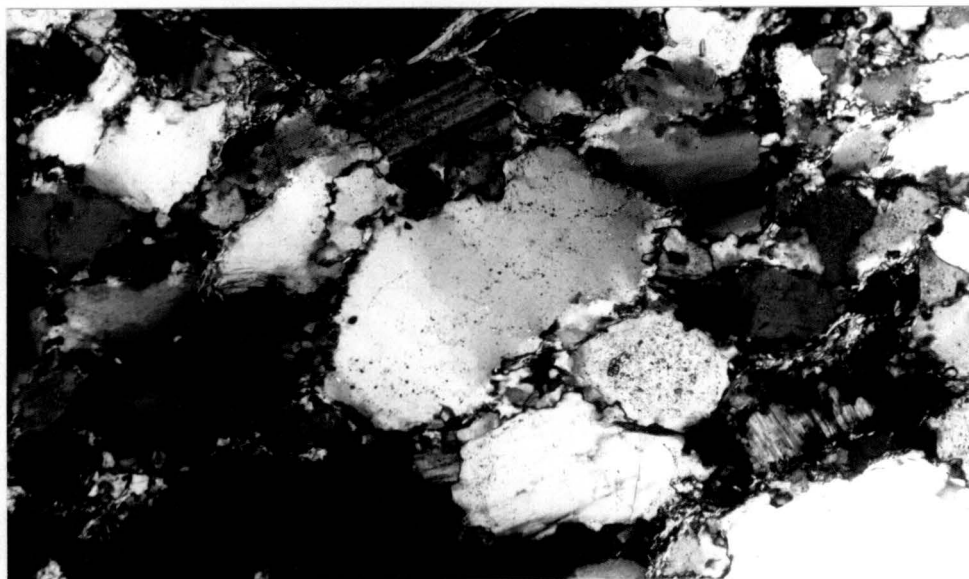
Two different values of strain for each sample in the thrust sheets were generated from the R_f/ϕ and normalized Fry methods. To determine which method yields the most satisfactory results, strain values must be compared with the accompanying suite of microstructures within each thrust sheet. Reconnaissance microstructural analysis of sandstone in the study area defined important trends that can be directly related to measured strain values. Tectonic microstructures observed in quartz in coarse-grained rocks throughout the study area include sweeping and patchy undulatory extinction, fluid inclusion planes or Tuttle lamellae (Mitra, 1987; Groshong, 1988; Wu and Groshong, 1991), deformation or Fairbairn lamellae (Fairbairn, 1941; Ingerson and Tuttle, 1945; Carter and others, 1964; Carter, 1971; Groshong, 1988; Wu and Groshong, 1991), sutured and serrated grain boundaries, mortar textures and subgrains, intragranular fractures (Groshong and others, 1984; Wu and Groshong, 1991), and transgranular stylolites (Groshong and others, 1984; Wu and Groshong, 1991). These microstructures are characteristic of low metamorphic grade and were produced by deformation mechanisms including dislocation glide, dislocation creep, pressure-solution, and microfracturing (Groshong, 1988; Knipe, 1989; Lloyd and Knipe, 1992; Onasch and Dunne, 1993).

R_f/ϕ and normalized Fry strain values are very low in the Great Smoky thrust sheet. Microstructures accompanying these low strain values include sweeping undulatory extinction in some grains and sutured grain boundaries, but the dominant microstructure in the Great Smoky and Maggie's Mill thrust sheets is fluid inclusion planes (Fig. III-26A). No fluid inclusion planes were recognized in rocks east of the Miller Cove fault. Unstrained monocrystalline quartz grains are also common in sandstone and conglomerate of the Great Smoky thrust sheet, and some of the other microstructures in these rocks (i.e. undulatory quartz grains) may be structures inherited from detrital multiple-cycle quartz grains. This microstructural suite dominated by transgranular fracture mechanisms is characteristic of low-

Figure III-26: Common microstructures in the Great Smoky and Miller Cove thrust sheets. (A) Photomicrograph (plane polarized light) of fluid inclusion planes within Cochran Formation sandstone, Locust Mountain, (station MEC 240), Mecca 7.5-minute quadrangle. Orientation of fluid inclusion planes (FIP) noted by black line. Field of view is 1.5 mm. (B) Photomicrograph (crossed nicols) of mortar texture and subgrains from sandstone of the feldspathic metagraywacke member, Wilhite Formation, Coker Creek (station MCF 782), McFarland 7.5-minute quadrangle. Large grains still preserve unrecovered strain, but small grains are recrystallized and unstrained. Field of view is 1.5 mm.



(A)



(B)

temperature brittle deformation (Lloyd and Knipe, 1992). Given this microstructural suite and the textural characteristics (i.e., moderately to well-sorted and subrounded grains) of the samples from the Great Smoky thrust sheet, the R_f/ϕ method, which measures strain as a function of individual grain shape (Ramsay, 1967), is interpreted to provide a better measurement of strain. Higher normalized Fry values in the Great Smoky thrust sheet may be recording whole rock-diagenetic compaction orientations rather than tectonic strain (Couzens and others, 1993). The generally parallel orientation of both R_f/ϕ and normalized Fry X axes to bedding strike also suggests a strong component of diagenetic compaction (Figs. III-21; III-24).

Microstructures east of the Miller Cove fault include patchy and sweeping undulatory extinction, sutured and serrated grain boundaries, deformation bands, mortar texture, and subgrains. Of these, serrated grain boundaries, mortar texture, and subgrains are the most common (Fig. III-26B) and indicate static recrystallization at increased temperatures of deformation (Hirth and Tullis, 1992). Unstrained monocrystalline quartz is characteristically absent and the lack of abundant fluid-inclusion planes within quartz grains suggests these fractures have been almost completely annealed if they existed. Here, as in the Great Smoky thrust sheet, normalized Fry analysis yields strain values higher than values obtained using the R_f/ϕ method. Normalized Fry values, measuring strain based on the spatial distribution of markers (Fry, 1979), appear to be a better indicator of the amount of strain in the Miller Cove thrust sheet. Microstructures within the thrust sheet suggest increased deformation, and normalized Fry values, indicative of whole-rock strain rather than strain within individual markers, correlates with this observed increase. Quality R_f/ϕ values from the Miller Cove thrust sheet still reflect increased strain, but may provide regional values that are too low when compared to normalized Fry values because of changes to the shapes and sizes of the quartz grain strain markers from recrystallization.

Microstructures within the Maggies Mill thrust sheet include characteristic microstructures of both the Great Smoky and Miller Cove thrust sheets. These include

sweeping and patchy undulatory quartz, sutured and serrated grain boundaries, deformation lamellae, fluid inclusion planes, and transgranular stylolites. This microstructural suite and accompanying values of strain (Figs. III-21; III-24) suggest that the Maggie's Mill thrust sheet may be transitional between the less-strained Great Smoky thrust sheet to the west and the more-strained Miller Cove thrust sheet to the east.

Conclusions

- 1) Strain values obtained from R_f/ϕ , normalized Fry, and Flinn methods are consistent in magnitude and general orientation with strain measurements from previous studies north of the Little Tennessee River and reflect the typical low-grade metamorphism with related deformation in this region.
- 2) Just as previous studies indicated strain values increase parallel to increasing mesoscopic deformation in rocks in the Great Smoky Mountains National Park region, similar southeasterly intensifying trends are recognized in this study. Strain in the frontal Blue Ridge thrust sheet in southeast Tennessee is characteristically lower than strain in more easterly thrust sheets. This is reflected not only in values of strain, but in associated microstructural suites as well.
- 3) No correspondence exists between the orientation of the X/Y plane and regional slaty cleavage in any of the western Blue Ridge thrust sheets in southeastern Tennessee. Williams (1976) demonstrated that the X/Y plane can only parallel slaty cleavage if the strain history is coaxial throughout deformation. Likewise, if the strain history is non-coaxial, only those ellipses forming in the hinge zone of a fold will exhibit X/Y planes that are parallel to the coeval slaty cleavage (Williams, 1976). Therefore, strain ellipsoids calculated in this study may record non-coaxial incremental strains produced during the F_2 event, or they may represent a strain event that developed prior to regional F_2 deformation.
- 4) Because strain magnitudes and orientations within these postmetamorphic thrust sheets in southeastern Tennessee are consistent with magnitudes and orientations of strain within

premetamorphic thrust sheets in the vicinity of the Great Smoky Mountains National Park, the regional strain history recorded in rocks of the western Blue Ridge in southeastern Tennessee may be the result of one period of pre- to synmetamorphic deformation rather than a superposition of polyphase western Blue Ridge strain events.

Chapter IV

Depositional and Structural Chronology of the Western Blue Ridge in Southeastern Tennessee

Introduction

Major lithostratigraphic units in the western Blue Ridge of eastern Tennessee, southwestern North Carolina, and northwestern Georgia (Ocoee Supergroup, Murphy belt, and the Chilhowee Group rocks) preserve a record of the depositional and structural history of the southeastern margin of Laurentia. Recently reported stratigraphic and paleontological evidence from parts of these lithostratigraphic sequences conflict with established stratigraphic views and has questioned the traditional interpretation of the depositional regime, age, and tectogenesis of the western Blue Ridge.

Depositional history of the Ocoee Supergroup, southeastern Tennessee

Traditional interpretation suggests that western Blue Ridge lithostratigraphy represents Late Proterozoic to Early Cambrian synrift deposition (Ocoee Supergroup and lower parts of the Murphy belt sequence) and post-rift stable shelf sedimentation (Chilhowee Group and upper parts of the Murphy belt stratigraphy) along the rifted Laurentian margin (King and others, 1958; Hadley, 1970; DeWindt, 1975; Rankin, 1975; Hatcher, 1978; Rast and Kohles, 1986; Thomas, 1993). New hypotheses from stratigraphic and paleontological evidence from the Walden Creek and Mineral Bluff groups (Tull and Groszos, 1990; Unrug and Unrug, 1990; Thompson and Tull, 1991; Unrug and others, 1991; Tull and others, 1993) have been used to suggest a younger age for part of the Laurentian margin. Tectonic models proposed by Tull and Groszos (1990) and Unrug and others (1991) suggest that at least the upper formations of the Ocoee Supergroup (Walden Creek and Great Smoky groups) and the Murphy belt sequence (Mineral Bluff group) are Paleozoic (Middle Ordovician to Mississippian) in age and were deposited above the regional basal Middle

Ordovician unconformity in post-Taconic successor basins along the Laurentian margin.

Stratigraphic data from this and previous studies in the western Blue Ridge support the traditional interpretation of the origin of the Ocoee Supergroup. First, the conformable stratigraphic contact between the Lower Cambrian Chilhowee Group (Cochran Formation) and the Sandsuck Formation (Walden Creek Group) (Rackley, 1951; Phillips, 1952), and the nonconformable contact between Grenville basement and the Snowbird and Great Smoky groups (Keith, 1907a; King and others, 1958; Odom and others, 1973) brackets the age of deposition of the Ocoee Supergroup between the Middle Proterozoic and Early Cambrian. Secondly, no evidence of a regional unconformity has been found in the Foothills belt of southeastern Tennessee separating Walden Creek Group rocks from other western Blue Ridge stratigraphic sequence, suggesting regional correlations between the Walden Creek and Mineral Bluff groups above the Middle Ordovician unconformity (Tull and others, 1993) are incorrect.

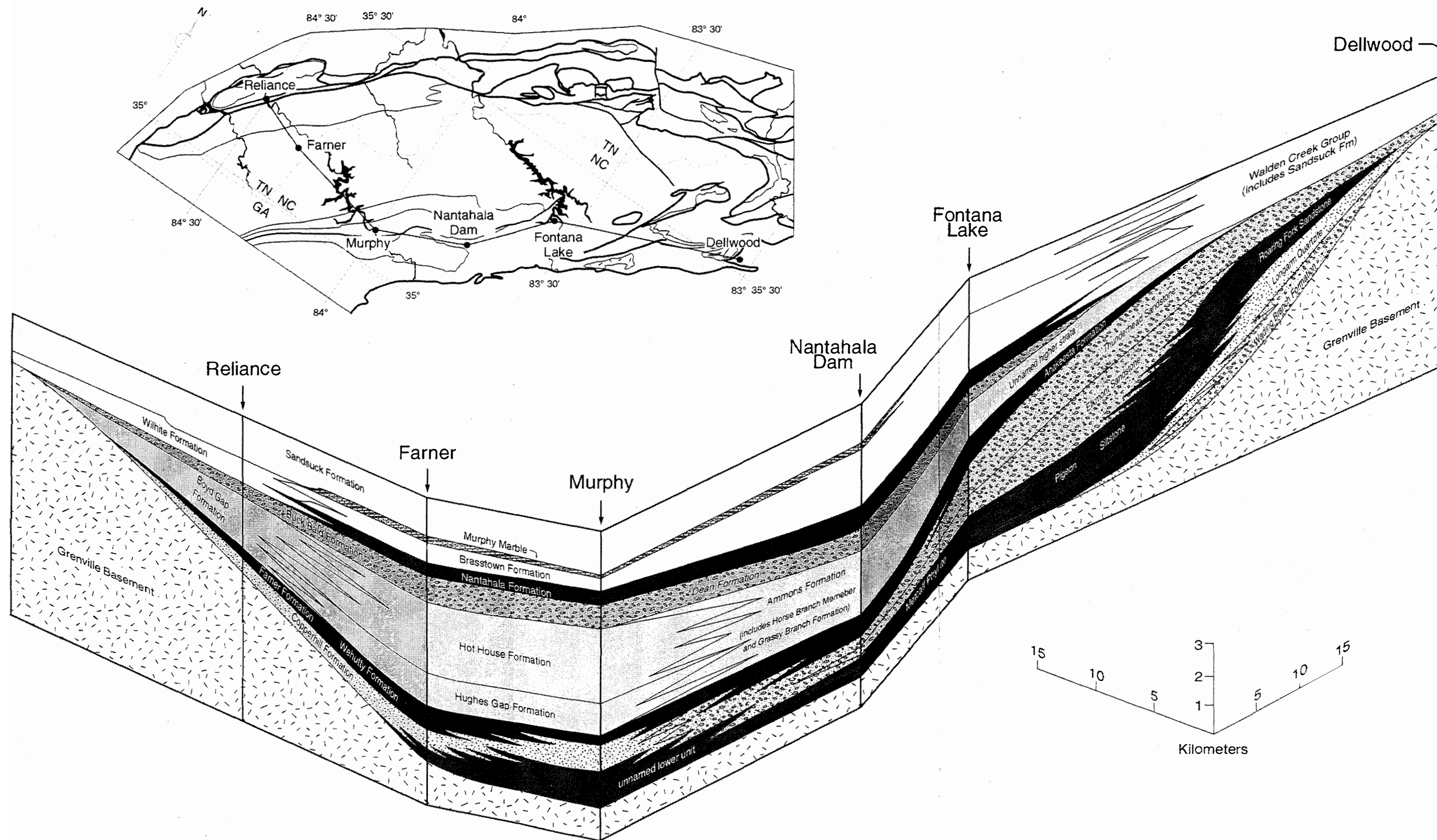
Depositional characteristics and environments of the Ocoee Supergroup, southeastern Tennessee

The lowest Ocoee Supergroup lithostratigraphic unit exposed in the western Blue Ridge south of the Great Smoky Mountains is an unnamed fine-grained unit of unknown thickness and extent that is conformably overlain by the Copperhill Formation in northwestern Georgia and southeastern Tennessee (Hurst, 1955; Hurst and Schlee, 1962; Hernon, 1968). Lower unexposed units may exist beneath this unnamed schist, but this unit is assumed to be the lowest in the stratigraphic sequence. To the north, coarse-grained rocks of the lower formations of the Snowbird Group comprise the lowest stratigraphic unit in the Ocoee succession and were deposited nonconformably on a deeply eroded and topographically subdued basement terrane. King (1964) concluded that coarse clastics of the lower formations of the Snowbird Group (Wading Branch Formation and Longarm Quartzite) were derived from a nearby eastern granitic and gneissic terrane and deposited in shallow water along the northwestern edge of the

sedimentary basin. DeWindt (1975) suggested that the sediments of the Wading Branch Formation were concentrated in shallow lagoons or estuaries whereas the Longarm Quartzite was interpreted to have an origin as transgressive fluviodeltaic and littoral sands. In northwestern Georgia, coarse-grained rocks possibly equivalent to the Snowbird Group (Pinelog and Par Branch Formations) (McConnell and Costello, 1980, 1982, 1984) occupy a similar stratigraphic and paleogeographic position. These coarse-grained rocks in northwestern Georgia may also have been deposited as transgressive sequences along the extreme southern fringe of the gradually subsiding basin. Earlier workers postulated the Roaring Fork Sandstone, Pigeon Siltstone, and Metcalf phyllite are finer-grained, deeper-water facies of the shallow-water sediments of the Wading Branch Formation and Longarm Quartzite (King, 1964; DeWindt, 1975). King (1964) suggested that these upper Snowbird Group formations were derived from the same source area as the Wading Branch and Longarm Quartzite, but were trapped by rapid subsidence. DeWindt (1975) interpreted the Roaring Fork Sandstone and Pigeon Siltstone to represent delta-front, interdeltic, and prodeltic deposits laterally transitional between the shallow-water Longarm and deeper water Metcalf phases. The unnamed schist in northwestern Georgia and southeastern Tennessee may be the southern equivalent of these deeper-water Snowbird Group facies to the north (Fig. IV-1), and a laterally transitional facies between the Snowbird Group, and the Pinelog and Par Branch Formations to the south.

The first Great Smoky Group lithostratigraphic unit in southeastern Tennessee is the Copper Hill Formation. The Copperhill Formation consists dominantly of graded metagraywacke, metaarkose, and metaconglomerate. Hurst (1955) noted that the Copperhill Formation is characterized by the absence of very coarse debris, so the formation is interpreted to be the southern, relatively finer-grained equivalent of the Elkmont and Thunderhead sandstones to the northeast (Fig. IV-1). King (1964) interpreted the southward-thickening, coarse-grained graded sandstones and conglomerates of the Elkmont and Thunderhead sandstones to be turbidites deposited in a deep marine trough. Hadley and Goldsmith (1963) suggested that

Figure IV-1: Schematic fence diagram through the restored Ocoee basin. Unit thickness for the construction of this diagram taken from this study - Reliance; Hernon (1968), Merschatt and Hale (1983) - Farner; Hurst (1955) - Murphy; Ausburn (1983) - Nantahala Dam; Mohr (1973, 1975) - Fontana Lake; King and others (1958) - Dellwood.



leucogranite clasts within these formations may have been derived from a rapidly eroded northeastern or northwestern granitic terrane. The Copperhill Formation is likewise interpreted to have a northerly derived turbiditic origin. These lower Great Smoky Group formations may have been deposited in extensive turbidite fans at the base of a steep escarpment along the northern margin of the recently activated rift basin. Unclassified formations of King and others (1958) (e.g., the Cades, Rich Butt, and Webb Mountain sandstones) were also interpreted by DeWindt (1975) to be deep-water turbidite fans, possibly derived from the major deltas within the Longarm-Roaring Fork paleoenvironmental realm to the east, and may be northwestern equivalents to the Copperhill Formation.

Above the coarse-grained lower formations of the Great Smoky Group is a thick section of euxinic shales, represented by the Anakeesta Formation to the north and the Wehuty and Farner Formations to the south. Hadley and Goldsmith (1963) and King (1964) suggested that the Anakeesta Formation, consisting of dark silty and argillaceous deposits containing abundant sulfides and carbon, accumulated more slowly than the lower coarser units in deep stagnant water. Hernon (1968) observed that the few coarse-grained beds in the predominantly fine-grained Wehuty Formation were better sorted than the lower coarser-grained units, which also suggests that the formation may have been slowly deposited in deeper water. The widespread deposition of these deep-water euxinic shales suggests that the active rifting (the catalyst for deposition of the coarse-grained lower units) along the northern rim of the basin may have ceased by this time.

The Hughes Gap, Grassy Branch, Hothouse, and Ammons formations to the east and the Boyd Gap Formation to the west are the first coarser-grained units above the euxinic shale deposits of the Anakeesta, Wehuty, and Farner formations (Fig. IV-1). Although generally fine-grained, these formations contain thick beds of coarse-grained graded metagraywacke, metaarkose, and metaconglomerate that may represent initial deposition as turbidite fan deposits into the gradually subsiding reactivated rift basin. Banded metasilstone, a dominant lithology of

these formations, possibly represents the distal finer-grained fan facies along the margin of the submarine fan complex. Euxinic shale deposits within this sequence, including the Horse Branch Member of the Ammons Formation (Mohr, 1973, 1975; Ausburn, 1983), may record quiescent lulls in coarser turbidite sedimentation. A southeastern source for these fans is suggested because the eastern sequence (Hughes Gap, Grassy Branch, Hothouse, and Ammons formations) is relatively coarser-grained, more feldspathic, and thicker than the western Boyd Gap Formation (Hurst, 1955; Mohr, 1973; Wiener and Merschat, 1992). The great thickness of this stratigraphic package (approximately 5,000 m east of Ducktown, Tennessee) suggests that this pulse of turbiditic sedimentation was concentrated in the deeper south-central portion of the Ocoee basin, but some sedimentation may have occurred in the north-central part of the basin and is probably represented by King's (1964) unnamed higher unit of the Great Smoky Group in the southern Great Smoky Mountains.

This stage of sedimentation was eventually capped by a wide-spread coarse-grained graded turbidite sequence that is represented by the Dean Formation to the east and the lower lithofacies of the Buck Bald Formation to the west. The lower lithofacies of the Buck Bald Formation in the study area is a moderately well sorted, clean granule metaconglomerate containing much more quartz than feldspar or lithic fragments, while the Dean formation to the east generally consists of coarse quartz-pebble metaconglomerate and metasandstone interbedded with finer-grained rocks and local lenses of metagraywacke and metaarkose. Hurst (1955) suggested that sediments of the Dean Formation were derived from a source area of low relief and far removed from the site of deposition. Hurst's (1955) conclusions are substantiated by the moderately well-sorted and quartz-rich lower lithofacies of the Buck Bald Formation in the study area. These characteristics suggest that the detritus comprising the Buck Bald Formation was thoroughly reworked before final deposition as a turbidite fan. Rutiliferous blue quartz is common in the Buck Bald Formation as well as in other Great Smoky Group rocks throughout the western Blue Ridge, and is interpreted to be derived from a charnockitic (granulite) source

terrane (Hadley and Goldsmith, 1963; Rast and Kohles, 1986). The westward thinning of the Buck Bald Formation implies that these sediments may have been deposited near the margin of a submarine fan complex.

Graded deposits of granitoid boulder metaconglomerate, feldspathic graywacke metaconglomerate, and quartz-pebble metaconglomerate of the upper lithofacies of the Buck Bald Formation in the study area may be attributed to renewed uplift, possibly along the southeastern margin of the rift basin. The lenticular geometry of the granitoid boulder metaconglomerate and quartz pebble metaconglomerate deposits suggests these units may have been deposited as suprafan channels along the outer margin of a larger fan complex, but direct evidence for large-scale channeling is lacking. The location of these deposits corresponds to the thickest section of lower lithofacies sediments, and may imply that this area remained as a major site of deposition (possibly as a submarine canyon) throughout upper Great Smoky Group sedimentation. Besides granitoid clasts, white quartz pebbles, and angular feldspar grains, quartzite, shale, and carbonate clasts are also common in these upper lithofacies deposits as well as the uppermost equivalent beds of the lower lithofacies. The presence of these carbonate clasts suggests that the source area for these sediments was sufficiently shallow and far from terrigenous influx to develop a carbonate shelf before uplift. During uplift, both the sedimentary cover and underlying basement complex provided detritus for deposition of the Buck Bald Formation. Blue quartz grains become rare and white to clear quartz grains dominate in the sediments of the upper lithofacies. This change in quartz composition suggests a source terrane dominated by pegmatite veins, and may reflect either unroofing of the same charnockitic terrane that provided detritus for older Great Smoky Group lithostratigraphic units, or a different source terrane for the upper lithofacies of the Buck Bald Formation.

After deposition of the coarse-grained turbidites of the Great smoky Group, basin-wide fine-grained sedimentation of the Walden Creek Group occurred. King (1964) interpreted the lithologically diverse sediments of the Walden Creek Group to have an origin on an unstable

shelf. DeWindt (1975) inferred a nearby northwestward primary source for these unstable shelf deposits. These sediments, derived from a deeply eroded source terrane as well as a carbonate shelf, were redeposited as slumps from the unstable shelf into the deeper water of the sedimentary basin (King, 1964). Slumping may have been initiated by local reactivations of the basin margins. In southeastern Tennessee, these slump deposits may be represented by ungraded lenses of feldspathic metagraywacke and feldspathic metasandstone, quartz-pebble metaconglomerate, and granitoid-cobble metaconglomerate of the metasandstone members of the Wilhite Formation. Elsewhere in this part of the basin, banded metasilstone of the Wilhite Formation was deposited as thin (approximately 1 cm) graded beds. Locally, the banded metasilstone preserves ripple marks and ripple-cross laminations which may have been produced by gentle basin floor currents.

The Nantahala and Brasstown formations, and the Murphy Marble are interpreted to be the southeastern equivalents of the Wilhite Formation (Fig. IV-1). Hurst (1955) interpreted the predominantly dark, banded slate containing pyrite and organic matter to represent slow deposition in deep water. Paleocurrent indicators suggest a northwestward source area for the Nantahala Formation (Aylor, 1991). The Nantahala Formation may be the deeper-water euxinic shale facies of the Wilhite Formation farther west. The generally coarser-grained Brasstown Formation consists of metasubgraywacke, quartzite, metasilstone, and schist (Hurst, 1955; Aylor, 1991), and paleocurrent data suggests a southwestward source area (Aylor, 1991). The Brasstown Formation may represent the filling of the deeper, southern end of the basin by a northeastward prograding deltaic environment. Lastly, the Murphy Marble may represent a shallow-water carbonate shelf deposit which developed atop the older Brasstown delta after terrigenous influx ceased.

The transition from rift facies to passive margin sedimentation along the Laurentian margin is preserved in the rocks of the Sandsuck Formation in southeastern Tennessee. Coarse-grained rocks in the lower and middle members of the Sandsuck Formation may represent base-

of-slope slump deposits initiated by waning reactivation along the basin margins. After a brief period of fine-grained sedimentation represented by shale and siltstone of the middle member, coarse-grained sediments of the upper member may represent the initial development of the Cambro-Ordovician passive margin.

The lower member of the Sandsuck Formation consists of massive quartz arenite, quartz-pebble conglomerate, feldspathic sandstone, and carbonate. Sandsuck Formation carbonates in southeastern Tennessee include fine-grained micrite, calcareous sandstone, and breccia containing carbonate clasts. The depositional regime in which these bedded carbonates were deposited has been disputed. Early studies by Hanselman and others (1974) concluded that the carbonates are shallow-water to subaerial shelf deposits and postulated that the carbonate breccias were produced by subaerial desiccation cracks and solution cavities. Hanselman and others (1974) also suggested that original bedding in some carbonate units was destroyed by burrowing organisms, but reported no discrete trace fossils. Keller (1980) was the first to challenge this view by suggesting that most carbonate allochems and mud that produced these carbonates were originally transported from shallow, shelf- or bank-edge facies into deeper water. Later studies by Rast and Kohles (1986), Naylor and Follo (1988), and Unrug and Unrug (1990) have reconfirmed Keller's (1980) conclusions. Rast and Kohles (1986) suggested that the carbonate bodies were olistoliths and breccias displaced from *in situ* shelf sedimentation atop a basement horst block, but evidence for this basement block capped by a carbonate platform is lacking in the western Blue Ridge stratigraphic record. More recently, Naylor and Follo (1988) and Unrug and Unrug (1990) agreed that the carbonates were olistoliths, and concluded that the carbonates of the Wilhite Formation in the vicinity of the Great Smoky Mountains National Park have facies characteristics indicative of a base-of-slope sedimentary environment along a tectonically active basin margin.

Sedimentological characteristics of the sandstones that enclose these carbonates in southeastern Tennessee may provide important clues to the origin and depositional regime of

both the sandstones and carbonates. The quartz-rich composition of the sandstone, as well as the well-sorted nature of the arenite, the relatively high abundance of heavy minerals, including well-rounded zircon and tourmaline, and the abundance of microcline, suggest that the sandstones may have originally been derived from a deeply eroded granitic terrane and deposited in a high-energy environment such as a beach and dune regime. Unlike a beach and dune environment in which graded and cross beds are common, few sedimentary structures are preserved in the massively bedded sandstones. Although the lack of sedimentary structures may indicate bioturbation, thick beds (usually greater than 3.0 m) of this sandstone precludes the possibility of bioturbation and suggests that the sandstone probably originated in a shallow-water environment, but was subsequently transported offshore and deposited as a slump in a base-of-slope regime. During down-slope transport, carbonate clasts were incorporated into the quartz-rich multicycle sand slurry.

Finding the source of these Walden Creek Group carbonates has been as difficult as deciphering the depositional regime in which they were deposited. Rast and Kohles (1986) suggested a carbonate platform developed atop a basement horst block that separated the Ocoee Supergroup into two successions. More recently, Unrug and Unrug (1990) proposed the source of the carbonate was the Cambro-Ordovician carbonate platform sequence of southeastern Laurentia. Because these carbonates in southeastern Tennessee cannot be younger than Early Cambrian based on the stratigraphic continuity of Sandsuck Formation rocks with Lower Cambrian Chilhowee Group rocks, and no evidence of Rast and Kohles' (1986) carbonate shelf is preserved in the western Blue Ridge stratigraphic sequence, neither proposal for the source of these carbonates is viable.

An alternative hypothesis is that the source of these carbonate clasts was the Murphy Marble. Previous work by Keith (1907a) tentatively correlated the Murphy Marble with the Shady Dolomite, based entirely on gross similarities between the two formations. I propose that the Murphy Marble is an eastern carbonate facies of the Walden Creek Group. As previously

suggested, coarse-grained beach and dune sands may have been transported down slope as slurries from the edge of the basin, probably along localized submarine channels. These slurries of near-shore sands may have incorporated clasts of Murphy carbonate in transit to the final base-of-slope depositional area. The paleogeographic extent of the Murphy Marble is unknown because Paleozoic deformation and subsequent Tertiary erosion has removed most of the western Blue Ridge stratigraphic sequence north and west of the Murphy syncline. In the late Proterozoic, the Murphy Marble may have extended much farther west than now recognized and could have easily provided large quantities of carbonate detritus into the Walden Creek Group depositional basin.

Evidence for final reactivations along the basin margin may be recorded in the rocks of the middle and upper members of the Sandsuck Formation. These reactivations possibly mark the final periods of rifting prior to the opening of Iapetus. Ungraded and unsorted feldspathic graywacke conglomerate of the middle member (lower lithofacies) of the Sandsuck Formation, consisting of quartz pebbles and angular feldspar grains suspended in a finer-grained matrix, suggest rapid deposition as a down-slope slurry initiated by brief periods of uplift and derived from a nearby (northwesterly?) source. Quartz-pebble conglomerate lenses within the middle member (lower lithofacies) were also probably deposited in a similar setting. Carbonate clasts within the conglomerates suggest that they were derived from a shallow-water carbonate shelf, but the paleogeographic location of this shelf is unknown. Fine-grained units within the middle member suggest that uplift was short-lived. Coarse-grained micaceous and arkosic sand deposits of the middle member may have originated as slumps along an oversteepened unstable slope rather than represent detritus from renewed uplift.

Even limited reactivation along the basin margins is interpreted to have ceased by the time sediments of the upper member of the Sandsuck Formation were deposited. Thin, ungraded lenses of feldspathic and arkosic quartz-pebble conglomerate may represent slump deposits derived from an oversteepened slope rather than detritus from renewed uplift. Likewise, the

very local, thin deposit of carbonate breccia near the top of the upper member probably represents redeposition of carbonate clasts derived from a carbonate shelf by slumping. The unit as a whole appears to have developed as broad, deltaic deposits, with localized deposition of carbonate rocks between deltaic lobes. Because uplift appears to have ceased by the time these sediments were deposited, the upper member of the Sandsuck Formation may represent stabilization of the rifted Laurentian margin and may also signal the initial development of the Cambro-Ordovician passive margin of the newly opened Iapetus Ocean. By the time sediments of the Cochran and higher Chilhowee Group formations were deposited, stable passive margin sedimentation was occurring along the entire southeastern margin of Laurentia.

Structural chronology of the Laurentian margin, southeastern Tennessee and western North Carolina

Until the recent report of Paleozoic microfossils from the Walden Creek Group (Unrug and Unrug, 1990; Unrug and others, 1991), traditional interpretation suggested that the stratigraphic record of the southeastern Laurentian margin preserved evidence for at least two periods of intense deformation after stabilization of the rifted margin, including an Early Ordovician (Taconic or Blountian) event and a late Paleozoic (Alleghanian) event (Drake and others, 1989; Hatcher and others, 1989b). Unrug and others (1991, p. 34-35), however, proposed that "transpressive oblique convergence" along the Laurentian plate boundary during the Acadian orogeny formed "transtensional grabens" into which sediments of the Ocoee Supergroup were deposited. Regional metamorphism and other deformation in the western Blue Ridge was proposed by Unrug and others (1991, p. 35) to be no older than "post-earliest Mississippian" and related to only to the Alleghanian orogeny. Deformation of rocks as young as Pennsylvanian in the Tennessee portion of the foreland fold-thrust belt provide unequivocal evidence of an Alleghanian event at this latitude (Hatcher and others, 1989b), but vestiges of two Taconic synorogenic clastic wedges are preserved in the Paleozoic stratigraphic record of east

Tennessee (Shanmugam and Lash, 1982; Drake and others, 1989). Radiometric dating, although equivocal, also suggests that a peak metamorphic event occurred in the southern Appalachians between 400 and 480 Ma (Butler, 1973; Dallmeyer, 1975).

Structural analysis of the study area indicates polyphase deformation, including an early event characterized by regional metamorphism, folding, and the development of axial-planar slaty cleavage, and a younger brittle stage dominated by faulting. This polyphase deformation suggests that more than one regional orogeny may have affected western Blue Ridge rocks, contrary to the tectonic model proposed by Unrug and others (1991, p. 35), but the older tectonic event cannot be definitively correlated with either the Taconic or Acadian orogenies. It is also possible that the polyphase deformation represents two or more stages within one regional orogeny. Following the interpretations of some previous workers in the western Blue Ridge, however, regional metamorphism in the study area is inferred to be related to the Taconic orogeny (Eckelmann and others, 1959; Neuman and Nelson, 1965; Butler, 1972; Dallmeyer, 1975; Connelly and Dallmeyer, 1991), and regional brittle thrusting is interpreted to be a product of the Alleghanian orogeny (Keith, 1927; Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965; Woodward and others, 1991) (Fig. IV-2).

Structural chronology of the western Blue Ridge, southeastern Tennessee

After deposition and lithification, rocks of the syn- and post-rift Ocoee, Chilhowee, and younger formations along the Laurentian margin were initially deformed during the Ordovician Taconic orogeny. Early in this orogenic event, western Blue Ridge rocks in southeastern Tennessee were deformed by gentle to open 5th- and higher-order F_1 folds (Fig. IV-2). Farther to the northeast, the Rabbit Creek, Line Springs, Dunn Creek, and Greenbrier faults propagated through the thinner stratigraphic section while map-scale folds developed. During the peak of the metamorphic event, western Blue Ridge rocks along the Laurentian margin were synchronously metamorphosed (up to sillimanite grade to the east) and regionally folded. Axial-

Figure IV-2: Orogenic evolution diagram of the Late Proterozoic to late Paleozoic Laurentian margin in southeastern Tennessee.

<i>Time</i>	<i>Event</i>	<i>Metamorphism</i>	<i>Structures</i>
Permian 286 Ma	<i>Alleghanian orogeny</i>		faulting F₄ F₃ S₃ S_{3a}
Carboniferous 310 Ma P 360 Ma M			
Devonian 407 Ma	<i>Acadian orogeny</i>	restricted to the eastern Blue Ridge and Piedmont	
Silurian 438 Ma			
Ordovician 505 Ma	<i>Taconic orogeny</i>		F₁ F₂ S₂ S_{2a}
Cambrian 570 Ma			
<i>Late Proterozoic</i>	<i>Rifting</i>		S₀ F₀

planar slaty cleavage developed in rocks metamorphosed up to biotite grade; this cleavage transected earlier folds throughout the region. In the southeastern Tennessee Foothills belt, Taconic metamorphism (up to biotite grade) initiated the development of open to closed 1st- and higher-order F_2 folds and axial-planar slaty cleavage (S_2) that overprinted earlier F_1 folds (Fig. IV-2). Regional strain measurements record this period of intense deformation. During the waning stages of this event, pressure-solution cleavage (S_{2a}) may have developed coeval with F_2 folds and S_2 cleavage. Taconic metamorphism and related macro-, meso-, and microstructures account for most of the deformation preserved in rocks of the western Blue Ridge in southeastern Tennessee.

An alternative hypothesis is that regional western Blue Ridge metamorphism is related to the Devonian Acadian orogeny (Aldrich and others, 1958; Long and others, 1959; Hamilton, 1961; Hadley and Goldsmith, 1963; Tull, 1982) or the late Paleozoic Alleghanian orogeny (Unrug and others, 1991; Gastaldo and others, 1993). Acadian metamorphism and deformation in the southern Appalachians is speculated to be restricted to rocks east of the Hayesville fault (Butler, 1973; Odom and Fullagar, 1973; Kish, 1977; Butler and Fullagar, 1978; Hatcher, 1978; Lemmon, 1982; Glover and others, 1983; Dallmeyer, 1988). Uncorroborated microfossil evidence from the western Blue Ridge Foothills belt (Unrug and Unrug, 1990; Unrug and others, 1991) and rediscovered macrofossil plant remains from the western Blue Ridge of Alabama (Gastaldo and others, 1993) have led these workers to postulate that the regional metamorphism in the western Blue Ridge is associated with the Alleghanian orogeny. If western Blue Ridge metamorphism does represent an Acadian or Alleghanian event, F_2 folds and related axial-planar slaty cleavage would also have to be interpreted as Acadian or Alleghanian structures. This hypothesis implies that the only preserved structural vestiges of the Taconic orogeny in the western Blue Ridge may be the Greenbrier and other premetamorphic thrust systems in the vicinity of the Great Smoky Mountains National Park and regional F_1 folds that are transected by younger Paleozoic slaty cleavage.

The second orogenic event to deform rocks along the Laurentian margin at this latitude was the late Paleozoic Alleghanian orogeny. Alleghanian deformation, specifically the emplacement of the composite Blue Ridge megathrust sheet onto the Laurentian platform, accounts for the development of the laterally extensive foreland fold-thrust belt in the central and southern Appalachians, and Alleghanian metamorphism and overprinting structures are widespread throughout the igneous and metamorphic core of the mountain chain (Hatcher and others, 1989b). Structures attributed to the Alleghanian orogeny are preserved in rocks in the southeastern Tennessee Foothills belt and include foliations, folds and regional brittle thrust faults. Other than thrust faulting, most Alleghanian meso- and microstructures appear to have only mildly deformed western Blue Ridge rocks when compared to older, regionally penetrative Taconic structures, but the recognition and location of these Alleghanian structures provides important clues to the timing of emplacement and subsequent deformation of the three western Blue Ridge thrust sheets in the study area.

Unequivocal evidence for the Alleghanian orogeny in the western Blue Ridge is the development of the Blue Ridge fault system along the entire length of the Laurentian margin. Westward movement along this fault system transported rocks of the Blue Ridge megathrust sheet, including rocks of the study area along its westernmost edge, to their final emplacement on the Laurentian platform. The Miller Cove, Maggies Mill, and Great Smoky faults form the westernmost frontal thrusts in southeastern Tennessee and probably formed as a forward-breaking thrust sequence. Faulted Mississippian rocks in the footwall of the Great Smoky fault west of Chilhowee Mountain (Fig. I-2) provide direct evidence that at least these frontal Blue Ridge faults developed during the Alleghanian orogeny.

Synchronous with brittle faulting in southeastern Tennessee was the development of crenulation cleavage (S_3), spaced cleavage (S_{3a}), and F_3 folds. During the final emplacement of the frontal Blue Ridge thrust sheets throughout the region, footwall rocks were duplexed and hanging wall rocks were gently folded into F_4 folds. North of the study area, windows that

expose duplexed footwall rocks, and regionally folded cleavage along the Little Tennessee River, provide direct evidence for this period of footwall deformation (Neuman, 1951; King, 1964; Neuman and Nelson, 1965; Livingston, 1978; Hatcher and others, 1989a). Duplexing in the footwall and gentle folding in the hanging wall of the frontal Blue Ridge thrust sheets signaled the end of deformation along this portion of the Laurentian margin in southeastern Tennessee.

Chapter V

Conclusions

- 1) Metasedimentary rocks of three major Upper Proterozoic to Lower Cambrian western Blue Ridge lithostratigraphic units (upper formations of the Great Smoky Group [oldest], the Walden Creek Group, and lower formations of the Chilhowee Group [youngest]), are exposed in the frontal fault blocks of the Blue Ridge province in the study area. In addition to these units, unmetamorphosed Paleozoic rocks of the Valley and Ridge (Rome Formation, and Conasauga and Knox groups) are also exposed beneath the western Blue Ridge thrust sheets in the study area.
- 2) A conformable contact exists between the Great Smoky and Walden Creek Groups in the eastern part of the study area. This contact, previously mapped as the southern continuation of the Greenbrier fault south of the Great Smoky Mountains region, is marked by several distinctive lithologies of the Buck Bald Formation (Great Smoky Group), including granitoid-boulder metaconglomerate, quartz-pebble metaconglomerate, and feldspathic graywacke-granule metaconglomerate. Walden Creek Group rocks (Wilhite Formation) above the contact consist of banded metasilstone, feldspathic metasandstone, and feldspathic graywacke metasandstone.
- 3) The Sandsuck Formation (Walden Creek Group) is exposed along the western edge of the study area, and is divisible into three members. The lower member consists of carbonate (micrite, calcareous sandstone, and carbonate breccia), quartz arenite, and feldspathic sandstone. These rocks are separated from rocks of the Wilhite Formation to the east by the Miller Cove fault. To the west, the Maggies Mill fault separates these rocks from those of the upper members of the Sandsuck Formation. Quartz arenite is present in both the hanging wall and footwall of the Maggies Mill fault, and lithologically relates rocks of the lower member of the Sandsuck

Formation to the middle and upper members to the west.

4) Sandsuck Formation rocks are conformably overlain by rocks of the Lower Cambrian Chilhowee Group along the western edge of the study area. Here, thick sandstone beds and thinner beds of shale (upper member of the Sandsuck Formation) grade vertically into massive sandstone and conglomerate (Cochran Formation). This conformable contact indicates that at least the middle and upper members of the Sandsuck Formation in the study area cannot be younger than Early Cambrian.

5) Four major brittle thrust faults, four S-surfaces, and four generations of folds deform the metasedimentary rocks in the study area. These thrust faults (the Miller Cove, Maggies Mill, Great Smoky, and Bullet Mountain faults) divide the study area into four thrust sheets. The Miller Cove fault juxtaposes chlorite-grade rocks against anchizone metamorphosed rocks of the Maggies Mill and Great Smoky thrust sheets. The Great Smoky fault transported western Blue Ridge rocks over unmetamorphosed rocks of the Valley and Ridge. The Bullet Mountain fault may be the floor fault to a duplex that developed beneath the frontal edge of the western Blue Ridge thrust sheet in southeastern Tennessee.

6) The Miller Cove thrust sheet contains F_1 folds which are overprinted by regional F_2 folds and axial-planar slaty cleavage (S_2). F_2 folds and S_2 are related to regional metamorphism. Pressure-solution cleavage (S_{2a}), crenulation cleavage (S_3), and F_3 folds also deform rocks in the Miller Cove thrust sheet. Rocks in the Great Smoky and Maggies Mill thrust sheets are locally deformed by F_2 folds and S_2 , but dominant structures in these thrust sheets include F_3 folds and spaced cleavage (S_{3a}). Rocks of the Bullet Mountain thrust sheet are only deformed by F_3 folds and spaced cleavage (S_{3a}). F_4 folds are the youngest structures in the study area and fold rocks in the Miller Cove, Maggies Mill, and Great Smoky thrust sheets.

7) Strain analysis (normalized Fry and R_f/ϕ techniques) suggests that western Blue Ridge rocks in the study area were deformed by one strain event. Strain values throughout the study area are low ($R_s = 1.03$ to 1.78), but increase toward the southeast, parallel to increasing deformation. Strain ellipsoids calculated in this study may record non-coaxial incremental strains produced during the F_2 and S_2 event, or they may represent a strain event that developed prior to regional F_2 and S_2 deformation.

8) The Ocoee depositional basin is interpreted to have evolved during Late Proterozoic rifting of the Laurentian margin. Periods of rifting and quiescence along both margins of the basin, followed by stabilization of the rift basin and passive margin sedimentation, produced the complex stratigraphy of the western Blue Ridge.

9) The Wilhite Formation may be the western equivalent of the Nantahala and Brasstown formations, and the Murphy Marble. Carbonate clasts within breccias of the lower member of the Sandsuck Formation may have been derived from the Murphy Marble and deposited as base-of-slope slumps.

10) Deformation along the Laurentian margin occurred during the Taconic and Alleghanian orogenies. Regional metamorphism and F_1 folds, F_2 folds, axial-planar slaty cleavage (S_2), and pressure-solution cleavage (S_{2a}) were produced during the Taconic orogeny. During the Alleghanian orogeny, brittle thrust faults transported previously deformed Blue Ridge rocks westward over unmetamorphosed rocks of the Valley and Ridge. F_3 folds, crenulation cleavage (S_3), and spaced cleavage (S_{3a}) also developed during this orogeny. F_4 folds developed after the emplacement of the Miller Cove and Maggie's Mill faults. Duplexing of footwall rocks may have occurred during the emplacement of the western Blue Ridge thrust sheets.

References Cited

References Cited

- Aldrich, L. T., Wetherill, G. W., Davis, G. L., and Tilton, G. R., 1959, Radioactive ages of micas from granitic rocks by Rb-Sr and K-Ar methods: *Transactions, American Geophysical Union*, v. 39, p. 1124-1134.
- Alvarez, W., Engelder, T., and Geiser, P. A., 1978, Classification of solution cleavage in pelagic limestones: *Geology*, v. 6, p. 263-266.
- Ausburn, M. P., 1983, Stratigraphy, structure, and petrology of the northern half of the Tipton quadrangle, North Carolina [M. S. thesis]: Tallahassee, Florida, Florida State University, 174 p.
- Aylor, J. G., Jr., 1991, Stratigraphy of the Nantahala and Brasstown formations, Hiwassee River group, North Carolina, *in* Kish, S. A., ed., *Studies of Precambrian and Paleozoic stratigraphy in the western Blue Ridge: Carolina Geological Society Guidebook*, p. 87-95.
- Broadhead, T. W., Hatcher, R. D., Jr., and Costello, J. O., 1991, Tectonic and stratigraphic implications of mid-Paleozoic (?) fossils from the Late Proterozoic (?) Walden Creek Group rocks in the foothills belt, eastern Tennessee, *in* Kish, S. A., ed., *Studies of Precambrian and Paleozoic stratigraphy in the western Blue Ridge: Carolina Geological Society Guidebook*, p. 39-44.
- Broadhead, T. W., Hatcher, R. D., Jr., Walker, K. R., Lewis, R. F., III, Carter, M. W., and Adefuin, J. Y., 1993, Age of Walden Creek Group: Can it be demonstrated-biostratigraphically?: *Geological Society of America Abstracts with Programs*, v. 25, p. 5.
- Brown, P. M., 1985, Geologic map of North Carolina: North Carolina Geological Survey, scale 1:500,000.
- Butler, J. R., 1972, Age of regional metamorphism in the Carolinas, Georgia, and Tennessee southern Appalachians: *American Journal of Science*, v. 272, p. 319-333.
- Butler, J. R., 1973, Paleozoic deformation and metamorphism in part of the Blue Ridge thrust sheet, North Carolina: *American Journal of Science*, v. 273-A (Cooper volume), p. 72-88.
- Butler, J.R., and Fullagar, P.D., 1978, Petrochemical and geochronological studies of plutonic rocks in the southern Appalachians: III. Leucocratic adamellites of the Charlotte belt near Salisbury, North Carolina: *Geological Society of America Bulletin*, v. 89, p. 460-466.
- Campbell, M. R., 1899, Description of the Bristol quadrangle (Virginia-Tennessee): U. S. Geological Survey Geologic Atlas, Folio 59, 6 p.
- Carter, M. W., Martin, S. L., Geddes, D. J., Hatcher, R. D., Jr., Lombardi, C. E., and Costello, J. O., 1993, Western Blue Ridge tectonics of southeastern Tennessee, northern Georgia, and southwest North Carolina-Preliminary results, Part I: Structure: *Geological Society of America Abstracts with Programs*, v. 25, p. 484.
- Carter, N. L., 1971, Static deformation of silica and silicates: *Journal of Geophysical Research*, v. 76, p. 5514-5540.

- Carter, N. L., Christie, J. M., and Griggs, D. T., 1964, Experimental deformation and recrystallization of quartz: *Journal of Geology*, v. 72, p. 687-733.
- Connelly, J. B., 1993, Structural development, strain history, and timing of deformation in the eastern Great Smoky Mountains [Ph. D. Thesis]: Knoxville, Tennessee, University of Tennessee, 178 p.
- Connelly, J. B., and Dallmeyer, R. D., 1990, Ordovician or Silurian metamorphism in the western Blue Ridge, Tennessee? Evidence from $^{40}\text{Ar}/^{39}\text{Ar}$ whole rock phyllite ages: *Geological Society of America Abstracts with Programs*, v. 22, p. 231.
- Connelly, J. B., and Dallmeyer, R. D., 1991, Polymetamorphic evolution of the western Blue Ridge, Tennessee and North Carolina; Evidence from $^{40}\text{Ar}/^{39}\text{Ar}$ ages: *Geological Society of America Abstracts with Programs*, v. 23, p. 18.
- Connelly, J. B., and Dunne, W. M., 1993, Strain variations and strain factorization within an external crystalline thrust system, Great Smoky Mountains, Tennessee: *Geological Society of America Abstracts with Programs*, v. 25, p. 231.
- Connelly, J. B., and Woodward, W. B., 1992, Taconian foreland-style thrust system in the Great Smoky Mountains, Tennessee: *Geology*, v. 20, p. 177-180.
- Cook, F. A., Brown, L. D., Kaufman, S., and Oliver, J. E., 1983, The COCORP seismic reflection traverse across the southern Appalachians: *American Association of Petroleum Geologists Studies in Geology* no. 14, 61 p.
- Costello, J. O., 1978, Shear zones in the Corbin gneiss of Georgia, *in* Short contributions to the geology of Georgia: *Georgia Geological Survey Bulletin* 93, p. 32-37.
- Costello, J. O., 1984, Relationships between the Cartersville fault and Great Smoky fault in the southern Appalachians: A reinterpretation [M.S. thesis]: Columbia, South Carolina, University of South Carolina, 75 p.
- Costello, J. O., 1986, Corbin gneiss complex: Southernmost exposures of Grenville basement in the Appalachian Blue Ridge: *Geological Society of America Centennial Field Guide, Southeastern Section*, p. 277-280.
- Costello, J. O., 1991, Structural and metamorphic variations within the southern Appalachian foreland/hinterland transition zone: *Geological Society of America Abstracts with Programs*, v. 23, p. 18.
- Costello, J. O., and Hatcher, R. D., Jr., 1986, Contact relationships between the Walden Creek Group and Great Smoky Group in Ocoee Gorge, Tennessee: Implications for the regional extent of the Greenbrier fault: *Geological Society of America Abstracts with Programs*, v. 18, p. 216.
- Costello, J. O., and Hatcher, R. D., Jr., 1991, Problems of stratigraphic correlation between Great Smoky, Snowbird, and Walden Creek Groups between the Great Smoky National Park, central east Tennessee, and Ocoee Gorge, southeastern Tennessee, *in* Kish, S. A., ed., *Studies of Precambrian and Paleozoic stratigraphy in the western Blue Ridge: Carolina Geological Society Guidebook*, p. 13-25.

- Costello, J. O., McConnell, K. I., and Power, W. R., 1982, Geology of Late Precambrian and Early Paleozoic rocks in and near the Cartersville district, Georgia: Georgia Geological Society, 17th Annual Field Trip guidebook, 41 p.
- Couzens, B. A., Dunne, W. M., Onasch, C. M., and Glass, R., 1993, Strain variations and three-dimensional strain factorization at the transition from the southern to the central Appalachians: *Journal of Structural Geology*, v. 15, p. 451-464.
- Cressler, C. W., Blanchard, H. E., Jr., and Hester, W. G., 1979, Geohydrology of Bartow, Cherokee, and Forsyth Counties, Georgia: Georgia Geological Survey Information Circular 50, 45 p.
- Crickmay, G. W., 1936, Status of the Talladega Series in southern Appalachian stratigraphy: *Geological Society of America Bulletin*, v. 47, p. 1371-1392.
- Dallmeyer, R. D., 1975, Incremental $^{40}\text{Ar}/^{39}\text{Ar}$ ages of biotite and hornblende from retrograde basement gneisses of the southern Blue Ridge: Their bearing on the age of Paleozoic metamorphism: *American Journal of Science*, v. 275, p. 444-460.
- DeWindt, J. T., 1975, Geology of the Great Smoky Mountains, Tennessee and North Carolina, with road log for field excursion, Knoxville-Clingmans Dome-Maryville: *Compass*, v. 52, p. 73-129.
- Diggle, P. J., and Fisher, N. I., 1985, SPHERE: A contouring program for spherical data: *Computers and Geoscientists*, v. 11, p. 725-766.
- Donath, F. A., and Parker, R. B., 1964, Folds and folding: *Geological Society of America Bulletin*, v. 75, p. 45-62.
- Drake, A. A., Jr., Sinha, A. K., Laird, J., and Guy, R. E., 1989, The Taconic orogen, Chapter 3, in Hatcher, R. D., Jr., Thomas, W. A., and Viele, G. W., eds., *The Appalachian-Ouachita orogen in the United States*: Boulder, Colorado, Geological Society of America, *The Geology of North America*, v. F-2, p. 101-177.
- Dunnet, D., 1969, A technique of finite strain analysis using elliptical particles: *Tectonophysics*, v. 2, p. 117-136.
- Dunnet, D., and Siddans, A. W. B., 1971, Non-random sedimentary fabrics and their modification by strain: *Tectonophysics*, v. 12, p. 307-325.
- Ecklemann, F. D., Kulp, J. L., and Long, L., 1959, Tentative chronology of metamorphic-plutonic events in the southern Appalachians based on new K/A and Rb/Sr age determinations: *Geological Society of America Bulletin*, v. 70, p. 1761.
- Engelder, T., and Geiser, P., 1979, The relationship between pencil cleavage and lateral shortening within the Devonian section of the Appalachian Plateau, New York: *Geology*, v. 7, p. 460-464.
- Erslev, E. A., 1988, Normalized center-to-center strain analysis of packed aggregates: *Journal of Structural Geology*, v. 10, p. 201-209.
- Fairbairn, H. W., 1941, Deformation lamellae in quartz from the Ajibik Formation, Michigan: *Geological Society of America Bulletin*, v. 52, p. 1265-1278.

- Fairley, W. M., 1965, The Murphy syncline in the Tate quadrangle, Georgia: Georgia Geological Survey Bulletin 75, 71 p.
- Flinn, D., 1962, On folding during three – dimensional progressive deformation: Geological Society of London Quarterly Journal, v. 118, p. 385–433.
- Fry, N. 1979, Random point distributions and strain measurement in rocks: Tectonophysics, v. 60, p. 89-105.
- Fullagar, P. D., and Butler, J. R., 1976, Timing of Paleozoic igneous activity in the southern Piedmont and Blue Ridge: Geological Society of America Abstracts with Programs, v. 8, p. 178.
- Furcron, A. S., 1953, Comments on the geology of the Ellijay quadrangle, Georgia-North Carolina-Tennessee: Georgia Geological Survey Bulletin 60, p. 32-40.
- Gastaldo, R. A., Guthrie, G. M., and Steltenpohl, M. G., 1993, Mississippian fossils from southern Appalachian metamorphic rocks and their implications for late Paleozoic tectonic evolution: Science, v. 262, p. 732-734.
- Glover, L., III, Speer, J. A., Russell, G. S., and Farrar, S. S., 1983, Ages of regional metamorphism and ductile deformation in the central and southern Appalachians: Lithos, v. 16, p. 223–245.
- Gordon, C. H., 1920, Notes on the geology of the cove areas of east Tennessee: Science, v. 51, p. 492-493.
- Gray, D. R., 1977, Morphologic classification of crenulation cleavage: Journal of Geology, v. 85, p. 229–235.
- Gray, D. R., and Durney, D. W., 1979, Crenulation cleavage differentiation: implications of solution–deposition processes: Journal of Structural Geology, v. 1, p. 75–80.
- Groshong, R. H., Jr., 1988, Low-temperature deformation mechanisms and their interpretation: Geological Society of America Bulletin, v. 100, p. 1329-1360.
- Groshong, R. H., Jr., Pfiffner, O. A., and Pringle, L. R., 1984, Strain partitioning in the Helvetic thrust belt of eastern Switzerland from the leading edge to the internal zone: Journal of Structural Geology, v. 6, p. 5–18.
- Hadley, J. B., 1970, The Ocoee Series and its possible correlatives, *in* Fisher, G. W., Pettijohn, F. J., Reed, J. C., and Weaver, K. N., eds., Studies in Appalachian geology: Central and southern: New York, Wiley Interscience, p. 247-260.
- Hadley, J. B., and Goldsmith, R., 1963, Geology of the eastern Great Smoky Mountains, North Carolina and Tennessee: U. S. Geological Survey Professional Paper 349-B, 118 p.
- Hamilton, W. B., 1961, Geology of the Richardson Cove and Jones Cove quadrangles, Tennessee: U. S. Geological Survey Professional Paper 349-C, 55 p.
- Hanselman, D. H., Connolly, J. R., and Home, J. C., 1974, Carbonate environments in the Wilhite Formation of eastern Tennessee: Geological Society Bulletin, v. 85, p. 45-50.

- Hardeman, W. D., 1966, Geologic map of Tennessee: Tennessee Division of Geology, scale 1:250,000
- Harris, L. D., and Milici, R. C., 1977, Characteristics of thin-skinned style of deformation in the southern Appalachians, and potential hydrocarbon traps: U.S. Geological Survey Professional Paper 1018, 40 p.
- Hatcher, R. D. Jr., 1989, Tectonic synthesis of the U. S. Appalachians *in* Hatcher, R. D., Jr., Thomas, W. A., and Viele, G. W., eds., The Appalachian – Ouachita Orogen in the United States: Boulder, Geological Society of America, The Geology of North America, v. F-2, p. 7–100.
- Hatcher, R. D. Jr., and Hopson, J. L., 1989, Geology of the eastern Blue Ridge of northeastern Georgia, South Carolina, and adjacent North Carolina: Georgia Geological Society Guidebook, v. 9, no. 3, Plate 1.
- Hatcher, R. D. Jr., Costello, J. O., and Broadhead, T. W., 1991, Stop 2 - Carbonate in Walden Creek Group-Sandsuck Formation, *in* Kish, S. A., ed., Studies of Precambrian and Paleozoic stratigraphy in the western Blue Ridge: Carolina Geological Society Guidebook, p. 79-86.
- Hatcher, R. D., Jr., 1978, Tectonics of the western Piedmont and Blue Ridge, southern Appalachians: Review and speculation: American Journal of Science, v. 278, p. 276-304.
- Hatcher, R. D., Jr., and Butler, J. R., 1979, Guidebook for southern Appalachian field trip in the Carolinas, Tennessee, and northeastern Georgia: International Geological Correlation Program Project 27, University of North Carolina, Chapel Hill, 117 p.
- Hatcher, R. D., Jr., and Goldberg, S. A., 1991, The Blue Ridge province, *in* Horton, J. W., Jr., and Zullo, V. A., eds., The Geology of the Carolinas—Carolina Geological Society 50th Anniversary Volume: Knoxville, The University of Tennessee Press, p. 11–35.
- Hatcher, R. D., Jr., Larson, K. W., and Neuman, R. B., 1989a, Western Great Smoky Mountains windows: The foothills duplex *in* Hatcher, R. D., Jr. and Thomas, W. A., 1989, Southern Appalachian windows: Comparison of styles, scales, geometry, and detachment levels of thrust faults in the foreland and internides of a thrust-dominated orogen: 27th International Geological Congress Field Trip Guidebook T167, p. 49-60.
- Hatcher, R. D., Jr., Thomas, W. A., Geiser, P. A., Snoke, A. W., Mosher, S., and Wiltschko, D. V., 1989b, Alleghanian orogen, Chapter 5, *in* Hatcher, R. D., Jr., Thomas, W. A., and Viele, G. W., eds., The Appalachian–Ouachita orogen in the United States: Boulder, Colorado, Geological Society of America, The Geology of North America, v. F-2, p. 233–318.
- Hayes, C. W., 1891, The overthrust faults of the southern Appalachians: Geological Society of America Bulletin, v. 2, p. 141 - 152.
- Hayes, C. W., 1895, Description of the Cleveland sheet (Tennessee): U. S. Geological Survey Geologic Atlas, Folio 20, 12 p.
- Hayes, C. W., 1900, Geological relations of the iron-ores in the Cartersville District, Georgia: American Institute of Mining Engineers Transactions, v. 30, p. 403-419.
- Heron, R. M., 1968, Geology of the Ducktown, Isabella, and Persimmon Creek quadrangles, Tennessee and North Carolina: U.S. Geological Survey Open File, 71 p.

- Hernon, R. M., 1969, The Wehuttie Formation of North Carolina, *in* Cohee G. V., Bates, R. G., and Wright, W. B., Changes in stratigraphic nomenclature by the U. S. Geological Survey 1967: U. S. Geological Survey Bulletin 1274-A, p. 49-52.
- Hirth, G., and Tullis, J., 1992, Dislocation creep regimes in quartz aggregates: *Journal of Structural Geology*, v. 14, p. 145-159.
- Hopson, J. L., Hatcher, R. D., Jr., and Stieve, A. L., 1989, Geology of the eastern Blue Ridge, northeastern Georgia and the adjacent Carolinas, *in* Fritz, W. J., Hatcher, R. D., Jr., and Hopson, J. L., eds., *Geology of the eastern Blue Ridge of northeast Georgia and the adjacent Carolinas: Georgia Geological Society Guidebooks*, v. 9, p. 1-40.
- Hurst, V. J., 1955, Stratigraphy, structure, and mineral resources of the Mineral Bluff quadrangle, Georgia: *Georgia Geological Survey Bulletin* 63, 137 p.
- Hurst, V. J., and Schlee, J. S., 1962, Ocoee metasediments, north-central Georgia, southeastern Tennessee: *Geological Society of America Southeastern Section Meeting Guidebook* 3, Georgia Geological Survey, 28 p.
- Ingerson, E., and Tuttle, O. F., 1945, Relations of lamellae and crystallography of quartz and fabric directions in some deformed rocks: *American Geophysical Union, Transactions*, v. 26, p. 95-105.
- Jonas, A. I., 1932, Structure of the metamorphic belt of the southern Appalachians: *American Journal of Science*, v. 24, p. 228-243.
- Keith, A., 1895, Description of the Knoxville Sheet (Tennessee and North Carolina): U. S. Geological Survey *Geologic Atlas*, Folio 16, 6 p.
- Keith, A., 1896, Description of the Loudon sheet (Tennessee): U. S. Geological Survey *Geologic Atlas*, Folio 25, 6 p.
- Keith, A., 1902, Folded faults in the southern Appalachians: *Science*, v. 15, p. 822-823.
- Keith, A., 1903, Description of the Cranberry quadrangle (North Carolina-Tennessee): U. S. Geological Survey *Geologic Atlas*, Folio 90, 9 p.
- Keith, A., 1904, Description of the Asheville quadrangle (Tennessee and North Carolina): U. S. Geological Survey *Geologic Atlas*, Folio 116, 10 p.
- Keith, A., 1907a, Description of the Nantahala quadrangle (North Carolina and Tennessee): U. S. Geological Survey *Geologic Atlas*, Folio 143, 11 p.
- Keith, A., 1907b, Description of the Roan Mountain quadrangle (Tennessee-North Carolina): U. S. Geological Survey *Geologic Atlas*, folio 151, 12 p.
- Keith, A., 1927, Great Smoky overthrust: *Geological Society of America Bulletin*, v. 38, p. 154-155.
- Kellberg, J. M., and Grant, L. F., 1956, Coarse conglomerates of the Middle Ordovician in the southern Appalachian valley: *Geological Society of America Bulletin*, v. 67, p. 697-716.

- Keller, F. B., 1980, Late Precambrian stratigraphy, depositional history, and structural chronology of part of the Tennessee Blue Ridge [Ph. D. Thesis]: New Haven, Connecticut, Yale University, 353 p.
- King, P. B., 1949, The base of the Cambrian in the southern Appalachians: *American Journal of Science*, v. 247, p. 513 - 530, 622 - 645.
- King, P. B., 1955, A geologic cross section across the southern Appalachians, an outline of the geology in the segment in Tennessee, North Carolina, and South Carolina, *in* Russell, R. J., ed., *Guides to southeastern geology: Geological Society of America Annual Meeting*, p. 332-373.
- King, P. B., 1964, Geology of the central Great Smoky Mountains, Tennessee: U. S. Geological Survey Professional Paper 349-C, 148 p.
- King, P. B., and Ferguson, H. W., 1960, *Geology of northeasternmost Tennessee: Geological Survey Professional Paper 311*, 136 p.
- King, P. B., Ferguson, H. W., Craig, L. C., and Rodgers, J., 1944, Geology and manganese deposits of northeastern Tennessee: *Tennessee Division of Geology Bulletin* 52.
- King, P. B., Hadley, J. B., Neuman, R. B., and Hamilton, W. B., 1958, Stratigraphy of the Ocoee Series, Great Smoky Mountains, Tennessee and North Carolina: *Geological Society of America Bulletin*, v. 69, p. 947-966.
- Kish, S. A., 1974, The structural and metamorphic history of the northern terminus of the Murphy belt [M. S. thesis]: Tallahassee, Florida State University, 131 p.
- Kish, S. A., 1977, Geochronology of plutonic activity in the inner Piedmont and Kings Mountain belt in North Carolina, *in* Burt, E. R., ed., *Field guides for the Geological Society of America Southeastern Section Meeting*, Winston-Salem, North Carolina: Raleigh, North Carolina Department of Natural and Economic Resources, Geology and Mineral Resources Section, p. 144-149.
- Kish, S. A., 1989, Igneous and metamorphic history of the eastern Blue Ridge, southwestern North Carolina: K-Ar and Rb-Sr studies *in* Fritz, W. J., Hatcher, R. D., Jr., and Hopson, J. L., eds., *Geology of the eastern Blue Ridge of northeast Georgia and the adjacent Carolinas: Georgia Geological Society Guidebook*, v. 9, p. 41-55.
- Kish, S. A., 1991, Potassium-argon dating in the western Blue Ridge of North Carolina and Tennessee, *in* Kish, S. A., ed., *Studies of Precambrian and Paleozoic stratigraphy in the western Blue Ridge: Carolina Geological Society Guidebook*, p. 69-77.
- Kligfield, R., Crespi, J., Naruk, S., and Davis, G. H., 1984, Displacement and strain patterns of extensional orogens: *Tectonics*, v. 3, p. 577-609.
- Knipe, R. J., 1989, Deformation mechanisms-recognition from natural tectonites: *Journal of Structural Geology*, v. 11, p. 127-146.
- Knoll, A. H., and Keller, F. B., 1979, Late Precambrian microfossils from the Walden Creek Group, Ocoee Supergroup, Tennessee: *Geological Society of America Abstracts with Programs*, v. 11, p. 185.

- Knoll, A. H., and Swett, K., 1985, Micropaleontology of the Late Proterozoic Veteranen Group, Spitsbergen: *Paleontology*, v. 28, p. 451-473.
- Laajoki, K., 1993, Revision of the lithostratigraphy of the Walden Creek Group in southeastern Tennessee and its implications to the basin models of the Ocoee Supergroup: *Southeastern Section, Geological Society of America Abstracts with Programs*, v. 5, p. 28.
- LaForge, L., and Phalen, W. C., 1913, Description of the Ellijay quadrangle (Georgia-North Carolina-Tennessee): U. S. Geological Survey Geologic Atlas, Folio 187, 18 p.
- Laurence, R. A., and Palmer, A. R., 1963, Age of the Murray Shale and Hesse Quartzite on Chilhowee Mountain, Blount County, Tennessee: U. S. Geological Survey Professional Paper 475-C, p. C53-C54.
- Lemmon, R. E., 1982, Evidence for an Acadian tectonic event in the western Inner Piedmont: *Geological Society of America Abstracts with Programs*, v. 14, p. 34.
- Lewis, J. C., 1988, Structural geology and finite strain analysis of the Precambrian Thunderhead Sandstone along the Greenbrier fault and the Roundtop klippe [M. S. thesis]: Knoxville, University of Tennessee, 186 p.
- Lisle, R. J., 1977, Clastic grain shape and orientation in relation to cleavage from the Aberystwyth Grits, Wales: *Tectonophysics*, v. 39, p. 381-395.
- Lisle, R. J., 1985, Geological strain analysis: A manual for the R_f/ϕ method: New York, Pergamon Press, 99 p.
- Livingston, J. E., 1978, Structural analysis of the Great Smoky thrust sheet along the Little Tennessee River, Tennessee [M. S. thesis]: Knoxville, University of Tennessee, 112 p.
- Lloyd, G. E., and Knipe, R. J., 1992, Deformation mechanisms accomodating faulting of quartzite under upper crustal conditions: *Journal of Structural Geology*, v. 14, p. 127-143.
- Long, L. E., Kulp, J. L., and Eckelmann, F. D., 1959, Chronology of major metamorphic events in the southeastern United States: *American Journal of Science*, v. 257, p. 585-603.
- Mack, G. H., 1980, Stratigraphy and depositional environments of the Chilhowee Group (Cambrian) in Georgia and Alabama: *American Journal of Science*, v. 280, p. 497-517.
- Marshak, S., and Engelder, T., 1985, Development of cleavage on limestones of a fold-thrust belt in eastern New York: *Journal of Structural Geology*, v. 7, p. 345-359.
- McConnell, K. I., and Costello, J. O., 1980, Guide to geology along a traverse through the Blue Ridge and Piedmont provinces of north Georgia, *in* Frey, R. W., ed., *Excursions in southeastern geology*: American Geological Institute, v. 1, p. 241 - 258.
- McConnell, K. I., and Costello, J. O., 1982, Relationship between Talladega belt rocks and Ocoee Supergroup rocks near Cartersville, Georgia, *in*, Bearce, D. N., Black, W. W., Kish, S. A., and Tull, J. F., eds., *Tectonic studies in the Talledega and Carolina slate belts, southern Appalachian orogen*: Geological Society of America Special Paper 191, p. 19-30.

- McConnell, K. I., and Costello, J. O., 1984, Basement-cover rock relationships along the western edge of the Blue Ridge thrust sheet in Georgia: Geological Society of America Special Paper 194, p. 263-280.
- McKinney, T. F., 1964, Geology along the Great Smoky fault, Groundhog Mountain area, Tellico Plains, Tennessee [M. S. thesis]: Knoxville, University of Tennessee, 49 p.
- Merschat, C. E. and Wiener, L. S., 1973, Provisional geologic map of the Ocoee Supergroup, southwestern North Carolina and southeastern Tennessee: Geological Society of America Abstracts with Programs, v. 5, p. 420.
- Merschat, C. E., and Hale, R. C., 1983, Geologic map and mineral resources summary of the Farner quadrangle, Tennessee and North Carolina: North Carolina Geological Survey Geologic Map GM 133-NE, scale 1:24,000.
- Michel-Lévy, A., 1877, De l'emploi du microscope polarisant a lumière parallèle: *Annuel Mines*, v. 12, p. 392-471.
- Mitra, G. and Elliott, D., 1980, Deformation of the basement in the Blue Ridge and the development of the South Mountain cleavage, in Wones, D. R., ed., *Proceedings, The Caledonides in the USA: Virginia Tech Department of Geological Sciences, Memoir 2*, p. 307-311.
- Mitra, S., 1987, Regional variations in deformation mechanisms and structural styles in the central Appalachian orogenic belt: *Geological Society of America Bulletin*, v. 96, p. 569-590.
- Mohr, D. W., 1973, Stratigraphy and structure of part of the Great Smoky and Murphy belt groups, western North Carolina: *American Journal of Science*, v. 273-A, p. 41-71.
- Mohr, D. W., 1975, Geologic map of the Noland Creek quadrangle, North Carolina: North Carolina Geological Survey, GM 158-NE, scale 1/24,000.
- Myrow, P. M., 1983, A paleo-environmental analysis of the Cheshire Formation in west-central Vermont: *Vermont Geological Society Bulletin*, v. 9, p. 12-13.
- Naylor, C. R., Jr., and Follo, M. F., 1988, Fan-delta sedimentation in the late Precambrian Wilhite Formation of the Great Smoky Mountains, east Tennessee: *Geological Society of America Abstracts with Programs*, v. 20, p. A79.
- Neuman, R. B., 1951, The Great Smoky fault: *American Journal of Science*, v. 249, p. 740-754.
- Neuman, R. B., 1955, Middle Ordovician rocks of the Tellico-Sevier belt, eastern Tennessee: *U. S. Geological Survey Professional Paper 274-F*, p. 141-178.
- Neuman, R. B., and Nelson, W. H., 1965, Geology of the western part of the Great Smoky Mountains, Tennessee: *U. S. Geological Survey Professional Paper 349-D*, 81 p.
- Nuttall, B. D., 1951, The Nantahala-Ocoee contact in north Georgia [M.S. thesis]: Cincinnati, University of Cincinnati, 32 p.

- Odom, A. L., and Fullagar, P. D., 1973, Geochronological and tectonic relationships between the Inner Piedmont, Brevard zone, and Blue Ridge belts, North Carolina: *American Journal of Science*, v. 273-A, p. 133-149.
- Odom, A. L., Kish, S., and Leggo, P. J., 1973, Extension of "Grenville basement" to the southern extremity of the Appalachians: U-Pb ages of zircons: *Geological Society of America Abstracts with Programs*, v. 5, p. 425.
- Onasch, C. M., and Dunne, W. M., 1993, Variation in quartz arenite deformation mechanisms between a roof sequence and duplexes: *Journal of Structural Geology*, v. 15, p. 465-475.
- Owens, W. H., 1984, The calculation of a best-fit ellipsoid from elliptical sections on arbitrarily oriented planes: *Journal of Structural Geology*, v. 6, p. 571-578.
- Peach, C. L., and Lisle, R. J., 1979, A Fortran IV program for the analysis of tectonic strain using deformed elliptical markers: *Computers and Geosciences*, v. 5, p. 325-334.
- Pettijohn, F. J., 1949, *Sedimentary rocks*, 1st ed., New York, Harper, 526 p.
- Phillips, H. E., 1952, *The geology of the Starr Mountain area, southeast Tennessee* [M.S. thesis]: Knoxville, University of Tennessee, 61 p.
- Pickering, S. M., 1976, *Geologic map of Georgia*: Georgia Department of Natural Resources, Geologic and Water Resources Division, Georgia Geological Survey, scale 1:500,000
- Poppelreiter, B. S., 1980, *A structural analysis of metasedimentary rocks of the Ocoee Supergroup above the Great Smoky overthrust in southeast Tennessee* [M. S. thesis]: Knoxville, University of Tennessee, 115 p.
- Powell, C. McA., 1974, Timing of slaty cleavage during folding of Precambrian rocks, northwest Tasmania: *Geological Society of America Bulletin*, v. 85, p. 1043-1060.
- Powell, C. McA., 1979, A morphological classification of rock cleavage: *Tectonophysics*, v. 58, p. 21-34.
- Press, W. H., 1989, *Numerical recipes: The art of Scientific computing*: New York, Cambridge University Press, 702 p.
- Rackley, R. I., 1951, *Geology of the Bean Mountain area* [M. S. thesis]: Knoxville, University of Tennessee, 76 p.
- Ramsay, J. G., 1967, *Folding and fracturing of rocks*: New York, McGraw-Hill, 568 p.
- Ramsay, J. G., and Huber, M. I., 1983, *The techniques of modern structural geology, volume 1: Strain analysis*: London, Academic Press, 307 p.
- Rankin, D. W., 1975, The continental margin of eastern North America in the southern Appalachians: The opening and closing of the Proto-Atlantic ocean: *American Journal of Science*, v. 275-a, p. 298-336.

- Rankin, D. W., Drake, A. A., Jr., Glover, L., III, Goldsmith, R., Hall, L. M., Murray, D. P., Ratcliff, N. M., Read, J. F., Secor, D. T., and Stanley, R. S., 1989, Pre-orogenic terranes *in* Hatcher, R. D., Jr., Thomas, W. A., and Viele, G. W., eds., *The Appalachian–Ouachita Orogen in the United States*: Boulder, Geological Society of America, *The Geology of North America*, v. F–2, p. 7–100.
- Rast, N., and Kohles, K. M., 1986, The origin of the Ocoee Supergroup: *American Journal of Science*, v. 286, p. 593-616.
- Reks, I. J., and Gray, D. R., 1982, Pencil structure and strain in weakly deformed mudstone and siltstone: *Journal of Structural Geology*, v. 4, p. 161-176.
- Rodgers, J., 1953, Geologic map of east Tennessee with explanatory text: Tennessee Division of Geology Bulletin 58, Part II, 168 p.
- Safford, J. M., 1856, A geological reconnaissance of the state of Tennessee: Nashville, 1st Biennial Report of the State Geologist, 164 p.
- Safford, J. M., 1869, *Geology of Tennessee*: Nashville, Tennessee, Mercer, 550 p.
- Salisbury, J. W., 1961, Geology and mineral resources of the northwest quarter of the Cohutta Mountain Quadrangle: Georgia Geological Survey Bulletin 71, 61 p.
- Schwab, F. L., 1970, Origin of the Antietam Formation (Late Precambrian? - Lower Cambrian), central Virginia: *Journal of Sedimentary Petrology*, v. 40, p. 354-366.
- Secor, D. T., Jr., Snoke, A. W., Bramlett, K. W., Costello, O. P., and Kimbrell, O. P., 1986, Character of the Alleghanian orogeny in the southern Appalachians: Part I. Alleghanian deformation in the eastern Piedmont of South Carolina: *Geological Society of America Bulletin*, v. 97, p. 1319-1328.
- Shanmugam, G., and Lash, G. C., 1982, Analogous tectonic evolution of the Ordovician foredeeps, southern and central Appalachians: *Geology*, v. 11, p. 562–566.
- Stose, G. W., and Stose, A. J., 1944, The Chilhowee Group and Ocoee Series of the southern Appalachians: *American Journal of Science*, v. 242, p. 367-390, 401-416.
- Stose, G. W., and Stose, A. J., 1947, Origin of the Hot Springs at Hot Springs, North Carolina: *American Journal of Science*, v. 245, p. 624-644.
- Stose, G. W., and Stose, A. J., 1949, Ocoee Series of the southern Appalachians: *Geological Society of America Bulletin*, v. 60, p. 267-320.
- Stose, G. W., 1898, Manuscript geologic map of part of the Mount Guyot quadrangle, Tennessee, U. S. Geological Survey Files.
- Sutton, T. C., 1971, Relationship between metamorphism and geologic structure along the Great Smoky fault system, Parksville quadrangle, Polk and Bradley Counties, Tennessee [Ph.D. thesis]: Knoxville, University of Tennessee, 148 p.

- Swingle, G. D., 1949, Petrography of the Chilhowee Group near Walland, Tennessee [M. S. thesis]: Knoxville, University of Tennessee, 34 p.
- Thomas, W. A., 1993, Low-angle detachment geometry of the late Precambrian-Cambrian Appalachian-Ouachita rifted margin of southeastern North America: *Geology*, v. 21, p. 921-924.
- Thompson, T. W., and Tull, J. F., 1991, Stratigraphy of the Mineral Bluff Group, southwestern North Carolina, *in* Kish, S. A., ed., *Studies of Precambrian and Paleozoic stratigraphy in the western Blue Ridge*: Carolina Geological Society Guidebook, p. 97-110.
- Tobisch, O. T., and Patterson, S. R., 1988, Analysis and interpretation of composite foliations in areas of progressive deformation: *Journal of Structural Geology*, v. 10, p. 745-754.
- Tull, J. F., 1982, Stratigraphic framework of the Talladega slate belt, Alabama Appalachians, *in* Bearce, D. N., Black, W. W., Kish, S. A., and Tull, J. F., eds., *Tectonic studies in the Talladega and Carolina slate belts, southern Appalachian orogen*: Geological Society of America Special Paper 191, p. 3-18.
- Tull, J. F., and Groszos, M. S., 1988, Murphy belt: Stratigraphic complexities and regional correlations, *in* Fritz, W. J., and La Tour, T. E., eds., *Geology of the Murphy belt and related rocks, Georgia and North Carolina*: Georgia Geological Society Guidebook, v. 8, no. 1, p. 35-74.
- Tull, J. F., and Groszos, M. S., 1990, Nested Paleozoic "successor" basins in the southern Appalachian Blue Ridge: *Geology*, v. 18, p. 1046-1049.
- Tull, J. F., Ausich, W. I., Groszos, M. S., Thompson, T. W., 1993, Appalachian Blue Ridge cover sequence ranges at least into the Ordovician: *Geology*, v. 21, p. 215-218.
- Tull, J. F., Thompson, T. W., Groszos, M. S., Aylor, J. G., Jr., and Kish, S. A., 1991, Murphy belt stratigraphic nomenclature *in* Kish, S. A., ed., *Studies of Precambrian and Paleozoic stratigraphy in the western Blue Ridge*: Carolina Geological Society Guidebook, p. 79-86.
- Unrug, R., and Unrug, S., 1990, Paleontological evidence of Paleozoic age for the Walden Creek Group, Ocoee Supergroup, Tennessee: *Geology*, v. 18, p. 1041-1045.
- Unrug, R., Unrug, S., and Palmes, S. L., 1991, Carbonate rocks of the Walden Creek Group in the Little Tennessee River valley: Modes of occurrence, age, and significance for the basin evolution of the Ocoee Supergroup: *Carolina Geological Society Guidebook*, p. 27-36.
- Van Horn, E. C., 1948, Talc deposits of the Murphy marble belt: North Carolina Division of Mineral Resources Bulletin 56, 54 p.
- Walcott, C. D., 1890, The fauna of the lower Cambrian or *Olenellus* zone: U. S. Geological Survey, 10th Annual Report, pt. 1, p. 509-760.
- Walcott, C. D., 1891, Correlation papers, Cambrian: U.S. Geological Survey Bulletin 81, 447 p.
- Walker, J. D., and Driese, S. G., 1991, Constraints on the position of the Precambrian-Cambrian boundary in the southern Appalachians: *American Journal of Science*, v. 291, p. 258-283.

- Walker, D., and Rast, N., 1991, The Walden Creek Group: Is it part of the Ocoee Supergroup?, in Kish, S. A., ed., *Studies of Precambrian and Paleozoic stratigraphy in the western Blue Ridge: Carolina Geological Society Guidebook*, p. 45-56.
- Walters, R. R., 1988, Structural geometries, fabrics, and stratigraphic relationships in the Cades Cove region, Great Smoky Mountains National Park [M. S. thesis]: Knoxville, University of Tennessee, 155 p.
- Wiener, L. S. and Mersch, C. E., 1978, Summary of geology between the Great Smoky fault at Parksville, Tennessee and basement rocks of the Blue Ridge at Glade Gap, North Carolina in Milici, R. C., ed, *Feld Trips in the southern Appalachians*, Tennessee Division of Geology Report of Investigation No. 37, p. 2-29.
- Wiener, L. S., and Mersch, C. E., 1981, Provisional geologic map of southwest North Carolina, southwest Tennessee, and north Georgia: North Carolina Geological Survey Open File Map, scale 1:250,000.
- Wiener, L. S., and Mersch, C. E., 1992, Geologic map of southwestern North Carolina, including adjoining southeastern Tennessee and northern Georgia: North Carolina Geological Survey, scale 1:250,000.
- Williams, P. F., 1970, A criticism of the use of style in the study of deformed rocks: *Geological Society of American Bulletin*, v. 81, p. 3283-3296.
- Williams, P. F., 1976, Relationships between axial-plane foliations and strain: *Tectonophysics*, v. 30, p. 181-196.
- Williams, P. F., 1985, Multiply deformed terrains—Problems of correlation: *Journal of Structural Geology*, v. 7, p. 269-280
- Wilson, C. W. Jr., 1935, The Great Smoky overthrust in the vicinity of Tuckaleechee, Wear, and Cades Coves, Blount and Sevier Counties, Tennessee: *Tennessee Academy of Science Journal*, v. 9, p. 57-63.
- Woodward, N. B., Connelly, J. B., Walters, R. R., and Lewis, J. C., 1991, Tectonic evolution of the Great Smoky Mountains in Kish, S. A., ed., *Studies of Precambrian and Paleozoic stratigraphy in the western Blue Ridge: Carolina Geological Society Guidebook*, p. 57-68.
- Wu, S., and Groshong, R. H., Jr., 1991, Low-temperature deformation of sandstone, southern Appalachian fold-thrust belt: *Geological Society of America Bulletin*, v. 103, p. 861-875.

Appendix

Table A-I: Structural measurements corresponding to stations in the study area (Plate II).

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 1	SS								MCF47	ST							
2	SS	018 26E							48	ST	224 59W	27 50E					
3	SS								49	ST		216 81W					
4	SL								50	ST	29 05E	42 56E					
5	SS	221 22W							51	ST	205 71W						
6	SS								52	ST	226 51W						
7	ST	223 52W							53	ST		38 69E					
8	ST	218 35W	215 18W				221 4		54	CG	232 56W						
9	SS								55	ST	204 50W						
10	ST		208 25W						56	ST	210 34W						
11	ST	227 60W	51 57E						57	ST	200 50W						
12	ST		40 68E						58	ST		22 74E					
13	ST	231 61W	44 41E						59	ST	227 25W	23 35E					
14	ST	231 49W							60	ST	186 20W						
15	ST	227 62W	57 55E						61	ST	225 24W	12 60E					
16	ST	55 52E							62	ST	200 60W						
17	ST	33 10E							63	ST	184 48W	26 41E					
18	ST	214 45W							64	ST		210 80W					
19	ST		34 50E						65	ST	198 47W	12 70E					
20	ST		32 49E						66	ST		27 60E					
21	ST	39 71E							67	ST	216 46W	20 52E					
22	ST	231 19W	28 70E						68	ST	22 46E	19 57E					
23	ST		43 65E						69	ST	17 68E	15 63E					
24	ST	212 70W	24 65E						70	SS	70 22E						
25	ST		15 52E						71	ST		10 74E					
26	ST	25 06E							72	ST		24 56 2W					
27	ST		19 29E						73	SS	22 83E						
28	SS		26 67E						74	ST		000 72E					
29	ST	217 72W	30 29E						75	ST	005 80E	005 56E					
30	ST	27 89E							76	ST		42 29E					
31	ST	227 66W							77	ST	70 82E						
32	ST		21 69E						78	ST		67 55E					
33	ST	21 75E							79	ST	239 61W	16 67E					
34	SS	36 62E							80	CG				55 25	30 35		
35	ST								81	CG	80 25E						
36	ST	221 60W							82	SS	52 50E						
37	ST	205 56W					18 25		83	ST	002 19E						
38	ST	204 61W							84	ST	35 06E	13 30E					
39	ST	225 60W							85	ST	40 19E	21 54E					
40	ST		24 60E						86	ST		20 55E					
41	ST	224 74W							87	ST	210 46W	30 57E					
42	CG								88	ST	21 65E						
43	CG								89	ST	46 89E	40 75E					
44	ST	202 76W	35 50E						90	ST	230 75W						
45	ST	35 50E							91	ST		30 75E					
46	CG								92	ST	34 89E						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 93	ST	209 56W	203 76W						MCF 139	SL	21 45E						
94	ST		35 75E						140	SL	45 42E						
95	ST	207 57W							141	SS	176 10W	41 33 E					
96	SS	197 31W							142	SS	40 28E						
97	ST								143	SS	354 06E	17 44 E		14 07			
98	SS	209 42W	22 74E						144	SS	25 27E						
99	ST								145	SL	33 39E						
100	SL	66 26E (195 46W)					19720	215 13	146	ST	64 48E						
101	SL	000 86E	20 66E						147	ST	56 53E						
102	SL	344 62E							148	SS	41 34E						
103	SL	345 46E					30 15		149	SL	18 19E						
104	SL	347 54E							150	SL	56 25E						
105	SS						73 04		151	SL	16 60E						
106	SL		46 50E						152	SS				40 04	40 72 E		
107	SL	56 40E							153	SS	22 34E						
108	SL	62 36E	33 89E						154	SS		37 56 E					165 05
109	SL	133 23W	18 75E						155	SL	50 20E						
110	SL				247 39	34 39 E			156	SL		26 54 E					195 10
111	SL	52 30E							157	SL	65 22E	17 46 E					
112	SL	18 37E							158	ST	65 15E						
113	ST	50 19E							159	SL	215 14W						
114	SS	33 40E							160	ST	42 34E						
115	SL	30 27E							161	SS	66 15E						
116	SL	25 34E							162	SS	08 35E						
117	SL	45 15E	28 17E				50 01		163	SS	15 16E						
118	SL	55 10E	20 46E						164	SS	23 11E						
119	SL	33 26E	22 34E						165	SL	000 00	(68 72 E)					
120	SL	35 30E	84 79E						166	SL	000 00	(54 83 E)					
121	SL	22 25E							167	CG	59 29E						
122	SS		51 40E		214 23	40 77 E			168	CG	180 24W						
123	SL	30 21E			34 09	35 26 E			169	CG	54 30E						
124	SL	130 30W	290 52W						170	SS	40 60E						
125	SL		32 35E						171	CG	000 49E						
126	SS				199 13	46 44 E			172	SS	40 25E						
127	SS	53 20E					185 11		173	SS							
128	SS	10 15E							174	ST							
129	ST	28 30E	24 20E						175	SL							
130	SS	40 30E	30 55E					40 04	176	SS	32 35E						
131	SS	35 20E							177	CG	39 30E	25 44 E					45 06
132	SS								178	SL	65 18E	(262 46 W)					
133	ST	65 20E	35 40E		31 05	47 54 E	196 10	20 02	179	ST		(230 65 W)					
134	SS	35 35E			199 06				180	SL	42 29E						
135	SS	22 41E							181	SS	61 15E	(65 74 E)					
136	SS	42 34E							182	SL	205 27W	22 66 E					
137	SS	352 09E							183	SS	06 20E	11 44 E					191 10
138	SL	22 45E							184	SL	262 11W	61 16 E					56 01

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 185	SL		(246 70 W)						MCF 231	LS	47 62E	52 39E					
186	SL		41 60 E						232	LS		42 50E					
187	SL	44 53E							233	SL	70 64E	54 56E		234 18	46 57E		
188	SL	000 00	21 24E				191 10		234	LS	52 15E						
189	ST	47 29E							235	ST	38 65E						
190	LS	41 20E							236	ST	30 40E						
191	SS		51 56E				34 09		237	SL	29 34E	(210 44W)				202 14	
192	SS	54 25E							238	SL	62 60E		199 46W				
193	SL	39 20E							239	SL	42 26E						
194	SS	45 21E							240	SL	39 34E	44 66E					
195	SL	41 32E			195 35	50 32E			241	SL	29 26E						
196	SS	41 30E							242	SL	35 26E			40 14	29 57E		
197	SL	45 30E	(237 64W)						243	LS	55 35E	64 65E					
198	ST	50 10E	30 34E		210 08	44 39E			244	CG	05 29E						
199	CG	23 15E							245	CG	19 55E						
200	SS	80 25E							246	SL	355 56E						
201	SS	52 19E	(244 30W)						247	ST	359 38E						
202	SL	34 14E							248	ST	44 14E						
203	SL	46 26E							249	SL	07 50E			160 16	335 62E		
204	SL	35 10E							250	SL							
205	SL	29 26E							251	SL	32 51E						
206	SS	66 26E			43 05	224 62W			252	SL	18 45E						
207	SS	283 25E							253	SL	28 42E	10 76E					
208	SS	328 26E	39 44E		69 10	60 30E			254	LS	18 42E			207 25	32 36E		
209	SS	172 11W							255	LS	25 40E	13 20E		195 20	72 27E		
210	ST	17 05E							256	LS	35 42E			195 20	30 44E		
211	SL	220 05W							257	LS	07 65E						
212	SS	232 30W							258	SL	22 56E			25 05	22 41E		
213	SS	150 06W							259	ST		35 38E					
214	SS	48 31E							260	ST	25 31E			20 11	18 46E		
215	SS	152 07W							261	ST	25 46E						
216	ST				251 25	74 59E			262	SL	44 50E	35 20E					
217	SL	56 25E							263	CG	25 65E						
218	SL				59 12	240 38W			264	CG	190 66W						
219	ST	62 14E	(230 56W)						265	SL	49 30E	42 65E				42 05	
220	SL	46 16E							266	ST	45 45E						
221	SL	32 10E	(237 55W)						267	LS	46 10E						
222	SL		37 39E						268	SL	56 27E						
223	ST	06 1E			27 07	09 32E			269	SL	42 41E	25 44E					
224	LS	17 15E							270	SL	236 36W	16 34E				42 05	
225	LS	42 15E			215 08	36 25E			271	SL	240 26W	32 18E					
226	LS	50 70E			199 26	62 52E			272	SL							
227	SL	62 56E	72 23E				204 25		273	SL							
228	SL		353 2E						274	SL	70 26E						
229	SL	44 46E							275	SL	73 26E					222 15	
230	SL	35 44E							276	SL	71 15E						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 277	SL	30 35E							MCF 323	LS	26 57E						
278	SL	62 15E	42 25E						324	LS	28 35E						
279	SL								325	SS							
280	SL	29 56E							326	SS	35 80E						
281	SS	55 49E							327	SS	207 05W						
282	SS	68 44E							328	SS	27 60E						
283	SL	005 46E							329	SL	27 60E						
284	SS	30 43E							330	SL	58 52E						
285	SL	18 19E	10 56E						331	SL	60 25E	30 41E					
286	SL	52 19E							332	SL	57 25E						
287	SL	32 24E							333	SL	35 30E						
288	SL	15 45E							334	SL	30 27E						
289	SL	30 39E							335	SL	32 39E						
290	SL	47 34E							336	SL	25 36E						
291	SL	61 42E							337	LS	201 62W						
292	SL	75 89E	50 46E						338	SS	195 29W						
293	SL	72 30E	332 35E		328 15	286 26E	150 15		339	SS	169 29W						
294	SL		356 40E						340	SS	200 66W						
295	SL	42 38E							341	ST	199 14W						
296	SL	35 44E							342	ST	209 64W						
297	SL	221 05W	22 34E						343	CG	15 36E						
298	SL	48 30E			42 15	36 71E			344	SS	24 80E						
299	SL	37 15E							345	LS	136 18W						
300	SL	41 25E	26 50E				34 10		346	LS				206 10	89 30 E		
301	SL	37 24E							347	LS	45 36E						
302	LS	42 26E							348	LS	50 07E						
303	LS	62 40E			241 15	70 45E			349	LS	115 15W						
304	SL	258 34W							350	LS	46 27E						
305	SS	44 56E							351	SL	35 56E						
306	ST	246 37W							352	SS	35 30E						
307	ST	72 61E							353	LS							
308	ST	14 51E							354	SL	41 43E	20 55E					
309	SL	22 27E							355	SS	40 36E						
310	SL	29 33E							356	SS	42 33E						
311	SS	42 20E							357	SS	209 22W						
312	SL	40 21E							358	LS	72 36E						
313	SS	234 55W	26 37E						359	LS	75 33E						
314	LS	60 42E	42 55E						360	SS	36 46E						
315	SL		52 65E		222 07	52 52E			361	SL	70 40E						
316	LS	47 25E							362	SS	55 65E						
317	LS	40 29E							363	ST	220 57W						
318	LS	61 15E							364	SS	25 25E						
319	SL	46 11E	50 32E				205 05		365	SL	56 31E			55 10	61 35 E		
320	SL	32 11E	32 30E				212 03		366	LS	249 40W						
321	SL	36 55E					60 14		367	SS							
322	SL	28 41E							368	SS	247 40W						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 369	ST				40 11	40 10E			MCF 415	ST		007 55E					
370	SS	002 36E							416	SS	009 42E						
371	SS	27 60E							417	SS	32 63E						
372	ST	188 27W	196 50W						418	CG	310 30E						
373	SS	205 80W							419	ST	25 65E						
374	ST	210 20W							420	ST	35 65E	36 55E	230 20W				
375	SL	35 34E							421	SL	25 40E						
376	SS	345 11E							422	ST	42 45E						
377	SS	15 04E							423	ST	38 35E						
378	SS	21 42E							424	SS	42 33E						
379	SS	009 37E							425	SS	220 32W						
380	LS	40 37E							426	ST	50 54E						
381	LS	241 26W							427	CG	56 27E						
382	LS	29 35E							428	SS	215 18W						
383	LS	59 30E							429	SS							
384	SS	252 42W							430	ST	18 34E						
385	SS	37 75E	115 75W						431	ST	52 25E						
386	ST	35 66E							432	ST			(16 45E)				
387	ST	47 44E							433				(15 30E)				
388	LS								434				(28 30E)				
389	ST	16 64E							435				(18 30E)				
390	SL	000 44E							436	ST	205 34W		(007 16E)				
391	SL	30 59E							437	ST	195 22W		(34 36E)				
392	SL	239 53W		246 15W					438	ST	215 33W		(35 34E)				
393	SL	40 55E							439	ST	205 25W		(16 65E)				
394	SS	35 44E							440	ST	000 00						
395	ST	20 62E							441	SS	196 36W		(32 42E)				
396	SL	18 22E							442	SS	202 40W						
397	SL	33 50E							443	ST	32 45E						
398	ST	15 50E							444	ST	005 90						
399	SL	30 74E	18 50E						445	ST	212 56W	25 67E					
400	ST	30 70E							446	ST	225 20W	46 64E					
401	ST	15 62E							447	SL	212 55W						
402	ST	35 70E							448	ST	207 46W						
403	ST	35 50E							449	ST	204 37W						
404	ST	230 24W	22 45E						450	ST	234 69W	005 55E					
405	ST	225 17W	24 52E						451	ST	30 56E						
406	ST	205 25W							452	ST	17 65E						
407	ST	272 62W							453	ST	202 25W						
408	ST		30 55E						454	ST	315 29W		(15 69E)				
409	ST	208 28W	22 47E						455	ST	222 47W						
410	ST	275 40W	25 50E						456	ST	216 17W						
411	ST	25 52E							457	ST	215 42W						
412	SL	190 18W	172 52W						458	SS	216 65W						
413	ST	11 80E							459	SL	210 44W						
414	ST	36 26E	25 43E						460	CG	224 40W						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 461	SL	000 47E							MCF 507	SS	28 17E						
462	SL	34 46E							508	ST	195 68W						
463	SL	35 42E							509	ST	329 42E						
464	SL	212 64W	31 96E						510	ST	255 59W			71 20E	68 15E		
465	SS	242 36W							511	ST	35 72E						
466	SS	305 10E							512	ST	215 48W						
467	ST	235 26W							513	SS	305 19E						
468	ST	195 13W							514	SS	309 19W						
469	SS	210 31W							515	SS	270 15N						
470	ST	255 20W							516	SS	322 24E						
471	ST	217 40W							517	SS	230 22W						
472	ST	80 16W							518	SS	268 24W						
473	ST	135 17W							519	SS	231 15W						
474	CG	207 15W							520	SS	255 11W						
475	SS	102 04W							521	SL	240 19W						
476	SS	202 11W							522	SL	200 20W						
477	ST	243 19W							523	SS	231 21W						
478	ST	206 35W							524	SS	222 25W						
479	SS	305 20E							525	SS	222 19W						
480	SS	235 08W							526	SS	235 15W						
481	ST	208 04W							527	SS	220 20W						
482	ST	326 15E							528	ST	265 04W						
483	ST	297 10E			70 20	62 25E			529	ST	37 06E						
484	ST	209 35W							530	ST	15 13E						
485	SS	33 12E			190 10	000 45E			531	ST	229 45W						
486	ST	175 10W							532	ST	55 26E						
487	SS	000 05E							533	ST	57 21E						
488	ST	190 15W							534	ST	52 34E						
489	CG	226 21W							535	ST	73 05E						
490	CG	230 35W							536	SS	215 34W						
491	ST	205 26W							537	ST	209 10W						
492	ST	204 46W							538	LS	82 10E						
493	ST	198 41W							539	ST	155 12W						
494	ST	217 53W							540	SS	36 17E						
495	SS	205 28W							541	SS							
496	SS	207 24W							542	LS	133 15W						
497	SS	224 15W							543	LS	89 30E						
498	SS	92 26W							544	LS	94 26W						
499	SS	55 10E							545	SS	225 46W						
500	LS	45 90							546	LS	73 34E						
501	ST	214 06W							547	SS	15 32E						
502	ST	188 19W							548	LS	375 4E						
503	ST	188 17W							549	SS	220 29W			45 10E	38 70E		
504	SS	203 16W							550	SL	42 60E						
505	ST	214 11W							551	SL	54 67E	45 25E					
506	SS	214 07W							552	SL	50 35E						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF553	SL		34 48E						MCF599	SL	000 16E						
554	SL	19 50E	35 40E						600	SL		10 25E					
555	SL	224 75W			55 05	85 25E			601	SS	10 35E						
556	SL		50 48E						602	ST	000 23E	24 43E					
557	CG	40 37E							603	SS	339 27E	002 53E					
558	SL	220 32W	40 55E						604	ST	14 90	25 35E					
559	SL	225 50W	38 45E						605	ST	210 10W						
560	SS	210 05W	45 46E						606	ST	20 62E						
561	SL		20 30E						607	ST	17 26E						
562	SL	53 10E	48 50E	235 09W					608	SS	20 65E						
563	SL	55 12E	57 46E	236 19W					609	SL		19 40E					
564	SS	64 14E	65 48E	246 29W					610	ST	009 33E						
565	ST	223 34W	45 52E						611	SS	46 15E						
566	ST	15 36E							612	ST	45 09E	40 42E					
567	ST	25 26E							613	ST	220 25W						
568	ST	13 40E	009 18E						614	SS		29 52E					
569	ST	48 79E							615	SS		35 66E					
570	ST	12 49E	20 17E						616	SS	36 44E	30 39E					
571	SL	25 65E	25 30E						617	SL	20 15E	15 58E					
572	SS	10 25E							618	SL		30 34E					
573	SL	75 20E			202 18	205 05W		216 15W	619	SS	30 15E						
574	SL	46 50E							620	SS	215 08W						
575	SL		37 45E						621	SS	29 26E						
576	SL	19 58E							622	SS	45 36E						
577	SL	48 65E	55 52E						623	SS	25 41E						
578	SL		45 65E	255 20W					624	ST	36 16E						
579	SL		45 47E						625	SL	30 16E						
580	CG	33 65E							626	SL	20 10E	15 25E					
581	CG	45 64E							627	CG	20 22E						
582	SL		20 34E	340 65E					628	SS	41 53E						
583	SL		55 64E	243 40W					629	SL		32 14E				30 05	
584	SS	28 65E							630	SL	230 45W	005 22E					
585	LS	22 50E							631	SL	30 20E						
586	SL	31 60E							632	SL	42 27E						
587	SL	25 62E							633	SL	212 32W	25 18E					
588	SL	17 40E							634	SL	235 25W	38 20E					
589	SL				191 11	25 33E			635	SL	50 20E	10 24E					
590	SL	26 42E							636	SL		30 25E					
591	SL	142 59W	45 24E						637	SL	000 00	20 15E					
592	SL	25 62E	33 27E						638	SL	215 60W	40 55E					
593	SL	218 23W	30 52E						639	SL	28 20E						
594	SL	190 27W	10 35E						640	SL	30 22E						
595	SL	217 65W	336 42E						641	SL	195 52W	26 27E					
596	ST	217 37W	21 41E						642	SL		41 32E					
597	SL		65 15E						643	SL	208 22W	34 35E					
598	SS	345 29E							644	ST	199 18W	000 36E					

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 645	ST	000 00	55 33E						MCF 691	SL	225 58W	36 30E					
646	SL	232 34W	55 16E						692	SL	240 75W	28 27E					
647	SL	20 30E							693	SL	230 16W	31 15E					
648	ST	30 35E							694	SL	240 15W	26 28E					
649	ST	69 13E	50 35E						695	SL	224 45W	24 31E					
650	ST	85 10E	55 35E						696	SL	232 20W	35 34E					
651	SS	40 20E	22 34E						697	ST	215 24W	005 24E					
652	SL	215 48W	23 40E						698	SL	215 03W	23 22E					
653	SS	009 07E							699	ST	20 11E						
654	CG	000 00							700	SL	25 45E	46 30E	233 55W				
655	SL	25 17E							701	SL	235 24W	43 34E					
656	SS	52 23E							702	SL	34 88E	19 35E	240 50W				
657	SL	15 10E							703	SL	28 85E	34 25E					
658	SL	242 45W	26 32E						704	SL		11 20E	226 66W				
659	ST	222 15W	33 34E						705	SL	28 80E	35 31E	226 49W				
660	SS	39 15E			43 05	30 47E			706	SL	246 68W	30 22E					
661	SL	220 15W	37 35E						707	SL		20 20E					
662	SL	220 45W	25 27E						708	SL	36 56E	10 26E					
663	SL	225 10W	43 30E						709	ST	220 50W	37 30E					
664	SL	215 05W	32 46E						710	ST	217 24W	30 34E					
665	SL	220 27W	20 32E						711	ST	42 59E	34 20E					
666	SL	230 34W	39 26E						712	ST	35 83E	35 27E					
667	SL	239 45W	40 19E						713	ST	12 86E	35 40E					
668	SL	215 60W	35 26E				3009		714	ST	25 35E						
669	SL	215 12W	48 31E						715	ST	18 59E	35 26E					
670	SL	210 70W	20 19E						716	SL		18 28E					
671	SL	205 70W							717	SL	230 61W						
672	SL	45 90	40 15E						718	SL	15 40E						
673	SL	65 57E	60 35E						719	ST	47 52E						
674	SL	000 00	005 35E						720	SS	197 40W	006 26E					
675	SS	000 35E							721	SS	23 45E						
676	SL	220 64W							722	ST	51 05E	15 35E					
677	SL	210 11W	35 30E						723	ST	218 35W						
678	SL	195 16W	25 30E						724	SS							
679	SL		28 31E						725	ST	10 65E						
680	SL	215 22W							726	SL	200 33W	20 43E					
681	SL		30 24E						727	SL	200 07W	10 50E					
682	SL	202 15W							728	ST	210 29W	20 35E					
683	SS	10 15E							729	SS	37 18E						
684	SL	222 51W	30 29E						730	SS		10 30E					
685	SL	218 60W	30 27E						731	SL	22 90	15 70E					
686	SS	25 57E							732	ST	25 66E	25 68E					
687	SS	35 40E							733	ST	217 66W	14 37E					
688	SS	35 42E							734	ST	210 35W	10 40E					
689	SS	225 55W							735	ST	200 68E	000 28E					
690	SL		38 50E						736	ST	203 66W						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 737	ST	28 90	39 33E						MCF 783	SS	33 20E						
738	ST	35 52E							784	SS		008 42E	356 85E				
739	SS	25 32E	13 32E						785	ST		38 40E					
740	ST		42 69E						786	ST	220 37W						
741	ST	205 38W	10 42E						787	SL	222 67W						
742	ST	265 25W							788	ST	24 27E						
743	ST	30 52E	15 36E						789	SL		28 45E					
744	ST	41 72E							790	SL	230 62W	005 34E					
745	ST	35 67E							791	SL							
746	ST	35 62E	15 35E						792	ST	49 65E						
747	SS	276 20E							793	SL	18 31E						
748	SS	295 06E			10 22	359 17E			794	SL	48 90	007 24E					
749	ST	236 65W							795	SL		350 30E					
750	ST	244 35W	56 32E						796	ST	88 10E						
751	CG	45 90							797	ST	200 05W	(65 80E)	235 55W			222 03	
752	SS	40 78E							798	SL		14 15E					
753	CG	237 52W							799	SL	220 44W	35 30E					
754	ST	40 82E	34 48E						800	SL		45 23E					
755	ST	34 74E	10 60E						801	SL	28 18E						
756	SS	25 71E							802	SL	218 35W	34 34E					
757	SS	40 45E							803	SL	48 90	20 28					
758	SS	35 90							804	SL	005 90	15 25E	294 57E				
759	SL	40 77E							805	SL		15 23E	240 71W				
760	ST	28 35E							806	SL	31 12E						
761	ST	32 30E							807	ST	230 68W	30 30E					
762	ST	15 35E							808	ST	215 75W						
763	ST	194 43W	30 41E						809	SL	16 30E		202 60W				
764	ST	35 06E	15 43E						810	ST							
765	ST	66 71E							811	ST	223 22W	46 26E					
766	ST		10 34E						812	ST	000 00	36 38E					
767	ST	210 74W							813	SL		20 29E					
768	ST	214 68W							814	SL	007 45E	20 28E					
769	ST	235 52W							815	SL		45 39E					
770	SS	28 35E							816	ST	24 90						
771	SS	25 24E							817	ST	27 90						
772	SS	26 90							818	ST	23 73E	25 57E					
773	ST	197 61W	33 60E						819	SS	217 44W						
774	ST	25 78E	15 44E						820	ST	265 34W	(56 90)					
775	ST		25 44E						821	SL		10 38E					
776	ST	19 49E							822	SL	215 55W	30 25E					
777	ST	40 44E							823	SL	225 70W	35 31E	235 55W				
778	ST	25 65E	29 40E						824	SL		10 40E					
779	SL	20 76E	15 42E						825	SL	320 15E						
780	ST	25 44E							826	SL	346 13E						
781	LS	25 26E	45 43E						827	ST	73 07E	52 20E					
782	SS	13 32E							828	SL	245 34W	35 26E					

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 829	ST	234 55W							MCF 875	SL	28 34E						
830	SS	22 30E							876	ST	210 35W						
831	SL	30 65E	34 43E						877	ST	50 50E						
832	SL	310 30E	10 41E						878	ST	330 09E						
833	ST	214 15W	20 50W						879	ST	344 52E						
834	SL	35 25E							880	ST	335 30E	304 36E					
835	ST	219 52W	31 44E						881	ST	31 21E						
836	ST	000 00	24 49E						882	SL	52 10E	35 29E					
837	ST	000 00	15 41E						883	ST	220 47W						
838	ST		10 31E						884	SL			245 60W				
839	SS	329 18E							885	SS	29 30E						
840	ST	25 27E							886	ST	235 55W	35 34E					
841	ST	004 10E	004 40E						887	ST	205 76W						
842	ST	32 20E	31 40E						888	ST	223 71W						
843	ST	19 15E							889	SL		19 50E					
844	ST	186 05W	40 50E						890	SS	249 08W	20 66E					
845	ST	20 14E	30 60E						891	ST	205 37W						
846	ST	347 25E							892	ST	000 00						
847	ST	20 13E	20 52E						893	ST	205 21W						
848	ST	000 00							894	ST	000 00	25 55E					
849	ST	305 22E	008 29E						895	ST	315 14E	(55 76E)					
850	ST	213 70W	40 32E						896	ST	15 74E						
851	ST	000 00	13 45E						897	ST	14 37E	39 38E					
852	ST	000 00							898	SS	235 25W						
853	ST	000 00	36 25E						899	ST	229 37W	212 13W					
854	ST	000 00							900	ST	215 59W						
855	SL		25 44E						901	ST	35 90						
856	SL	209 61W	23 34E						902	ST	30 90	35 45E					
857	SL	009 20E		223 45W					903	SL	10 50E						
858	ST	210 08W							904	ST	35 90						
859	SS	60 10E							905	SL	45 79E						
860	ST	003 07E			27 10	205 75W			906	ST	44 83E	50 47E					
861	SS	65 15E							907	ST	35 33E						
862	LS	000 00	20 40E						908	SL		30 31E				55 09	
863	SL	45 20E	35 45E						909	ST	245 50W						
864	SL		47 52E						910	SL		28 40E					
865	SL		54 20E						911	ST	221 09W	45 50E					
866	ST	262 35W			55 15	55 08E			912	ST	215 21W						
867	SL	66 24E					230 05		913	SL		30 25E					
868	SS	85 13E					220 05		914	SL	195 64W	30 56E					
869	ST	40 40E							915	CG	45 15E						
870	ST	45 31E							916	SS	20 35E						
871	ST	000 00	55 37E						917	SS	215 85W						
872	ST	000 00	43 35E						918	CG	41 35E						
873	ST	000 00							919	ST	41 65E						
874	ST	30 33E							920	SS	18 67E						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF921	ST	41 20E							MCF967	SL	(45 79E)						
922	ST	35 08E	28 33E						968	SL	25 32E						
923	ST	000 00	36 57E						969	ST	47 07E	38 42E					
924	ST	000 00	60 41E						970	ST	215 47W	30 54E					
925	SL	27 24E	42 38E						971	ST	215 19W						
926	SL	000 00	50 34E				65 25		972	SL	38 48E	24 33E					
927	SS	14 23E	36 52E						973	SS	65 26E						
928	CG	85 44E							974	SS	23 30E						
929	CG	250 66W	45 34E						975	SS	275 18E	62 41E					
930	CG	92 27W							976	ST	48 32						
931	SS	30 55			185 40	15 75E			977	SL							
932	CG	38 35E							978	ST	42 64E	18 42E					
933	SS	41 37E							979	ST	352 34E						
934	SS	40 27E							980	SL	51 59E						
935	SL		31 45E						981	SL		57 32E					
936	CG	55 24E							982	SL	46 46E						
937	SL	45 18E							983	SL	55 50E						
938	SS	26 35E							984	ST	75 36E						
939	SL		34 40E						985	ST	65 49E						
940	SL	66 05E	28 35E						986	SL	85 44E						
941	SL	39 48E		225 52W					987	ST	120 33W						
942	SL	53 05E	45 35E						988	ST	44 29E						
943	SL	35 17E							989	SL	210 15W						
944	SS	225 63W							990	ST	218 32W						
945	SS	55 38E							991	SL	000 00	65 30E					
946	SS	90 50S							992	ST	222 29W	358 30E					
947	SS	165 23W (259 80W)							993	ST	205 15W	11 25E					
948	ST	350 25E							994	SS	10 40E						
949	ST	000 00							995	SL		350 30E					
950	ST	355 15E	55 56E		210 29	50 42E			996	ST	343 26E						
951	SL				000 47	005 83E			997	ST	150 35W	10 30E					
952	SL		47 72E						998	SL	000 00	28 30E					
953	SL	95 36W	47 62E						999	SL	000 00	43 36E					
954	SS	74 30E	65 27E						1000	SL	52 23E	40 45E					
955	ST	000 00	25 30E						1001	SS	340 76E						
956	ST	354 20E							1002	LS	48 33E						
957	SL		3049E						1003	LS	235 55W						
958	SL		40 38E						1004	LS				185 05	005 35E		
959	SL	000 00	64 35E						1005	LS	245 29W	35 40E					
960	ST	210 15W							1006	SL	62 41E						
961	ST	29 26E							1007	SL	5542E						
962	SL	000 00							1008	SL		35 37E					
963	ST	45 10E	20 26E						1009	SL		31 30E					
964	SL	46 11E					83 19		1010	SL	46 19E						
965	SL	35 05E	(52 71E)						1011	SL	68 18E						
966	ST	203 33W	28 40E						1012	SL	34 57E						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 1013	ST	233 39W	35 37E						MCF 1059	ST	189 69W						
1014	ST	61 55E	45 38E						1060	ST	195 54W						
1015	SL		44 42E	250 58W					1061	SL	100 27W						
1016	ST	52 25E	44 35E				185 26		1062	ST	42 90						
1017	SL	42 80E	25 32E						1063	SS	93 32W						
1018	SS		34 39E		208 10	37 10E			1064	SL	30 47E	52 30E					
1019	ST	43 55E							1065	ST	30 86E	27 53E					
1020	SL	30 18E	35 47E						1066	ST	30 65E						
1021	SL	29 40E	15 35E						1067	ST	40 70E						
1022	LS	35 40E							1068	ST	216 54W						
1023	LS	36 50E							1069	ST	185 12W						
1024	SL		40 40E		32 20	49 54E			1070	ST	173 46W						
1025	ST	212 37W			80 12	267 67W			1071	ST	33 90	45 37E					
1026	SS	210 35W							1072	SS	180 75W						
1027	SS	230 51W							1073	SS	160 35W						
1028	SS	40 46E							1074	ST	18 74E						
1029	SS	46 51E							1075	CG	37 70E						
1030	SS	275 56W							1076	SS	46 66E						
1031	SS	213 26W		(25 42E)					1077	ST	44 20E		(28 36E)				
1032	SS	003 27E							1078	ST	23 13E	45 44E		196 10	15 60E		
1033	SS	261 15W							1079	CG	77 14E						
1034	ST	209 20W		(46 48E)					1080	CG	53 18E	50 50E					
1035	ST	193 27W							1081	CG	175 05W						
1036	ST	215 59W							1082	CG	175 15W						
1037	ST	200 38W							1083	SS	224 35W		(53 51E)				
1038	ST	210 24W							1084	SS	210 66W		(164 63W)				
1039	SS	196 24W							1085	SS	25 73E			172 57	352 90		
1040	SS	199 20W							1086	ST	35 50E						
1041	SS	205 15W							1087	ST	205 76W	25 43E					
1042	SS	205 31W							1088	ST	54 70E	15 57E					
1043	SS	18 68E							1089	ST	64 80E	18 36E					
1044	ST	220 54W							1090	ST	43 90						
1045	SS	37 75E							1091	SS	37 69E						
1046	SS	21 58E							1092	ST	33 72E						
1047	ST	245 30W							1093	SS	44 78E						
1048	ST	30 62E							1094	ST	54 83E			76 55	243 55W		
1049	ST	40 40E							1095	ST	80 90						
1050	ST			(13 46E)					1096	SS	45 31E						
1051	ST	000 00							1097	SS	44 39E						
1052	ST	197 47W							1098	ST	306 19E	45 42E		227 32	45 42E		
1053	ST	219 21W							1099	ST	233 63W	326 30E					
1054	SS	180 25W							1100	SS	85 40E						
1055	CG	18 47E							1101	CG	85 82E						
1056	ST	226 43W							1102	CG	46 64E						
1057	ST	188 15W							1103	CG	42 54E						
1058	ST	180 18W							1104	SL	49 57E						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 1104	SL	49 57E							MCF 1150	ST	15 34E						
1105	SS	54 85E							1151	ST	10 60E	26 44E					
1106	SS	232 57W							1152	ST	55 36E	40 73E	237 26W				
1107	SS	37 43E							1153	SS	40 26E	14 44E					
1108	CG	277 35E							1154	SS	32 19E						
1109	SL	44 48E							1155	ST	217 76W	40 36E					
1110	SL	51 70E	42 39E						1156	ST	37 57E						
1111	SL	237 67W							1157	ST	15 90	26 18E					
1112	CG		64 49E						1158	ST	231 61W						
1113	ST	31 44E							1159	ST	230 53W						
1114	CG	74 40E							1160	SS	26 55E	28 41E		215 10	3040E		
1115	ST	95 57W							1161	ST	80 16E	65 62E					
1116	ST	55 80E							1162	ST	70 26E						
1117	ST	49 70E							1163	SS	81 45E						
1118	ST	50 70E	18 46E						1164	ST	335 4E						
1119	ST	251 65W	67 56E						1165	ST	359 40E						
1120	ST	46 90							1166	ST	63 41E	45 25E					
1121	SL	18 69E							1167	ST	006 31E			185 05	005 35E		
1122	ST	20305W							1168	ST	210 31W	009 31E					
1123	ST	26 59E							1169	ST	38 71E	30 31E					
1124	ST	20644W							1170	ST	35 66E						
1125	ST	25 09E	29 61E						1171	ST	60 44E						
1126	SS	216 40W							1172	ST	131 13W	47 51E		231 10W	46 66E		
1127	ST	45 51E							1173	ST	41 42E						
1128	SS	61 90							1174	ST	255 22W						
1129	SS	51 50E							1175	LS	45 78E						
1130	ST	45 48E							1176	ST	694 5E						
1131	ST	45 90							1177	ST	216 22W	27 70E					
1132	ST	210 52W							1178	ST	35 65E						
1133	SS	215 24W							1179	ST	66 74E						
1134	SS	26 69E							1180	SL	37 60E	11 50E				36 23	
1135	ST	000 00							1181	ST	55 74E						
1136	SS	196 75W	15 63E		211 10	28 34E			1182	ST	62 65E						
1137	ST	19 29E							1183	SS	87 56E						
1138	CG	27 78E							1184	ST	74 14E	65 56E					
1139	ST	35 76E	50 40E		29 07	45 45E			1185	ST	64 65E	65 49E					
1140	ST	227 23W							1186	ST	555 4E						
1141	SS	220 41W							1187	ST	36 66E	50 26E					
1142	SS	234 57W							1188	SL	66 90E						
1143	ST	295 35E	35 23E				105 15		1189	ST	64 70E						
1144	SS	55 28E							1190	ST	30 90	10 38E					
1145	SL	223 24W	25 34E						1191	ST	55 65E	45 42E					
1146	ST	39 36E							1192	ST	233 70W	37 32E					
1147	SL		25 40E						1193	ST	65 90						
1148	SL	23 26E							1194	SL		274 5E					
1149	ST	23 47E							1196	SL		204 4E	195 31W				

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 1197	LS								MCF 1243	ST	51 85E	34 46E					
1198	ST	43 76E							1244	ST	16 10E						
1199	ST	91 10W	33 25E						1245	ST	43 46E	45 39E					
1200	LS	107 60W							1246	ST	66 55E						
1201	LS	230 45W							1247	ST	227 35W			211 07	45 38E		
1202	ST	73 67E							1248	ST	235 74W						
1203	ST	71 66E							1249	ST	45 47E	46 56E					
1204	ST	315 20W	71 45E						1250	ST	56 50E						48 03
1205	SL	87 20E							1251	ST							
1206	LS	215 14W	45 42E						1252	ST	18 39E						
1207	ST	10 16E							1253	ST	330 24E						
1208	ST	31 36E							1254	SL		009 50E					
1209	ST	109 22E							1255	ST	54 19E	23 58E					
1210	ST	19 36E							1256	ST	35 25E						
1211	SL		60 44E						1257	SL	15 22E	008 43E					
1212	SL	55 26E	37 47E				201 05		1258	ST	348 11E						
1213	ST	226 27W							1259	ST	180 19W	45 54E					
1214	SL	215 24W	44 46E						1260	ST	35 06E	37 42E					
1215	SL	47 30E							1261	ST	76 21E	46 53E					
1216	SL	55 50E							1262	SL	211 20W	28 51E					
1217	ST								1263	SL	44 90	45 56E		234 15	45 56E		
1218	ST								1264	ST	42 35E	28 53E					
1219	SL		45 56E						1265	SL		37 56E					
1220	ST	217 59W							1266	ST	20 39E						
1221	ST	37 20E							1267	ST	15 35E	35 56E					
1222	SL	27 60E	10 31E						1268	ST	18 34E						
1223	ST		25 38E						1269	ST		14 44E					
1224	ST	255 60W							1270	ST	20 46E						
1225	ST	206 11W	353 29E						1271	ST	005 84E						
1226	ST	46 87E	19 36E						1272	ST	60 90	008 62E					
1227	ST	345 23W							1273	ST	347 75W						
1228	ST	355 66E	348 41E						1274	ST	005 75E						
1229	ST	345 14W	007 43E						1275	ST	310 60W	009 54E					
1230	ST	69 36E							1276	SL		006 58E					
1231	ST		13 30E						1277	ST	19 53E						
1232	SS	95 35W							1278	ST	63 35E						
1233	SL		21 38E						1279	ST	220 77W						
1234	ST	206 14W	29 34E						1280	ST	75 85E						
1235	ST	225 70W	19 27E						1281	ST	75 37E						
1236	ST	36 26E							1282	SL		56 66E	211 20W				
1237	ST		30 30E						1283	SL	38 74E	46 54E					
1238	ST	326 11W							1284	ST		51 70E					
1239	SL	208 29E							1285	SL	37 65E	54 73E	185 05W				
1240	SL	24 29E	11 46E						1286	ST	225 76W	234 80W					
1241	ST	16 27E	31 55E						1287	ST	231 76W	54 58E					
1242	ST	45 62E							1288	ST	199 66W	61 71E					

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 1289	ST	235 34W	45 63E						MCF 1335	ST	36 31E						
1290	ST	46 54E							1336	ST	36 20E	44 47E					
1291	ST		55 65E						1337	ST	39 37E	45 65E		251 15			
1292	ST	50 19E	55 70E						1338	ST		55 59E					
1293	ST	54 39E	67 76E						1339	ST	46 30E	48 73E					
1294	SL		80 51E						1340	ST	232 19W	40 62E					
1295	ST	14 16E	45 52E						1341	ST		35 75E					
1296	ST		24 56E						1342	SL	55 07E	48 61E					
1297	SL		48 60E						1343	ST	251 32W	15 37E					
1298	SL		62 55E	225 64W					1344	ST	188 24W						
1299	ST	98 26E	61 65E						1345	SL	87 14E	005 61E					
1300	ST	345 71W							1346	ST	211 08W	28 30E					
1301	SL	17 50E	50 64E						1347	ST	268 04 W	25 45E					
1302	SL		48 74E						1348	SS	348 17E						
1303	ST	305 40E							1349	SL	22 65E						
1304	ST	104 58E	51 61E						1350	SS	20 66E						
1305	ST	79 81E							1351	SS	18 59E						
1306	SL		58 67E						1352	SS	45 74E						
1307	ST	83 80E	42 53E						1353	SS	203 05W	27 28E					
1308	ST	44 90							1354	ST	29 40E		92 84W				
1309	ST	265 67W							1355	SS	10 30E						
1310	ST	239 84 W	53 76E						1356	SS	33 33E						
1311	ST	56 19E	67 79E						1357	ST	213 85W	10 45E					
1312	ST		62 63E						1358	ST	30 76E						
1313	ST	65 45E							1359	ST	202 53W	006 45E					
1314	ST		63 71E	250 15W					1360	ST	211 79W	11 44E					
1315	ST	45 56E	62 70E	188 19W					1361	SL	359 86E	24 47E					
1316	ST	34 39E	37 64E						1362	SS							
1317	ST		22 70E						1363	ST							
1318	ST		22 66E						1364	SS	40 26E						
1319	ST	16 20E	37 74E						1365	SS	36 17E						
1320	ST	15 41E							1366	SS		38 75E					
1321	ST	241 43W	29 52E						1367	SS	37 30E	15 63E					
1322	SS	204 41W							1368	SS	31 64E						
1323	ST	195 35W	23 52E						1369	ST	28 31E	36 61E		57 06E	3661E		
1324	SS	208 44W	28 51E						1370	SS	18 37E						
1325	SS	55 75E							1371	SS	44 30E						
1326	ST		22 56E						1372	SS	28 32E						
1327	ST	217 59							1373	ST	34 74E						
1328	ST	213 66W	40 47E						1374	ST	211 70W						
1329	ST	20 10E	15 56E						1375	ST	202 43W						
1330	ST	37 50E	15 48E						1376	ST	29 06E	25 47E					
1331	ST	199 73W	20 48E						1377	ST	234 36W	(36 79E)					
1332	SS	34 37E							1378	SS	225 22W						
1333	SS	38 21E							1379	ST	256 29W						
1334	SL	30 11E	35 44E						1380	SL	209 53W	009 43E	202 38W				

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 1381	SS	18 51E							1427	ST		28 47E					
1382	SS	30 20E							1428	SS	19 26E						
1383	SS	18 28E							1429	SL	54 65E	15 30E					
1384	SS	28 18E	(24 77E)					215 9W	1430	SS	58 40E						
1385	SS	21 28E							1431	SL	263 14W	006 45E					
1386	ST	262 10W	18 62E		31 06	18 62E			1432	ST	17 53E	34 25E					
1387	ST	102 14E	009 32E						1433	SL	233 10W	009 30E					
1388	ST	224 21W	18 50E						1434	SS	26 39E						
1389	ST	210 61W							1435	SS	18 31E						
1390	ST	205 66W							1436	SS	215 44W	28 49E					
1391	ST	215 24W	22 48E						1437	SS	42 70E						
1392	ST	250 40W	33 37E						1438	SS	27 43E						
1393	ST	230 51W							1439	SS	41 51E						
1394	SS	110 06N							1440	ST	261 15N	20 33E					
1395	SS	340 12E							1441	ST	277 13N	19 29E					
1396	SS	28 36E							1442	SS	28 26E						
1397	SS	55 30E							1443	SS	37 41E						
1398	SS	28 25E							1444	SS	12 50E						
1399	SS	28 24E	(009 60E)						1445	SS	31 66E						
1400	SS	39 43E							1446	CG	345 36E						
1401	SS	35 31E							1447	SS	358 20E						
1402	SS	35 62E							1448	SS	28 21E						
1403	SS	36 54E							1449	SS	356 44E						
1404	SS	309 24E							1450	ST	356 27W	009 41E					
1405	ST	225 29W	46 43E						1451	ST	259 16N	37 90					
1406	ST	55 22E	19 34E						1452	ST							
1407	ST	40 14E	37 51E						1453	SS	30 27E						
1408	ST	30 44E							1454	ST	194 60W	007 20E					
1409	SS	005 41E							1455	ST	200 80W						
1410	SS	47 65E							1456	ST	207 18W	008 34E					
1411	SS	69 46S							1457	ST	190 21W	15 46E					
1412	ST		35 23E						1458	ST	29 05E	37 44E					
1413	ST	234 40W							1459	ST	15 16E	18 49E					
1414	ST	35 74E							1460	ST	211 11W						
1415	ST	38 42E	31 35E						1461	ST		26 48E					
1416	ST	44 46E							1462	ST	71 82E						
1417	ST	44 73E							1463	ST	15 16E	24 50E					
1418	ST	49 56E							1464	ST	209 54W	25 51E					
1419	ST	224 62W	008 26E						1465	ST	38 43E						
1420	ST	29 46E							1466	ST	35 27E	348 58E					
1421	SS	27 30E							1467	SS	340 74E						
1422	SS	24 38E							1468	ST	15 55E						
1423	SS	31 54E							1469	SS	70 79E	28 38E					
1424	ST	004 06E	005 39E						1470	ST	200 30W	17 43E					
1425	SL	27 64E	007 30E						1471	ST	45 41E						
1426	SS	19 16E							1472	ST		27 50E					

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 1473	SS	44 33E							1519	SL	63 26E						
1474	SS	226 10W	37 55E						1520	SS	32 35E						
1475	ST	28 14E	26 41E						1521	ST	25 27E						
1476	ST	16 35E	25 42E						1522	SL	22 16E	14 45E					
1477	SS	31 33E							1523	SL	222 16W						
1478	SS	209 71W							1524	CG	61 20E						
1479	CG	26 51E							1525	LS	122 36W						
1480	SL	194 44W	12 52E						1526	ST	52 10E						
1481	ST	33 74E	11 30E						1527	ST	45 16E	(230 32W)					
1482	SS	202 40W							1528	SL	32 10E	35 55E					
1483	SS	56 28E							1529	ST	15 24E						
1484	SS	24 44E							1530	SL	225 34W	34 35E		359 18	34 35E		
1485	SS	28 28E							1531	SL		005 61E					
1486	SS	40 25E							1532	SL	000 00	22 30E					
1487	SS	31 33E							1533	ST	43 10E	36 37E					
1488	SS	350 25E							1534	SS	28 26E						
1489	SS	31 31E							1535	SS	23 20E						
1490	SL		39 38E						1536	SS	19 19E						
1491	SS	45 25E							1537	SS	34 60E						
1492	SS	10 31E							1538	SS	25 61E						
1493	SS	16 40E							1539	ST	32 33E						
1494	ST	30 36E	(202 56W)						1540	SL	60 80E	59 46E					
1495	SS	10 34E							1541	SS	60 90						
1496	ST	44 27E	22 54E						1542	SL	67 90						
1497	SL	30 16E	32 48E						1543	SL	235 65W						
1498	SL	208 39W	19 55E						1544	SL	43 46E						
1499	ST	227 46W							1545	SL	220 54W						
1500	SL	52 80E	16 34E						1546	SL	49 74E	55 54E		84 24	55 54E		
1501	SL		25 44E						1547	SS	34 44E						
1502	SL	44 80E	36 24E						1548	SL	53 47E	47 30E					
1503	SL	196 10W	18 48E						1549	SS		56 32E					
1504	SL		33 35E	184 53W					1550	SL	30 52E						
1505	SL		19 22E						1551	ST	25 47E						
1506	SL		14 50E						1552	ST	37 47E	339 37E					
1507	ST	191 69W	31 35E						1553	SL	46 64E	36 30E					
1508	SL		15 36E	22 76E					1554	ST	65 20E						
1509	ST	202 38W	13 54E						1555	ST	43 50E						
1510	ST	91 30N	35 56E	193 52W					1556	SS	64 30E						
1511	SL		28 77E	336 65W					1557	SL	81 66S						
1512	ST	15 40E	23 60E						1558	SL	18 26E						
1513	ST	218 70W	21 60E						1559	ST	41 51E						
1514	ST	228 22W	42 47E						1560	ST	44 73E	35 55E					
1515	ST	20 45E							1561	ST	242 43W						
1516	SL	32 45E							1562	ST	45 65E						
1517	ST	78 40N	24 65E						1563	ST	220 47W						
1518	SL	36 24E	29 51E		37 15	29 51E			1564	ST	240 76W						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 1565	ST	246 06W	43 39E						MCF 1611	SL	29 11E	16 51E					
1566	ST	42 06E							1612	SL	000 00						
1567	ST	200 20W							1613	SL	231 10W						
1568	ST	264 44W							1614	SL	35 90			215 10	47 35E		
1569	ST		33 40E						1615	SL				37 05	40 41E		
1570	ST	215 26W							1616	SS	000 00						
1571	ST	49 81E							1617	ST	203 09W						
1572	ST	270 18N							1618	SL	28 12E						
1573	ST	43 90							1619	SL	46 09E						
1574	ST	228 55W	41 20E						1620	ST	222 20W	37 42E					
1575	ST	233 40W		57 81E					1621	ST	225 33W						
1576	ST	37 10E	42 44E						1622	ST	42 20E						
1577	ST	250 52W			009 41	19 30E			1623	SL	55 18E						
1578	ST	19 22E							1624	ST	62 19E	49 39E					
1579	ST	298 30E	48 17E						1625	ST	310 30E						
1580	ST	41 34E							1626	ST	000 00						
1581	ST	10 04E							1627	ST	000 00	51 30E					
1582	ST	237 10W	53 27E						1628	SL	66 19E						
1583	ST	202 31W							1629	SS	37 20E						
1584	ST	196 60W							1630	SS	73 30E						
1585	ST	218 34W	45 35E		243 24	45 35E			1631	ST	245 30W						
1586	ST	237 76W							1632	SL	000 00						
1587	ST	229 78W							1633	SL	26 80E			47 05	45 37E		
1588	ST	221 30W							1634	ST	229 25W	40 31E					
1589	ST	63 85E	20 36E						1635	CG	60 76E						
1590	SS	41 47E							1636	SL	55 12E						
1591	SS	176 10W			230 10	75 16E			1637	CG	265 14W						
1592	ST	31 85E							1638	SL	332 06E						
1593	ST	25 90							1639	SL	26 79E	30 47E		229 16	30 47E		
1594	LS	188 35W							1640	ST	203 57W						
1595	SL	216 39W	29 33E						1641	LS	22 55E						
1596	LS								1642	ST	210 62W						
1597	SS	223 34W							1643	ST	211 70W	20 24E					
1598	ST	225 40W	26 30E						1644	ST	000 62E			173 05	10 19E		
1599	ST	220 34W							1645	ST	212 16W	18 20E					
1600	LS	210 40W							1646	ST	225 32W						
1601	LS	36 24E	46 41E						1647	ST	222 12W	35 30E					
1602	SL	205 16W							1648	ST	200 24W			218 10	29 30E		
1603	SL	000 00	45 50E						1649	ST	200 09W	25 30E					
1604	SS	20 20E							1650	ST	000 00						
1605	LS	200 19W							1651	SL	67 15E						
1606	SS	000 00							1652	SL	204 35W						
1607	ST	223 17W	40 47E						1653	SL	53 16E						
1608	SL	215 21W	45 45E						1654	ST	208 47W						
1609	SS	000 00							1655	SL	65 20E	32 40E					
1610	ST	239 20W	30 59E						1656	SL	43 25E						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 1657	ST	221 80W	26 28E						MCF 1703	SL	000 00	27 32E	199 45W				
1658	SL	39 20E	(46 83E)						1704	SL	283 22E	19 24E					
1659	ST	66 72E	25 35E						1705	ST	235 24W						
1660	ST	210 56W							1706	SL	362 9E						
1661	ST	232 60W							1707	ST	62 90						
1662	ST	215 57W	30 45E						1708	SL	225 31W	55 28E	215 85W				
1663	SS	55 35E							1709	ST	200 20W	44 24E					
1664	SS	49 28E							1710	ST	248 48W						
1665	ST	18 26E	29 66E						1711	ST	156 35W	57 28E					
1666	ST	69 14E	43 50E						1712	ST	222 50W						
1667	ST				220 10	37 40E			1713	ST	60 61E	38 25E					
1668	CG	35 60E							1714	ST	243 56W	55 25E					
1669	ST	23 52E							1715	ST	46 54E						
1670	ST	39 24E							1716	ST	74 10E						
1671	SS				210 10	33 47E			1717	ST	14 40E						
1672	ST	35 40E							1718	ST	47 20E	38 51E					
1673	LS	242 45W							1719	ST	000 00	52 55E					
1674	SL	54 20E	28 59E						1720	SL		24 56E					
1675	LS	42 45E							1721	ST	201 10W						
1676	SL	34 26E							1722	ST	224 35W	47 40E					
1677	CG	85 34E	24 60E						1723	ST	240 36W						
1678	CG	63 61E							1724	ST	232 16W						
1679	SL	65 53E							1725	SS	55 36E						
1680	CG	45 72E							1726	SS	24 29E						
1681	CG	37 70E							1727	SS	25 42E						
1682	CG	48 25E							1728	ST	42 36E						
1683	SS	29 34E							1729	ST	84 20E	(284 70E)					
1684	SL	44 44E			55 15	35 44E			1730	ST	48 24E						
1685	SL	34 55E							1731	ST	26 18E	35 55E					
1686	LS	42 18E							1732	ST	25 32E						
1687	ST	21 16E							1733	ST	13 18E	35 51E					
1688	SL	35 17E							1734	ST	66 47E						
1689	LS	53 75E							1735	ST	52 26E	47 34E					
1690	SS	22 26E	(232 85W)						1736	SS	28 55E						
1691	ST	220 35W	47 40E						1737	SL	26 46E						
1692	ST	216 27W							1738	SL	26 39E						
1693	ST	195 53W							1739	SL	31 25E	20 47E					
1694	ST	198 40W							1740	ST	58 21E	23 39E					
1695	LS	233 24W							1741	ST	35 49E			198 11	56 22E		
1696	SS	205 15W							1742	LS	76 20E	48 50E					
1697	ST	206 21W	38 18E						1743	ST	75 27E	30 54E					
1698	SL	39 49E							1744	SS	134 10W	38 54E					
1699	SL		35 28E						1745	SL		30 52E	181 37W				
1700	SS	20 44E							1746	SS	35 31E			220 15	40 50E		
1701	ST	50 56E							1747	ST	42 35E						
1702	ST	227 66W	22 35E						1748	SS	52 46E						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MCF 1749	ST				202 09	44 47E			MCF 1795	CG	327 25E						
1750	ST				210 15	42 54E			1796	SS	337 26E						
1751	CG								1797	ST	227 42W						
1752	SS	30 54E							1798	SS	42 42E						
1753	SS	56 74E							1799	ST	44 23E						
1754	SS	30 74E							1800	CG	62 25E						
1755	ST	44 53E							1801	SS	39 64E						
1756	SL	32 21E	29 36E						1802	ST	31 07E						
1757	SL	26 37E							1803	SS	35 63E						
1758	ST	212 29W	25 44E						1804	SS	009 69E						
1759	ST	35 52E	25 34E						1805	SS	208 70W						
1760	SL		27 42E						1806	SS	206 34W						
1761	SL	38 47E							FAR 1	SL	36 39E	(46 64E)					
1762	SS	34 41E		204 44W					2	SS	707 9E	28 38E					
1763	ST	76 15E	32 57E						3	SS	130 63W						
1764	ST	195 25W							4	SL	20 74E						
1765	ST	61 12E							5	ST	10 79E						
1766	ST	67 30E							6	CG	294 38E						
1767	ST	34 45E							7	ST	229 30W						
1768	ST	39 38E							8	ST	234 75W	46 63E					
1769	ST	31 22E							9	SS	235 80W						
1770	ST	18 36E	25 50E						10	ST	236 54W						
1771	ST	207 39W							11	SL	53 90						
1772	SL	219 45W	45 50E						12	CG	36 76E						
1773	ST	41 60E							13	SL	25 84E						
1774	ST				219 16	35 46E			14	SS	36 50E						
1775	ST	31 80E							15	ST	249 80W	26 58E					
1776	ST	20 05E	(350 66E)						16	SL	36 90	26 63E					
1777	ST	238 64W							17	ST	43 90						
1778	SL	36 22E	38 54E						18	SS	37 80E						
1779	SL	219 50W							19	SL	42 73E						
1780	ST	165 67W							20	ST	205 80W						
1781	SL	15 57E							21	ST	25 70E						
1782	ST	31 22E	10 44E						22	SL	30 71E						
1783	SL	27 67E							23	SL	43 74E						
1784	ST	20 28E	55 48E						24	SL	40 90	31 44E					
1785	LS	15 35E							25	SL	46 72E						
1786	SL	34 67E	28 57E						26	SL	35 70E						
1787	SL	193 25W	185 1E	206 34W					27	CG	55 90						
1788	SL	20 50E							28	CG	26 90						
1789	LS	16 54E							29	SL	215 35W	28 55E					
1790	SL	229 58W	35 49E						30	SL	42 72E						
1791	SL	237 72W							31	SL	51 45E						
1792	SL				003 10	43 50E			32	SS	261 15W						
1793	SL	191 40W							33	SS	15 63E						
1794	CG	237 61W							34	CG	14 41E						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued) (Stations Far 122-126 compiled from Merschat and Hale, 1983)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
FAR 35	CG	45 40E							FAR 81	SS	50 50E						
36	CG	23 47E							82	SS	88 41E						
37	ST	261 25W	21 36E						83	ST	189 18W						
38	SS	115 90							84	SS	87 35E						
39	ST	217 27W							85	SS	002 55E						
40	ST	255 09W	35 44E						86	SS	118 25W						
41	ST	265 09W							87	ST	245 67W	28 55E					
42	SL	215 22W							88	SS	38 65E	55 38E		215 15	35 80E	227 07	
43	ST	245 22W	38 35E		33 09	23 55E	47 09		89	SS	001 90						
44	ST	226 30W							90	CG	63 40E						
45	SS	265 09W	30 33E						91	CG	107 78W						
46	SS	71 36E							92	ST		20 67E					
47	SS	245 67W							93	CG	215 73W						
48	ST	212 80W							94	ST	43 25E	35 65E					
49	SS	355 80E							95	ST	30 16E	10 63E					
50	SS	26 67E							96	ST	20 25E	30 68E					
51	SS	18 83E							97	CG	40 53E	31 58E					
52	SS	44 62E							98	CG	45 50E						
53	SS	24 56E							99	ST	275 49E						
54	SS	27 90							100	SL	229 85W						
55	SS	37 39E							101	CG	345 60E						
56	SS	43 39E							102	CG	35 41E						
57	SS	25 79E							103	SL	50 42E						
58	SS	220 71W							104	ST	62 90						
59	SS	45 15E							105	SS	234 45W						
60	SS	40 29E							106	SS	36 50E						
61	SS	201 75W							107	SL	277 37E						
62	ST	22 37E							108	SL	477 4E						
63	ST	000 00	42 46E						109	SL	232 84W						
64	ST	33 53E							110	SL	51 80E						
65	SS	337 27E							111	SL	320 31E						
66	SS	15 56E							112	SL	337 79E						
67	ST	41 53E							113	SL	577 4E						
68	ST	34 60E							114	CG	328 30E						
69	ST	45 70E							115	CG	003 34E						
70	CG	19 71E							116	CG	53 65E						
71	CG	005 70E							117	SL	45 55E						
72	SL	340 43E	22 74E						118	SL	14 47E						
73	ST	220 51W							119	CG	31 25E						
74	ST	51 31E							120	CG	260 40W						
75	ST		21 45E						121	SL	000 60E						
76	SS	235 80W							122	ST	221 64W	32 50E					
77	ST	290 31E							123	ST	243 16W						
78	ST	265 45E							124	CG	22 35E						
79	ST	223 86W							125	CG	22 86E	31 68E					
80	SS	30 50E							126	CG	13 78E	17 46E					

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued) (Stations FAR 127-143 compiled from Merschat and Hale, 1983)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
FAR 127	CG	243 30W							OD 30	ST	198 58W						
128	CG	200 32W	27 60E						31	ST	225 40W						
129	ST	224 41W							32	SS	225 51W						
130	ST	323 22E							33	ST	208 45W						
131	ST	228 13W							34	ST	215 37W						
132	ST	007 88E							35	ST	215 35W						
133	ST	215 24W							36	ST	18 22E						
134	ST	15 39E							37	ST	195 52W						
135	ST	31 75E							38	ST	209 38W						
136	ST	198 36W	22 38E						39	ST	195 60W						
137	ST	161 15W							40	SS	195 59W						
138	SS	42 23E							41	SS	196 33W						
139	SS	212 50W							42	ST	206 14W						
140	ST	10 72E							43	ST	165 14W						
141	ST	003 40E							44	ST	215 32W						
142	SS	11 41E							45	ST	00000						
143	SS	342 15E							46	LS	00000						
OD 1	SL	209 17W							47	ST	208 25W						
2	SL	179 23W							48	SS	210 45W						
3	LS	188 14W							49	ST	218 47W						
4	LS	188 21W							50	ST	216 48W						
5	LS	349 26E							51	SS	160 16W						
6	LS	163 23W							52	ST	183 20W						
7	SS	165 14W							53	ST	35 80E						
8	ST	325 09E							54	SS	00000						
9	ST	130 10W							55	ST	235 19W						
10	LS	188 15W							56	SS	220 24W						
11	LS	000 00							57	ST	211 28W						
12	ST	35 25E							58	CG	194 24W						
13	SS	95 17W							59	SS	225 19W						
14	SS	43 17E							60	SS	225 15W						
15	SS	70 15E							61	ST	236 41W						
16	CG	358 35E							62	ST	245 31W						
17	SS	225 19W							MEC 1	ST	207 32W						
18	SL	14 20E	24 57E						2	ST	225 29W						
19	SL	25 68E							3	SS	225 23W						
20	SL	221 45W	15 57E						4	SS	230 39W						
21	SL	264 25W							5	SS	205 17W						
22	SL	39 75E	40 59E						6	SS	244 19W						
23	CG	28 33E							7	SL	240 22W						
24	ST	230 40W	17 57E						8	SL	244 26W						
25	ST	272 21E	15 52E						9	SL	247 11W						
26	ST	245 78E							10	SL	280 11E						
27	ST	340 22E	24 64E						11	SL	240 26W						
28	ST	220 17W	20 69E						12	SL	220 20W						
29	ST	209 39W							13	SS	100 25W						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MEC 14	SL	40 33E							MEC 60	ST	30 57E						
15	ST	217 50W							61	SL	28 39E						
16	ST	217 41W							62	SL	69 75E	35 41E					
17	ST	205 49W							63	ST	55 75E						
18	SS	242 50W							64	ST	254 64W						
19	SS	205 54W							65	SS	90 25S						
20	CG	210 36W							66	ST	290 30E						
21	ST	232 31W							67	ST	275 17E						
22	ST	189 40W							68	SS	245 60W						
23	ST	210 24W							69	SS	275 09E						
24	ST	219 35W							70	ST	115 21W						
25	ST	210 51W							71	ST	000 00	40 34E					
26	ST	232 50W							72	ST	227 15W						
27	ST	230 45W							73	SS	226 07W						
28	ST	215 44W							74	SS	216 14W						
29	SS	221 46W							75	SS	214 39W						
30	SS	228 44W							76	SL	197 27W						
31	SS	233 72W							77	SS	244 16W						
32	SS	224 25W							78	SS	195 09W						
33	ST	285 28E							79	SS	210 09W						
34	ST	264 31W							80	SL	000 00						
35	ST	192 24E							81	SL	202 14W						
36	ST	230 58W							82	ST	220 24W						
37	SS	220 61W							83	SL	248 57W						
38	SS	21 59E							84	SL	25 69E						
39	ST	40 46E							85	SL	70 36E						
40	ST	55 30E							86	SL	80 19E						
41	ST	207 17W							87	ST	63 28E						
42	ST	200 42W							88	ST	218 18W						
43	ST	000 00							89	ST	000 00						
44	ST	230 16W							90	ST	64 64E						
45	SL	228 20W							91	ST	250 69W						
46	ST	200 21W							92	ST	214 22W						
47	ST	215 27W							93	SS	89 29E						
48	ST	55 15E							94	SS	265 44W						
49	ST	166 08W							95	ST	40 14E						
50	ST	157 28W							96	ST	220 15W						
51	ST	32 61E							97	ST	00000						
52	ST	155 09W							98	ST	25 26E						
53	ST	27 38E							99	ST	42 90						
54	ST	225 38W							100	SS	50 35E						
55	SS	280 27E							101	CG	55 61E						
56	CG	57 25E							102	ST	35 53E						
57	SL	28 61E							103	ST	76 90	56 52E					
58	ST	46 52E							104	ST	301 26E						
59	ST	43 65E							105	ST	000 00						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MEC 106	ST	000 00							MEC 152	ST	203 47W						
107	ST	215 19W							153	ST	205 40W						
108	SS	230 36W							154	ST	216 35W						
109	SS	201 22W							155	ST	186 36W						
110	SS	210 25W							156	SS	194 24W						
111	SS	231 12W							157	CG	199 39W						
112	ST				235 10	63 28E			158	SL	160 55W			137 05	338 43E		
113	ST	220 22W							159	SL	216 62W						
114	ST	61 10E							160	SL	33 47E						
115	ST	65 48E							161	SL	48 50E						
116	ST	245 20W							162	CG	22 29E						
117	SL	229 72W							163	SS	222 34W						
118	SL	35 54E							164	SL	218 31W						
119	SL	220 72W							165	ST	213 28W						
120	SL	173 69W							166	SL	188 32W						
121	SL	210 47W							167	SL	194 44W						
122	SL	32 55E			34 07	34 85E			168	CG	199 30W						
123	SL	259 45W							169	SS	199 34W						
124	LS	175 55W							170	ST	188 39W						
125	SL	280 55E							171	SS	39 65E						
126	LS	60 34E							172	SS	46 54E						
127	SL	55 65E							173	CG	290 85E						
128	LS	90 35S							174	SL	43 60E						
129	LS	50 34E							175	SS	169 36W						
130	LS	66 49E							176	SL	195 11W						
131	SL	345 41E							177	SL	63 90						
132	SL	27 49E							178	SL	57 39E						
133	LS	46 20E							179	LS	217 13W						
134	SL	229 82W			40 04	40 15E			180	SL	33 41E						
135	SS	236 81W							181	SS	227 36W						
136	SL	63 66E							182	SL	107 60W						
137	SL	228 49W							183	SS	212 17W						
138	SL	60 38E							184	LS	155 21W						
139	SL	43 37E							185	SL	234 30W			287 13	105 47W		
140	SL	260 52W							186	ST	57 79E						
141	SS	100 85W							187	SL	107 39W						
142	SS	70 70E							188	SL				208 09	33 41E		
143	CG	337 40E							189	SS	304 56E			356 07	35 72E		
144	SS	70 65E							190	SL				94 06	85 73E		
145	SS	69 39E							191	SL	199 60W						
146	SS	227 64W							192	SL				203 49	33 76E		
147	SS	226 46W							193	SL	261 58W						
148	CG	226 56W							194	SL	293 36E						
149	CG	174 44W							195	SL	000 00						
150	SS	193 29W							196	SL	81 55E						
151	CG	196 31W							197	SL				256 04	75 05E		

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MEC 198	SL	264 21W							MEC 244	SS	249 29W						
199	SL	93 44W							245	SS	233 51W						
200	SL	84 22E							246	SL	219 36W						
201	SL	54 68E	51 41E						247	ST	225 28W						
202	CG	63 25E							248	ST	223 48W						
203	CG	76 25E							249	SL	67 07E						
204	CG	127 21W							250	SL	47 19E						
205	CG	34 34E							251	SL	201 26W						
206	CG	64 47E							252	SL	246 15W						
207	SS	134 39W							253	SL	199 19W						
208	CG	28 41E							254	SL	213 48W						
209	CG	27 69E							255	SS	222 41W						
210	CG	57 25E							256	SL	34 10E						
211	CG	67 29E							257	SL	170 19W						
212	SS	54 25E							258	SL	000 00	32 28E					
213	SS	46 41E							259	SL		38 36E					
214	CG	32 35E							260	SL	000 00						
215	SS	56 45E							261	SL	57 06E						
216	SL	17 65E	44 22E						262	SL	223 37W						
217	ST	40 69E							263	SL	25 32E						
218	ST	304 20E	49 41E						264	SL	003 46E						
219	SL	62 27E							265	SL	130 21W						
220	SL	39 63E							266	ST	91 21W						
221	SL	49 64E	76 42E						267	ST	173 09W						
222	SS	59 37E							268	SL	000 00						
223	SL	55 40E							269	SL	176 05W						
224	SL	50 59E							270	SL	211 84W						
225	SL	42 64E							271	SL	000 00						
226	SL	232 46W							272	SL	36 27E						
227	SL	37 79E							273	ST	82 36E						
228	SL	213 37W							274	SS		71 26E					
229	SL	204 32W							275	SS	254 24W						
230	SL	203 44W							276	ST	235 33W						
231	SL	48 56E							277	SS	244 55W						
232	SL	202 46W							278	SS	92 70W						
233	CG	202 45W							279	ST	56 54E						
234	SL	202 34W							280	SS	259 54W						
235	SL	219 43W							281	SS	244 53W						
236	SL	196 28W							282	ST	000 00						
237	SL	212 36W							283	SS	254 06W						
238	CG	292 16E							284	ST	256 41W						
239	SL	223 29W							285	ST	248 25W						
240	SS	243 24W							286	ST	44 69E						
241	SL	208 30W							287	ST	218 57W						
242	SS	17 54E							288	ST	86 27E						
243	ST	216 31W							289	ST	54 13E						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MEC 290	ST	236 48W							MEC 336	ST	241 24W						
291	ST	249 74W							337	ST	178 29W						
292	ST	61 19E							338	ST	14 40E						
293	ST	239 48W							339	SL	51 54E			54 09	42 36E		
294	ST	93 17W							340	SS	234 86W			244 11	248 70W		
295	SS	72 07E							341	SS	11 35E						
296	SS	51 14E							342	CG	48 72E						
297	ST	19 34E							343	SS	53 90						
298	ST	004 11E							344	SS	164 42W						
299	SL	64 19E							345	SS	158 25W						
300	ST	32 25E							346	SS	150 22W						
301	SL	16 90							347	CG	261 56W						
302	SL	221 37W							348	ST	209 24W						
303	SL	000 00							349	ST	217 23W						
304	SL	32 75E							350	SS	215 16W						
305	SL	124 11W							351	SL	204 16W						
306	ST	57 07E							352	SL	236 10W						
307	ST	214 06W							353	SS	224 28W						
308	ST	196 61W							354	CG	221 31W						
309	ST	000 00							355	SS	236 22W						
310	ST	233 39W							356	ST	231 34W						
311	SS	39 39E							357	ST	216 26W						
312	SL	174 27W							358	ST	36 09E						
313	CG	232 36W							359	ST	208 16W						
314	SS	226 24W							360	ST	47 05E						
315	SS	164 31W							361	SS		57 45E					
316	SS	002 90							362	ST	242 41W	46 26E					
317	SS	21 90							363	SS	207 38W						
318	SS	34 69E							364	SL	89 62E						
319	CG	201 26W							365	SL	52 29E						
320	SS	220 33W							366	SL	94 46W						
321	SS	216 26W							367	SL	354 54E						
322	SS	214 46W							368	SS	41 63E						
323	SS	201 43W							369	SL	57 55E						
324	SL	213 37W							370	SS	72 39E						
325	ST	193 30W							371	ST	36 62E	33 41E					
326	ST	206 42W							372	ST	74 39E	42 43E					
327	ST	224 36W							373	ST	72 60E			256 06	7642E		
328	ST	221 56W							374	SS	73 30E						
329	ST	209 37W							375	SS	93 36W						
330	SL	233 06W							376	SS	127 07W						
331	SS	243 49W							377	SS	116 24W						
332	CG	241 49W							378	SS	127 34W						
333	SL	261 44W							379	SL	002 29E						
334	ST	211 36W							380	SL				20 24	10 35E		
335	ST	211 39W							381	SL	245 63W						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued) (Data from stations MEC 396-MEC 473 collected by C. Lombardi, 6/92-8/92)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MEC 382	SS	266 11W							MEC 428	SL	47 60E						
383	SS	255 54W							429	SL	226 50W						
384	SS	244 83W							430	SL	217 74W						
385	ST	43 25E							431	SL	135 67W						
386	SS	300 36E							432	SL	208 38W						
387	SS	303 49E							433	SL	56 68E						
388	SS	76 85E	37 34E						434	SL				38 47	24 53E		
389	SL	74 26E							435	SL	233 56W						
390	SL	55 90	35 65E						436	SL	222 63W						
391	SS	244 56W							437	SL	227 45W						
392	SS	194 41W							438	SL	41 62E						
393	SS	63 31E							439	SL	265 6E						
394	ST								440	SL	190 28W						
395	ST	62 36E							441	SL	257 14W						
396	SL	005 32E							442	SL	214 66W						
397	SL	52 21E							443	SL	342 28E						
398	SL	47 56E							444	SL	68 20E						
399	ST	216 52W							445	SL	25 31E						
400	SL	232 45W							446	CG	226 51W						
401	SL	29 57E							447	SL	33 41E						
402	SL	225 25W							448	SL	24 58E						
403	SL	52 70E							449	SS	270 59N						
404	ST	225 36W							450	SL	34 27E						
405	SL	233 42W							451	SS	217 50W						
406	SL	198 65W							452	SS	247 63W						
407	ST	52 35E							453	SS	243 75W						
408	SL	232 51W							454	SL	50 24E						
409	SS	65 51E							455	SL	238 64W						
410	SS	330 20E							456	CG	270 60N						
411	SL	260 56W							457	SL	68 57E						
412	SL	260 56W							458	SL	145 37W						
413	SL	290 68E							459	SL	207 33W						
414	SL	45 73E							460	SL	256 64W						
415	SL	43 24E							461	SL	57 15E						
416	SL	80 45E							462	SL	63 24E						
417	SL	200 25W							463	SL	156 15W						
418	SL	254 71W							464	SL	31 36E						
419	SL	58 46E							465	SL	209 31W						
420	SL	76 15E							466	SL	236 34W						
421	SL	71 18E							467	SL	248 21W						
422	SL	248 30W							468	SL	214 23W						
423	SL	44 56E							469	SL	71 29E						
424	SL	50 40E							470	SL	209 32W						
425	SL	50 25E							471	SL	232 31W						
426	SL	208 42W							472	SL	238 40W						
427	SL	58 52E							473	SL	242 54W						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued) (Data from stations MEC 474-MEC 565 collected by C. Lombardi, 6/92-8/92)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MEC 474	SL	226 57W							MEC 520	SS	78 82E						
475	SL	228 55W							521	SL	262 51W						
476	SL	256 54W							522	SL	45 32E						
477	SS	318 14E							523	SL	52 24E						
478	SS	297 62E							524	SS		72 26E					
479	SL	223 41W							525	SL	22 75E						
480	SL	143 50W							526	SS	64 83E						
481	SL	44 26E							527	SL	255 59W						
482	SS	61 24E							528	SL		292 17E					
483	SS	53 73E							529	SS	238 49W						
484	SL	236 68W							530	SS	000 54E						
485	SL		66 62E						531	ST	42 64E						
486	SS	318 49E							532	SS	46 68E						
487	CG	72 34E							533	SL		210 70W					
488	SS	240 88W							534	SS	54 38E						
489	SS	258 74W							535	SS	244 56W						
490	ST	78 25E							536	SS	62 24E						
491	ST	88 28E							537	SS	112 79W						
492	SS	90 36S							538	SS	222 30W						
493	SS	220 72W							539	SS	229 44W						
494	SS	68 14E							540	SS	62 34E						
495	ST	65 24E							541	SS	46 35E						
496	SL	000 63E							542	SS	227 52W						
497	CG	155 19W							543	SS	38 90						
498	CG	220 45W							544	SS	56 85E						
499	CG	180 32W							545	ST	332 15W						
500	SL	290 36E							546	ST	296 09E						
501	SL	41 34E							547	SS		101 58W					
502	SS		000 40E						548	SS	238 61W						
503	SS		345 15E						549	SS	62 90						
504	SS		40 90						550	ST	214 56W						
505	SS	319 19E							551	CG	68 70E						
506	SS	003 14E							552	ST	244 61W						
507	SS	341 25E							553	SS	32 24E						
508	SL	242 72W							554	SS	36 24E						
509	SL	66 54E							555	SS	47 26E						
510	SL	62 69E							556	SS	68 23E						
511	ST	318 49E							557	LS	44 18E						
512	SL	60 62E							558	ST	21 67E						
513	SL	48 71E							559	SS	46 21E						
514	SS		278 39E						560	ST	50 20E						
515	SS		164 68W						561	SS	28 30E						
516	SS	222 85W							562	ST	23 28E						
517	SL	005 27E							563	SS	54 90						
518	SS	008 32E							564	SS	74 90						
519	SS		106 64W						565	SS	80 44E						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-I: (continued) (Data from stations MEC 566-MEC 657 collected by C. Lombardi, 6/92-8/92)

St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})	St. no.	lithology	S ₀	S ₂ (S _{2a})	S ₃ [*] (S _{3a})	Fold axes	Axial surfaces	L _{0x2}	L _{0x2a} (L _{0x3})
MEC 566	SS	45 53E							MEC 612	ST	42 52E						
567	SS	42 49E							613	ST	5876E						
568	SS	54 43E							614	ST	38 36E	32 65E					
569	SL	66 32E							615	SL	234 59W	51 66E					
570	SL	50 16E							616	SL	000 00	24 41E					
571	SL	59 60E							617	SL		10 47E					
572	SL	75 72E							618	SS	24 32E						
573	SS	61 90							619	SS							
574	SS	69 57E							620	SS							
575	CG	84 42E							621	SS	33 66E						
576	SS	232 71W							622	CG	52 56E						
577	SS	64 26E							623	CG							
578	SS	66 31E							624	CG	23 80E						
579	SL	50 09E							625	SL	33 45E						
580	SS	46 16E							626	CG	24 49E						
581	SL		54 23E						627	SS							
582	SL	226 31W							628	CG	006 57E						
583	SL	22 58E							629	CG	40 59E						
584	SL	224 34W							630	CG	40 27E						
585	SL		46 42E						631	SS	84 31E	20 59E					
586	SL	217 29W	42 45E						632	SS	34 30E						
587	SL	30 08E							633	SL							
588	SL	38 09E							634	SL	000 42E	008 58E					
589	SL	52 58E							635	ST	53 32E						
590	SL		38 38E						636	SL	15 45E						
591	SL	43 52E							637	SS	32 67E						
592	SL		216 64W						638	LS	43 68E						
593	SL	38 36E	27 61E						639	SL	216 24W	43 47E					
594	SL		53 24E						640	SL	008 27E						
595	SL	28 71E	42 51E						641	SS							
596	SL	18 58E							642	SS	49 41E						
597	SL	50 45E							643	SS	55 22E						
598	SL				24 59	14 72E			644	SS	66 36E						
599	SL	138 17W	46 56E						645	SL	54 60E						
600	SL		37 44E						646	SL	16 21E						
601	SL	15 31E							647	SS	39 41E						
602	SL	218 46W							648	CG	36 31E						
603	SL	000 00	26 46E						649	CG	42 30E						
604	SS	18 38E							650	SS	26 29E						
605	ST	35 20E	30 39E						651	SL	39 70E						
606	ST	24 75E							652	SL	219 51W						
607	SL	14 23E	17 54E						653	LS	62 49E						
608	SL				196 26	18 54E			654	LS	62 90						
609	SL	81 37E	81 28E						655	CG	58 74E						
610	SL	30 86E	48 34E						656	SL	48 76E						
611	SL	216 71W	29 69E						657	SL	40 63E						

Key to lithology symbols: SL-slate; ST-siltstone; SS-sandstone; CG-conglomerate; LS-carbonate. * Axial surface.

Table A-II: Modal analyses of coarse-grained clastic rocks from the study area.

Stratigraphic unit	Cochran Fm	Sandsuck Formation						
		upper member		middle member		lower member		
Sample no.	MEC 240-V ²	MEC 181-V ¹	MCF 478-V ¹	MCF 1054 ¹	OD 23 ¹	MEC 208-V ¹	MEC 392-V ¹	MCF 338 ¹
Quartz	71	88.8	56.4	65.9	61.2	87.9	78.1	90.5
Plagioclase (composition)	1	0.5	7.1 (An ₃₁)	12.3	9.7 (An ₃₁)	Tr	2.7	0.7
Perthite			0.5	0.5	0.4		0.1	
Microcline		0.1	0.1				1.4	0.3
Clay/ Sericate	8	8.6	5.8	13.8	10.7	6.2	13.0	4.9
Chlorite			6.1	0.3	5.7			
Muscovite	1	0.1	0.3	0.5	Tr	0.1	1.2	
Biotite		Tr	0.1	0.1	Tr	Tr		
Magnetite/ Ilmenite	1		0.3	0.3	0.6	Tr	0.1	Tr
Hematite	5	1.3	5.2	2.9	3.3	5.8	2.7	3.5
Pyrite								
Carbonate								Tr
Calcite			16.7					
Zircon		0.2	Tr	0.3	0.2	0.1	0.4	0.5
Apatite					Tr			
Tourmaline		Tr	Tr	0.1	Tr	Tr	0.3	Tr
Epidote								Tr
Sphene								
Lithic Fragments	13 a,b	0.5 b,a,e	1.5 b,a	3.0 a	8.2 a,c,d		0.1 a	
Total	100	100.1	100.1	100.0	100.0	100.1	100.1	100.4
number of points counted	-	1000	1000	1000	1014	1000	1000	1000

Notes: Index to sample no. superscript key: 1 - modal analysis determined by point counting; 2 - modal analysis estimated by visual inspection. Index to lithic fragment superscript key: a - shale; b - siltstone; c - carbonate; d - quartzite; e - granitoid. Ordering denotes relative abundance. Plagioclase compositions obtained using the Michel-Lévy (1877) method.

Table A - II: (continued)

Stratigraphic unit	Sandsuck Fm	Wilhite Formation						
	lower mb	Interbedded sandstones of the Wilhite Formation					feldspathic sandstone member	
Sample no.	MCF 377-V ²	MCF 126 ²	MCF 282 ²	MCF 1499 ²	MCF 1650 ¹	MCF 749 ¹	MCF 916-V ²	MCF 917 ¹
Quartz	56	66	60	50	43.6	54.1	70	74.2
Plagioclase (composition)	14	15 (An 29)	15 (An 35)	13 (An 30)	3.2	14.7 (An 30)	12 (An 30)	8.9 (An 32)
Perthite		2	Tr			1.2		0.9
Microcline								
Clay/ Sericite	10	Tr	17	7	22.3	6.6	10	3.7
Chlorite		1			4.2	7.9	Tr	Tr
Muscovite	2	1	3	2	3.8	2.5	2	0.2
Biotite	Tr	Tr	2	Tr	Tr	Tr		
Magnetite/ Ilmenite	2		2	4	2.9	1.2		Tr
Hematite/Limonite	6	6	1	7	2.1	11.7	6	1.0
Pyrite								
Carbonate	1			17				
Calcite		9			17.6			11.0
Zircon		Tr	Tr	Tr	Tr	Tr	Tr	0.3
Apatite		Tr	Tr	Tr	0.1	0.2	Tr	Tr
Tourmaline	Tr	Tr	Tr	Tr	0.2	Tr	Tr	
Epidote								Tr
Sphene					Tr			
Lithic Fragments	10 a,d,c,e							
Total	100	100	100	100	100.0	100.1	100	100.2
number of points counted	-	-			1000	1000		1000

Notes: Index to sample no. superscript key: 1 - modal analysis determined by point counting; 2 - modal analysis estimated by visual inspection. Index to lithic fragment superscript key: a - shale; b - siltstone; c - carbonate; d - quartzite; e - granitoid. Ordering denotes relative abundance. Plagioclase compositions obtained using the Michel-Lévy (1877) method.

Table A-II: (continued)

Stratigraphic unit	Wilhite Formation		Buck Bald formation		
	graywacke sandstone member		lower Facies (granule to pebble metaconglomerate)	feldspathic graywacke (granule metaconglomerate)	
Sample no.	MEC 782-V ¹	MCF 1364 ¹	MCF 1668 ¹	FAR 28-V ¹	FAR 71 ¹
Quartz	59.7	55.9	72.4	74.0	62.5
Plagioclase (composition)	15.1	12.6 (An ₃₃)	3.7 (An ₃₅)	9.6 (An ₃₀)	4.5
Perthite	0.8	0.3	Tr	0.6	
Microcline				0.1	
Clay/ Sericite	13.9	15.9	9.6	5.3	22.2
Chlorite	4.6	7.8	1.1	6.5	7.0
Muscovite	1.0	1.2	1.3	0.9	1.9
Biotite	0.2	0.1	0.3	0.1	0.1
Magnetite/ Ilmenite	0.3	0.8	1.4	0.5	0.6
Hematite	3.8	3.1	0.2	0.6	1.2
Pyrite		0.2			
Carbonate				Tr	
Calcite		1.6	8.7	1.6	
Zircon	0.3	0.3	0.5	0.2	Tr
Apatite	0.2	0.2	0.1	Tr	
Tourmaline	0.1	Tr	Tr	0.1	
Epidote					
Sphene				Tr	
Lithic Fragments			0.8 ^{c,a}		0.1 ^a
Total	100.0	100.0	100.1	100.1	100.1
number of points counted	1000	1000	1000	1000	1000

Notes: Index to sample no. superscript key: 1 - modal analysis determined by point counting; 2 - modal analysis estimated by visual inspection. Index to lithic fragment superscript key: a - shale; b - siltstone; c - carbonate; d - quartzite; e - granitoid. Ordering denotes relative abundance. Plagioclase compositions obtained using the Michel-Lévy (1877) method.

Table A - III: Modal analyses of Sandsuck Formation carbonate rocks from the study area.

Sample no.	MCF 1022	MCF 1003	MCF 1197
Micritic Calcite	57.1	35.2	59.3
Sparry Calcite	19.2	6.4	
Intraclasts	4.6	1.2	
Onkolites		7.6	
Quartz	18.9	49.4	18.2
Plagioclase (composition)		0.2	15.8 (An ₃₁)
Potassium Feldspar			0.5
Perthite		0.1	
Magnetite/Ilmenite	0.1	Tr	1.0
Hematite	0.1		1.0
Clay			3.8
Biotite	Tr		
Chlorite	Tr		
Muscovite	Tr		0.5
Zircon		Tr	Tr
Tourmaline	Tr	Tr	
Total	100.0	100.1	100.1
number of points counted	1000	1000	209

Notes: Modal analyses determined by point-counts. Sample no. MCF 1197 derived from a clast within a carbonate breccia. Plagioclase compositions obtained using the Michel-Lévy (1877) method.

Table A-IV: Size orders of folds in the study area.

	Order	Amplitude Range	Wavelength Range	Examples
Regional Structures	1st	>500m	>5km	Ducktown anticline Murphy syncline
	2nd	500m - 50m	5km - 1.5km	Bean - Starr Mountain syncline Spring Creek anticline Towee Creek anticlinorium Epperson synclinorium
Map Scale (Quadrangle) Structures	3rd	50m - 15m	1.5km - 50m	Pond Mountain syncline McCulley Mountain anticline Big Bend anticline Perrys Branch syncline
Mesoscale Structures	4th	15m - 1m	50m - 1m	
	5th	1m - 10cm	1m - 10cm	
	6th	<10cm	<10cm	

Table A-V: Measurements of quartz pebble principal axes and axial ratios.

n	X (in mm)	Y (in mm)	Z (in mm)	X/Y	Y/Z	X/Z	n	X (in mm)	Y (in mm)	Z (in mm)	X/Y	Y/Z	X/Z
1	72	49	22	1.47	2.23	3.27	27	35	22	10	1.59	2.20	3.50
2	44	36	19	1.22	1.89	2.31	28	52	41	16	1.27	2.56	3.25
3	50	34	26	1.47	1.31	1.92	29	31	16	11	1.94	1.45	2.82
4	52	33	24	1.58	1.38	2.17	30	38	22	15	1.72	1.47	2.53
5	39	28	23	1.39	1.70	1.70	31	35	26	13	1.35	2.00	2.69
6	111	60	19	1.85	3.15	5.84	32	50	42	31	1.19	1.36	1.61
7	46	40	19	1.15	2.11	2.42	33	40	33	25	1.21	1.32	1.60
8	76	49	31	1.55	1.58	2.45	34	49	27	20	1.82	1.35	2.45
9	27	12	8	2.25	1.50	3.37	35	34	29	21	1.17	1.38	1.62
10	48	22	12	2.18	1.83	4.00	36	45	30	21	1.50	1.43	2.14
11	34	23	22	1.48	1.05	1.54	37	40	24	17	1.67	1.41	2.35
12	72	37	15	1.95	2.47	4.80	38	41	21	13	1.95	1.62	3.15
13	41	35	15	1.17	2.33	2.70	39	32	25	9	1.28	2.78	3.56
14	53	36	21	1.47	1.71	2.52	40	35	16	10	2.19	1.60	3.50
15	44	28	21	1.57	1.33	2.09	41	39	22	11	1.77	2.00	3.55
16	44	35	19	1.26	1.84	2.32	42	39	30	16	1.30	1.88	2.44
17	31	21	11	1.48	1.91	2.82	43	27	17	13	1.59	1.31	2.08
18	57	45	24	1.27	1.88	2.38	44	35	34	16	1.03	2.13	2.19
19	42	25	14	1.68	1.79	3.00	45	29	19	14	1.53	1.36	2.07
20	68	32	22	2.13	1.46	3.09	46	35	21	16	1.67	1.31	2.19
21	79	61	29	1.30	2.10	2.72	47	25	15	9	1.67	1.67	2.78
22	64	38	22	1.68	1.73	2.91	48	27	15	11	1.80	1.36	2.45
23	48	19	16	2.53	1.19	3.00	49	32	20	10	1.60	2.00	3.20
24	29	21	8	1.38	2.63	3.63	50	30	24	15	1.25	1.60	2.00
25	57	33	27	1.73	1.22	2.11	51	24	17	11	1.41	1.55	2.18
26	53	35	15	1.51	2.33	3.53	52	23	14	10	1.64	1.40	2.30
									mean and standard deviation		1.57 ± 0.31	1.75 ± 0.45	2.71 ± 0.80

Table A-VI: Measurements of granitoid pebble and cobble principal axes and axial ratios.

n	X (in mm)	Y (in mm)	Z (in mm)	X/Y	Y/Z	X/Z
1	155	89	35	1.74	2.54	4.43
2	34	27	11	1.26	2.45	3.09
3	60	34	20	1.76	1.70	3.00
4	48	37	13	1.29	2.85	3.69
5	38	28	12	1.36	2.33	3.17
6	34	24	10	1.42	2.40	3.40
7	34	26	14	1.31	1.86	2.43
8	64	43	13	1.49	3.30	4.92
9	85	72	33	1.18	2.18	2.58
10	34	24	11	1.42	2.18	3.09
11	40	19	11	2.10	1.73	3.64
12	63	34	19	1.85	1.79	3.32
13	40	30	16	1.33	1.88	2.50
14	43	25	16	1.72	1.56	2.69
mean and standard deviation				1.51 ± 0.26	2.20 ± 0.47	3.28 ± 0.69

Table A-VII: Results of 3-dimensional strain analysis using the R_f/ϕ method.

		X	Y	Z	X/Y	Y/Z	X/Z	X Orientation	Y Orientation	Z Orientation	X/Y Orientation	Y/Z Orientation	X/Z Orientation
Great Smoky thrust sheet	MEC 240	1.09	1.01	0.91	1.08	1.11	1.20	057 14°	147 01°	241 76°	331 14°E	147 76°W	237 89°N
	MEC 181	1.05	1.00	0.85	1.05	1.18	1.24	219 33°	330 30°	093 43°	183 47°W	309 57°N	060 60°S
	MCF478	1.07	1.00	0.91	1.07	1.09	1.18	155 25°	063 06°	320 64°	050 26°S	245 65°N	153 84°W
Maggies Mill thrust sheet	MCF 377	1.24	1.00	0.80	1.24	1.25	1.55	209 08°	114 29°	312 60°	042 30°E	299 82°N	204 61°W
	MEC 208	1.21	1.10	0.74	1.10	1.49	1.63	281 56°	190 01°	100 34°	190 56°W	011 34°E	280 89°N
	MEC 392	1.14	1.00	0.95	1.14	1.06	1.21	022 72°	169 15°	262 09°	352 81°E	112 18°S	259 75°N
Miller Cove thrust sheet	MCF 916	1.13	1.00	0.91	1.13	1.09	1.24	182 24°	061 49°	288 31°	018 59°E	272 66°N	151 41°W
	MCF 782	1.22	1.07	0.76	1.14	1.41	1.61	285 03°	195 04°	053 85°	143 06°W	015 87°W	285 86°N
	FAR 28	1.15	1.00	0.78	1.15	1.28	1.47	088 08°	183 32°	345 57°	075 33°S	178 82°W	273 58°N
		Mean and standard deviation			1.12 ± 0.05	1.22 ± 0.14	1.37 ± 0.18						

Note: First column corresponds to thrust sheet, second column corresponds to sample number.

Table A-VIII: Results of 3-dimensional strain analysis using the normalized Fry method.

		X	Y	Z	X/Y	Y/Z	X/Z	X Orientation	Y Orientation	Z Orientation	X/Y Orientation	Y/Z Orientation	X/Z Orientation
Great Smoky thrust sheet	MEC 240	1.14	0.99	0.88	1.15	1.13	1.30	084 40°	350 05°	254 50°	344 40°E	174 50°W	080 85°S
	MEC 181	1.11	1.05	0.86	1.08	1.21	1.30	353 01°	261 62°	083 28°	173 62°W	083 89°S	351 28°E
	MCF478	1.18	0.97	0.87	1.22	1.12	1.36	160 12°	068 10°	299 74°	029 16°E	250 78°N	158 80°W
Maggies Mill thrust sheet	MCF 377	1.32	0.99	0.76	1.33	1.30	1.73	207 05°	110 54°	301 36°	031 54°E	297 85°N	200 36°W
	MEC 208	1.24	1.06	0.75	1.17	1.45	1.65	291 54°	182 14°	083 33°	173 57°W	021 36°E	272 76°N
	MEC 392	1.31	0.92	0.83	1.42	1.11	1.58	320 07°	227 20°	068 69°	158 21°W	050 83°S	317 70°E
Miller Cove thrust sheet	MCF 916	1.23	0.98	0.82	1.26	1.19	1.50	176 38°	004 51°	269 04°	359 86°E	266 52°N	094 39°S
	MCF 782	1.37	0.95	0.77	1.44	1.23	1.78	335 09°	068 22°	223 66°	313 24°N	065 81°S	158 68°W
	FAR 28	1.15	1.12	0.77	1.03	1.45	1.49	120 59°	216 04°	308 31°	038 59°E	210 31°W	306 86°N
		Mean and standard deviation			1.23 ± 0.13	1.24 ± 0.12	1.52 ± 0.17						

Note: First column corresponds to thrust sheet, second column corresponds to sample number

Vita

Mark Wayne Carter was born in Richmond, Virginia, on March 1, 1968. He attended Hanover County public schools and graduated from Lee-Davis High School in June, 1986. The following August, he entered Old Dominion University in Norfolk, Virginia, and graduated in December, 1990, with a Bachelor of Science degree in Geology. After one semester of graduate school at Old Dominion, he transferred to the University of Tennessee, Knoxville, and graduated in May, 1994, with a Master of Science degree in Geology.

He is presently continuing his geological education at the University of Tennessee, Knoxville.

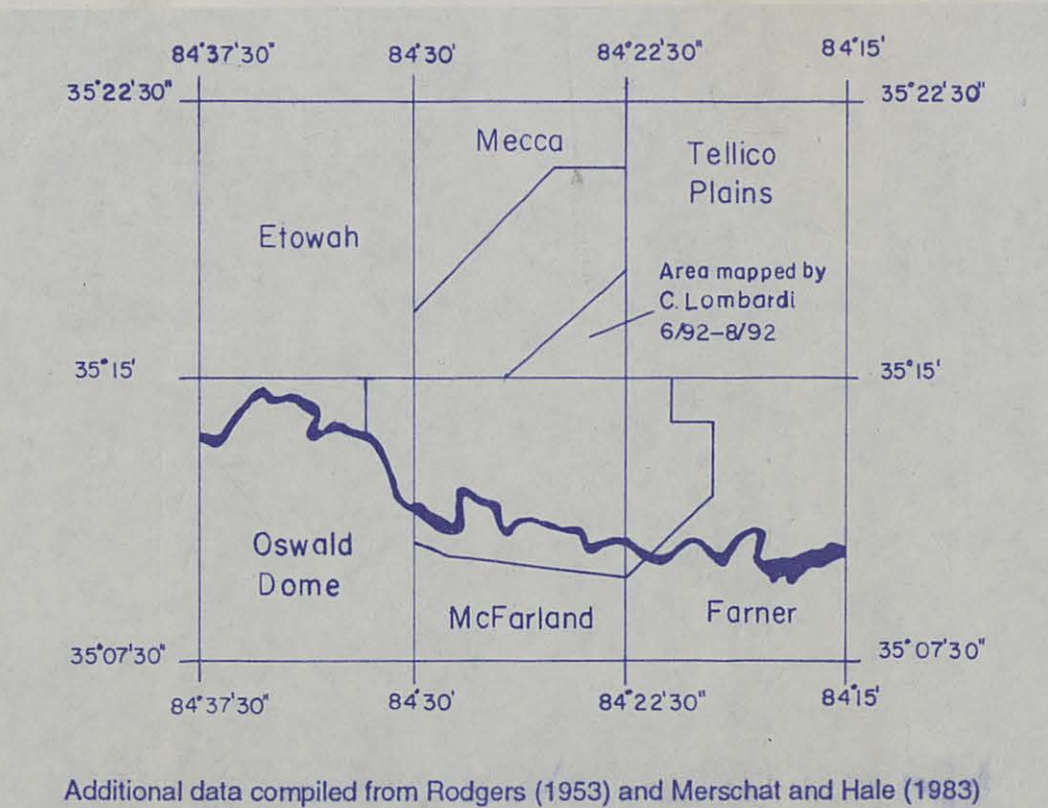
Mark W. Carter
1994

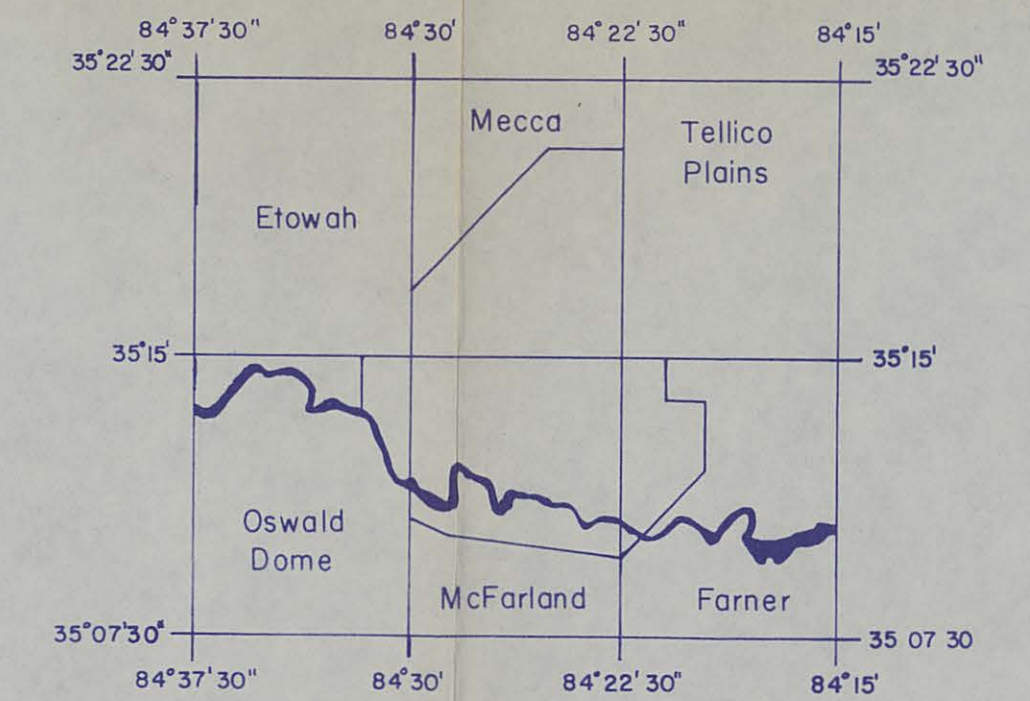
Scale 1:24,000

The diagram illustrates a geological column with three main sections: Knox Group, Rome Formation, and Chilhowee Group. The Knox Group is divided into the Walden Cove Group and the Great Smoky Group. The Rome Formation is a single unit. The Chilhowee Group is divided into the Sanduck Formation and the White Formation. The Sanduck Formation is further divided into upper, middle, and lower members. The White Formation is divided into upper lithoarches and lower lithoarches. The Great Smoky Group is divided into the Buck Bald Formation and the Boyd Gap Formation. The Buck Bald Formation is further divided into upper lithoarches and lower lithoarches. The Boyd Gap Formation is a single unit. The units are listed with their thicknesses in feet (ft) and their lithological descriptions.

Group	Formation	Member	Unit	Thickness (ft)	Description
Knox Group	Walden Cove Group				
Knox Group	Great Smoky Group				
Rome Formation					
Chilhowee Group	Sanduck Formation	upper member		25ft	shale, sandstone and conglomerate
				20ft	dolomitic siltstone
Chilhowee Group	Sanduck Formation	middle member		20ft	carbonate breccia
				20ft	micaceous sandstone
Chilhowee Group	Sanduck Formation	lower member		20ft	siltstone
				20ft	shale, sandstone and conglomerate
Chilhowee Group	White Formation	upper lithoarches		20ft	Maggies Mill fault
				20ft	sandstone
Chilhowee Group	White Formation	lower lithoarches		20ft	carbonate
				20ft	
Great Smoky Group	Buck Bald Formation	upper lithoarches		20ft	metasiltstone lithofacies
				20ft	feldspathic metasandstone member
Great Smoky Group	Buck Bald Formation	lower lithoarches		20ft	feldspathic metagraywacke member
				20ft	calcareous quartzite member
Great Smoky Group	Boyd Gap Formation			20ft	feldspathic graywacke-granule metaconglomerate
				20ft	quartz-pebble metaconglomerate
Great Smoky Group	Boyd Gap Formation			20ft	granitoid-boulder metaconglomerate
				20ft	

- Location map and index to 7.5-Minute Quadrangles

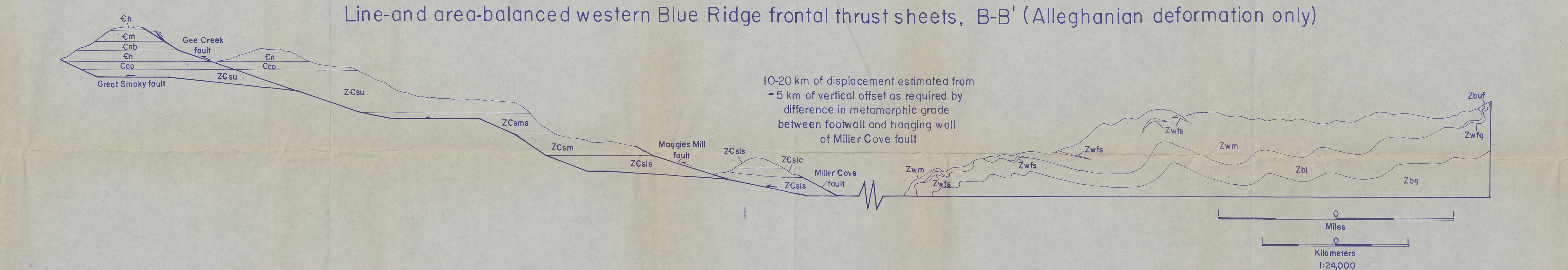
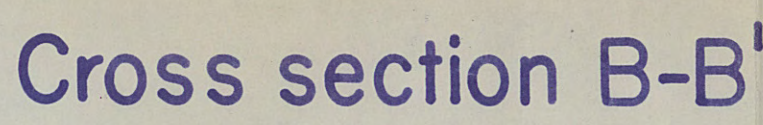
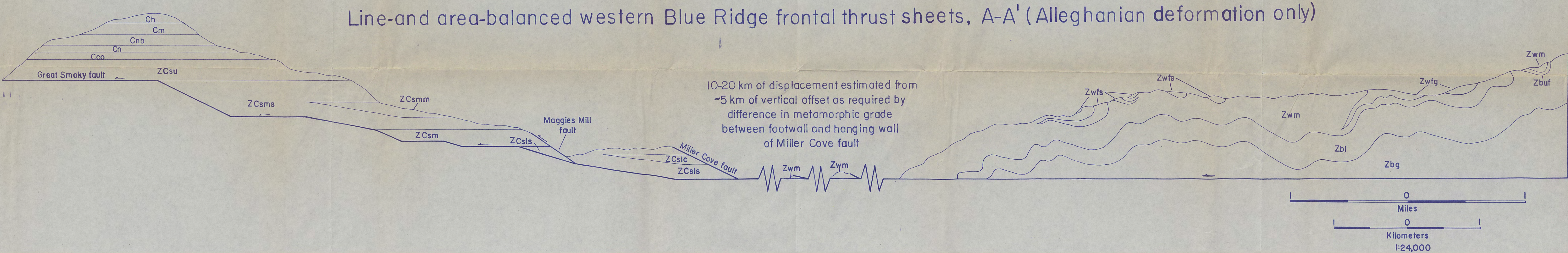


$84^{\circ}22'30''$ 

Stations on the Mecca 7.5-minute quadrangle begin with MEC prefix.
Stations on the McFarland 7.5-minute quadrangle begin with MCF prefix.
Stations on the Farmer 7.5-minute quadrangle begin with FAR prefix.
Stations on the Osborn Dome 7.5-minute quadrangle begin with OD prefix.
Stations MEC 396-MEC 657 located by C. Lombardi, 6/92-8/92

Scale 1:24,000

Retrodeformed Cross Sections, A-A' and B-B'

[illegible]

Additional geologic data for completion of cross sections
west of study area compiled from Hardeman (1966)