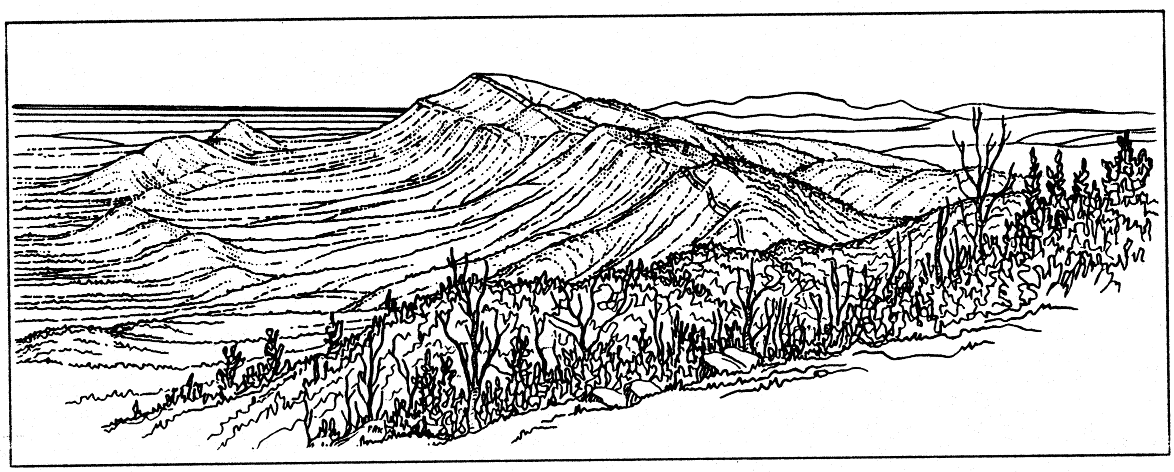
CAROLINA GEOLOGICAL SOCIETY

NOVEMBER 9-10, 1991

Studies of Precambrian and Paleozoic Stratigraphy in the Western Blue Ridge

edited by
Stephen A. Kish



Contributors:

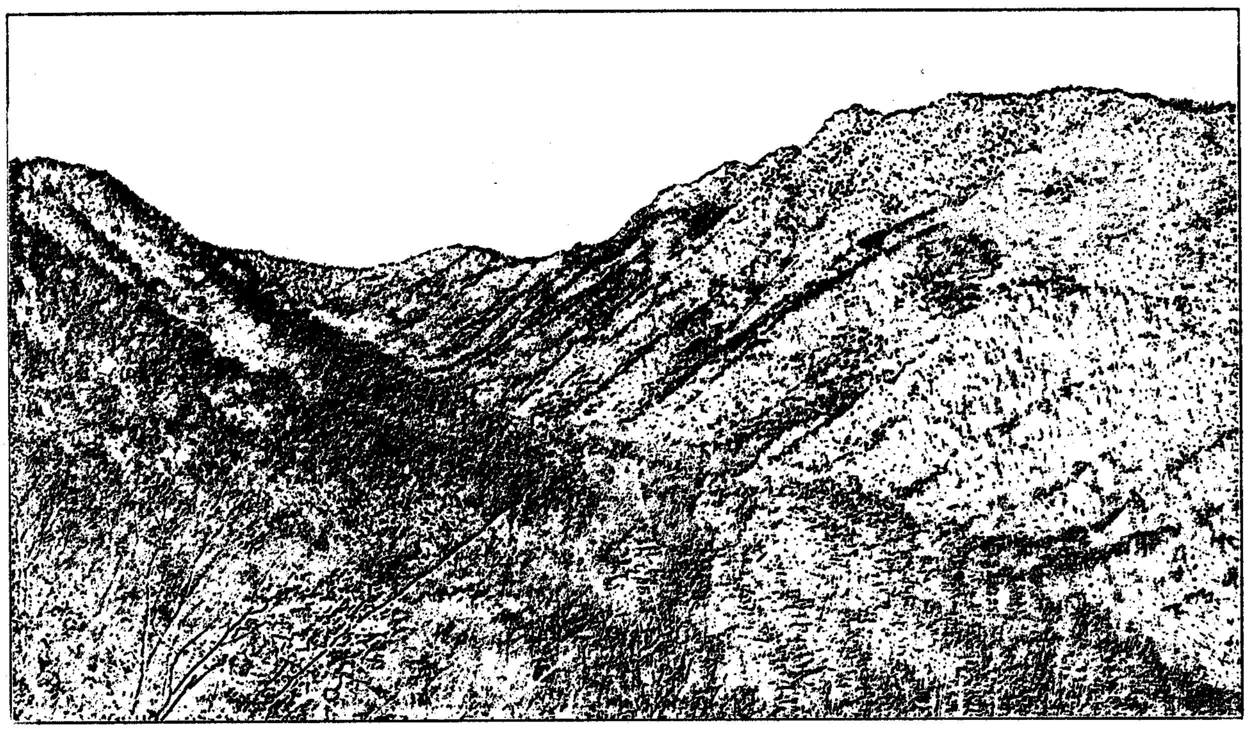
Joseph G. Aylor, Jr.
Thomas W. Broadhead
Jeffrey B. Connelly
John O. Costello
Mark S. Groszos
Robert D. Hatcher, Jr.
Stephen A. Kish
Jonathan C. Lewis
Carl E. Merschat
Robert R. Neuman
Nicholas Rast
John Rodgers
Stephen L Palmes
Troy W. Thompson
James F. Tull
Raphael Unrug
Sophia Unrug
Dan Walker
Randall R. Walters
Leonard S. Wiener
Nicholas B. Woodward

CAROLINA GEOLOGICAL SOCIETY

STUDIES OF PRECAMBRIAN AND PALEOZOIC STRATIGRAPHY IN THE WESTERN BLUE RIDGE

edited by

STEPHEN A. KISH



November 9-10, 1991

CAROLINA GEOLOGICAL SOCIETY

1991 OFFICERS

Carolina Geological Society Field Trip 1991

Joseph G. Aylor, Jr.
Department of Geology B-160
Florida State University
Tallahassee FL 32306

Thomas W. Broadhead
Dept. of Geological Sciences
University of Tennessee
Knoxville, TN 37996-1410

Jeffrey B. Connelly
Dept. of Geological Sciences
University of Tennessee
Knoxville, TX 37996

John O. Costello
Atlanta Testing and Engineering
11420 Johns Creek Parkway
Duluth, GA 30136

Mark S. Groszos
Dept. of Geology B-160
Florida State University
Tallahassee FL 32306

Robert D. Hatcher, Jr.
Dept. of Geological Sciences
University of Tennessee
Knoxville TN 37996-1410
& Oak Ridge National Laboratory

Stephen A. Kish
Dept. of Geology B-160
Florida State University
Tallahassee FL 32306

Johnathan C. Lewis
13690 Cedar Drive
Conifer CO 80433

Carl Merschat
North Carolina Geological Survey
59 Woodfin Place
Asheville, NC 28801

Robert B. Neuman
E-308 NBH
Smithsonian Institution
Washington, D.C, 20560

Stephen L. Palmes
Dept. of Geological Sciences
Wright State University
Dayton, OH 45435

Nicholas Rast
Dept. of Geological Sciences
University of Kentucky
211 Bowman Hall
Lexington KY 40506-0059

John Rodgers
Dept. of Geology & Geophy.
Yale University
P.O. Box 6666
New Haven CT 06511

Troy W. Thompson
Dept. of Geology B-160
Florida State University
Tallahassee FL 32306

James F. Tull
Department of Geology B-160
Florida State University
Tallahassee Fl 32305

Raphael Unrug
Dept. of Geological Sciences
Wright State University
Dayton, OH 45435

Sophia Unrug
Dept. of Geological Sciences
Wright State University
Dayton, OH 45435

Dan Walker
Kentucky Geological Survey
University of Kentucky
228 Mining & Mineral Resources Building
Lexington, KY 40506-0107

Randall R. Walters
Exxon Company U.S.A.
Midland, TX 79703

Leonard Wiener
North Carolina Geological Surve
59 Woodfin Place
Asheville NC 28801

Nicholas B. Woodward
Dept. of Geology
University of Maryland
College Park MD 20742

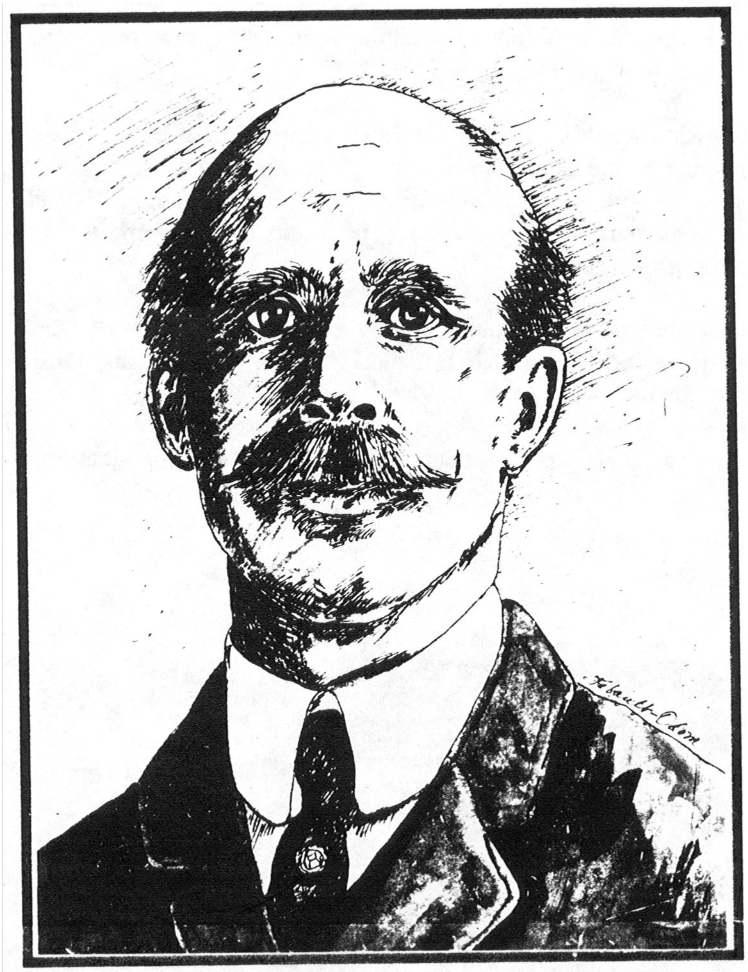
Stephen A. Kish (editor)

FRONT COVER: View northeast along the crest of Chilhowee Mountain. The trace of the Great Smoky Fault lies at the base of the foothills on the left. The ridgecrest is upheld by sandstones of the Chilhowee Group. The slope on the west (left) side of the main ridge is formed from units of the Sandsuck Formation of the Walden Creek Group. Sketch by PB King in Geology of the Central Smoky Mountains TN (US Geological Survey Professional Paper 349-C)

TITLE PAGE: View looking south – Nantahala Gorge. The ridges are formed by units of the Nantahala Formation - possible equivalent to portions of the Chilhowee Group. The valley contains the Murphy Marble - possible equivalent to the Shady Dolomite. For an additional description of this location, see the description for mileage 178.5 for the Saturday roadlog. Tone-line print from photo by Stephen Kish.

DEDICATION

ONE HUNDRED YEARS OF RESEARCH IN THE SOUTHERN APPALACHIAN BLUE RIDGE-U.S. GEOLOGICAL SURVEY (1891 – 1991)



Arthur Keith (ca 1887)
Pen & ink drawing by Annette Odom

Following the establishment of the United States Geological Survey in 1879, the survey's second Director, John Wesley Powell, obtained authorization from Congress "to continue the preparation of a geologic map of the United States." This commission allowed the Survey to move from its work on the western frontier, back to the eastern United States. Powell ensured that topographic mapping would be used for the preparation of the geologic map this was the beginning of the first generation of truly quantitative geological mapping in the United States the 30 minute folio series.

The initial work by the Survey in the southern Appalachians was largely devoted to studies in the Valley and Ridge. This work was supervised by Bailey Willis. Willis selected a young geologist fresh from Harvard, Arthur Keith, to extend the folio work into the labyrinth of the Blue Ridge. Keith's initial work in the Knoxville quadrangle was an unfortunate selection. At the time the true magnitude of thrust faulting was not recognized, thus Keith and Willis mapped the rocks of the Ocoee Supergroup as resting upon carbonates of the Knox Group. We know that what they observed were exposures of Knox within windows of the Great Smoky fault. However, there is some irony in their assignment of a Silurian age to the Ocoee rocks, since recent studies have suggested the same age. Subsequent mapping by Keith was more successful, and by the time he had completed his field studies in the southern Appalachians in 1907, he had complied over 15 folios with a final one published in 1931; this comprised an area of over 22,000 square miles. Only one other person has published more folio maps than Keith.

Keith's overall contribution to our understanding of Blue Ridge stratigraphy is best summarized by Philip King, "Keith's revised terminology and interpretation were remarkably perceptive for their time. His formations have proved to be useful geologic entities, recognizable over wide areas in much the manner originally shown, and were mostly placed in correct sequence. Later work has indicated the need for revision and amplification, because of more detailed mapping, and further understanding of the structure, sedimentation, and metamorphism; Keith's stratigraphy, however, forms the basis on which such revisions of the Ocoee can be made".

A half century following Keith's work, the U.S.G.S. again established a major program of geologic study in the Blue Ridge, this time it was mapping of the Great Smoky Mountains National Park. Under the leadership of Philip King, several geologists, including Jarvis B. Hadley, Richard Goldsmith, Robert B. Neuman, Willis Nelson, and Warren Hamilton, undertook a detailed mapping program in the park from 1946 – 1955. The results of their work has provided us with the current stratigraphic framework of the Ocoee Supergroup.

The U.S. Geological Survey has continued its long established tradition of excellence in research with other mapping programs in the Blue Ridge these included the Grandfather Mountain window, and most recently the mapping of the southern Appalachians on two degree quadrangles.

The Carolina Geological Society congratulates the United States Geological Survey for a century of work in the Blue Ridge.

s.k.

Great Smoky Mountains Field Party. September 1953. Left to right: Richard Goldsmith, Willis Nelson, Robert B. Neuman, Jarvis B. Hadley, and Philip B. King. Photo by Warren Hamilton.

CONTENTS

ACKNOWLEDGEMENTS

The Saturday road log was compiled by: John Costello, Leonard Wiener, Rapheal Unrug, Stephen Palmes, Robert Hatcher, and Carl Merschat. The Sunday road log was compiled by: James Tyll, Troy Thompson, and Joe Aylor, Stephen Kish coordinated road logs for both days.

Special thanks are given to the following people from Florida State University: Laura Hall (for manuscript preparation), Rosemarie Raymond (for drafting), and Gabriel Lee (for photography). Annette Odom provided the pen & ink drawing of Arthur Keith. The staff in the Photo Archives Field Records Section of the U.S. Geological Survey Denver were very helpful in obtaining archival material for the dedication section of the Guidebook.

This Guidebook benefited greatly from the comments provided by reviewers for articles within the Guidebook.

Finally, appreciation goes to L.K. and A.K. for their support during the preparation of the Guidebook.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 1-11

EVOLUTION OF IDEAS ABOUT THE OCOEE CONGLOMERATES AND SLATES

John Rodgers
Department of Geology and Geophysics, P.O. Box 6666, Yale University, New Haven, Connecticut 06511

ABSTRACT

Safford, when he named The Ocoee Conglomerates and Slates, placed them between The Chilhowee Sandstones and Shales and The Mica Slate or Metamorphic Group, although he recognized the existence of gradations at both contacts. When the U.S. Geological Survey began the folio mapping that covered large parts of the southern Appalachians in about 15 years, Willis and Keith challenged Stafford's view, interpreting the Ocoee as unconformably overlying not only the Chilhowee group but strata up to the Middle Ordovician. Hayes however demonstrated the importance of "overthrust" faults, and the Willis-Keith unconformity was ultimately recognized as a major thrust, the "Great Smoky overthrust". Thereafter Keith did not separate Ocoee and Chilhowee units but assigned all the strata in question to the Lower Cambrian; he showed that they unconformably overlie basement Precambrian granite and gneiss in northeast Tennessee but grade laterally into metamorphic rocks farther southwest.

The concept of a separate Ocoee "series" was revived first by George and Anna Stose during their reconnaissance, then by Philip B. King on the basis of much detailed mapping in and around the Great Smoky Mountains National Park. The Ocoee rocks were then followed (with or without the name) southwestward into Georgia, where strata in the core of the Murphy syncline were recognized as younger and in part unconformable, and northeastward into northeast Tennessee. Reconnaissance work in the mountains between the French Broad and Big Pigeon Rivers suggested a continuous section of Ocoee beneath the Chilhowee and down to the basement, and Keller mapped it out and showed how it records the growth and filling of a rift-basin. Knoll and Keller identified acritarchs and assigned them provisionally to the Vendian, and the Unrugs discovered Paleozoic shelly microfossils at approximately the same level. The story continues.

STAFFORD'S OCOEE

The name Ocoee for a major rock unit was proposed by James M. Stafford in his first biennial report as State Geologist of Tennessee (Safford, 1856, p. 149, 151 – 152). Following the lead of the New York Survey geologists, he gave place names to some of the rock units he recognized in his state, but he also numbered them, as the Rogers brothers had done in Pennsylvania and the Virginias. His headings for this unit and those above and below read:

Formation III. The Chilhowee Sandstones and Shales
Formation II. The Ocoee Conglomerates and Slates
Formation I. The Mica Slate Group.

Thus he was already quite definite about the stratigraphic position of the Ocoee unit. His descriptions of the stratigraphic units in this first report are quite short, for he had been asked to concentrate on the mineral resources of the state, but he gives the source of the name Ocoee (Stafford, 1856, p. 151; italics in original): "The rocks of this formation are grandly exposed along the *narrows* of the *Ocoee*, and hence the name of the group".

In his great report of 1869, Safford could expand far more on the strictly geological features of the state, and he devoted 16 pages to "The Ocoee Conglomerate and Slates" (Stafford, 1869, p. 183 – 198; note the omission of the s on Conglomerate). Here he classified the Ocoee as a formation of sub-group of the Potsdam Group, in which he included all the Tennessee strata up to the top of the Knox Dolomite. The name Potsdam, originally given by Emmons (1838, p. 214 – 217) to the basal sandstone of the "New York Paleozoic System" and now known to represent only part of the Upper Cambrian, was being expanded at just this time by the Upper Cambrian, was being expanded at just this time by James D. Dana, in his manual and textbook, to include all the Tennessee strata up to the top of the Knox Dolomite. The name Potsdam, originally given by Emmons (1838, p. 214 -–217) to the basal sandstone of the "New York Paleozoic System" and now known to represent only part of the Upper Cambrian, was being expanded at just at just this time by James D. Dana, in his manual and textbook, to include all the rocks now assigned to the Canbrian and Lower Ordovician,though Safford did debate (p. 182) whether to include the post-Chilhowee strata in the Potsdam Group. He recognized that both the lower and the upper boundaries of his Ocoee unit were gradational. Speaking of his first group, which in the 1869 report he called The Metamorphic Group, he stated (p. 177): "A portion of the beds are certainly referable to the Ocoee Group; the remainder, although conformable, may be older, and most likely are." Concerning the upper boundary, he stated (p. 182): "It is not easy to separate, lithologically, *the Ocoee sub-group* from the *Chilhowee,* as they often run into each other". But his conception of the stratigraphic order of the three groups has stood the test of time and several challenges, detailed below.

If one compares Safford's map, and his statements about where the various rock units are found, with recent geological maps, it becomes clear that his Ocoee group included at least some rocks nowadays generally referred to the Chilhowee group. Even along the northwest side of Chilhowee Mountain he recognized a narrow strip of "Ocoee conglomerate and slates" (see his map, the section on p. 190, and the test on p. 189-190), roughly what has since been mapped as Cochran conglomerate beneath the typical Chilhowee sandstone (Hesse and Nebo) that holds up the crest of the mountain. Similarly, along Laurel Creek in northeasternmost Tennessee (p. 195-196) he clearly assigned to the Ocoee the strata since mapped as lower Unicoi (he specifically mentions "two trap dikes", the well known Unicoi basalt layers), and he included a good deal of the conglomeratic upper Unicoi as well. Elsewhere, however, he apparently included Cochran or upper Unicoi strata in his Chilhowee group, as in the gorge of the Doe River northwest of Hampton (p. 201). Apparently he assigned the rocks to the Ocoee if the conspicuous rock type was conglomerate, to the Chilhowee if it was quartzite (especially quartzite with *Skolithus* tubes). My reason for emphasizing this matter becomes clearer below.

In 1873, Eugene A. Smith was appointed State Geologist of Alabama, and already in his first annual report (Smith, 1875) he announced that most of Stafford's stratigraphic units from Tennessee are clearly recognizable in Alabama, including both the Ocoee (p. 22) and the Chilhowee. That year he assigned the Ocoee to the Archaean, but the next year (Smith, 1876, p. 127) he placed it in the Acadian (i.e., Middle to Lower Cambrian)beneath the Chilhowee or Potsdam. In this report (p. 128-131) the gave a detailed description of the section of these rocks along Talladega Creek, and later (Snith, 1888) he called them the Talladega (Ocoee) group and assigned them to the Algondian. But the evolution of ideas about the Talladega is a complicated as that about the Ocoee and deserves an article equally as long as this one, so I must pass the subject by.

THE USGS – KEITH AND HIS COLLEAGUES

In the late 1880's, the fledgling U. S. Geological Survey began an ambitious program of geological mapping in the Appalachians under the general leadership of Bailey Willis, to the considerable annoyance of several state geologists such as Smith, who resented the Federal Survey's turning from the western Territories to invade the eastern States. Tennessee had no active state survey at this time, however (though Safford retained the courtesy title of State Geologists until his death in 1907), and most of East Tennessee along with adjacent parts of Virginia, North Caroina, Georgia, and Alabama were mapped as part of the Geologic Atlas of the United States, the famous USGS folios. Arthur Keith mapped the largest part of East Tennessee and adjacent North Carolina, but C. Willard Hayes and Marius R. Campbell mapped large areas to the southwest and to the northeast respectively.

Right at the start of this work, Willis and Keith challenged Safford' conclusion that the Ocoee underlies the Chilhowee. In "notes upon the geologic position of Prof. Safford's Ocoee formation", prepared by Willis for C. D. Walcott and published by Walcott (1891, p. 299-300), Willis C. Willard Hayes as well as from my own studies," the "Ocoee' strata of Safford, occurring southeast of Chilhowee Mountain around Cades, Tuckaleechee, and Weirs Coves, are known to belong to the Nashville on evidence of strict structural conformity to the Knox dolomite over three extensive quaquaversals and through transition beds from the dolomite to the slates." (Knox dolomite and Nashville were also Safford's names, classed at that time as Lower Silurian but now called Lower Ordovician (plus Upper Cambrian) and Middle Ordovician respectively).

In 1892, on the other hand, Keith published a paper describing the geology of Chilhowee Mountain (Keith, 1892), in which he expanded the "Chilhowee group" to include a good deal of what Safford had mapped as Ocoee; he placed the group beneath the "Knox dolomite" and assigned it to the Lower Cambrian, for in 1889 fossils had been found near the top of the group along Chilhowee Mountain. Furthermore he applied the name "Chilhowee conglomerate" (mentioned above) along the northwest side of the mountain. This double use of the name Chilhowee for a group and a formation was of course unacceptable, and in the Knoxville folio (Keith, 1895) he named the latter the Cochran conglomerate.

The Knoxville was Keith's first published folio in East Tennessee, and in it he mapped both the Chilhowee rocks on Chilhowee Mountain and the Ocoee rocks surrounding the three coves at the north foot of the Great Smoky Mountains, those mentioned in Willis's "notes upon the Ocoee". Although Keith mentioned both names, Chilhowee and Ocoee, I in the text, he didn't define them or use them formally as groups for the 13 formation names he proposed in the folio – 6 for the Chilhowee strata and 7 for the Ocoee. His sixth and lowest Chilhowee formation, lying beneath the Cochran conglomerate that he had already removed from Safford's Ocoee, he named the Sandsuck shale; he mapped it over considerable aras around the east end of Chilhowee Mountain, where Safford had certainly included it in the Ocoe. In his cross-sections moreover (the test remains vague on this point) Keith showed his lowest Ocoee formation (the Wilhite slate) lying unconformities above the Sandsuck, Cochran, and higher unites up to his "Silurian" Tellico sandstone (now included in the Middle Ordovician), in full accordance with the ideas expressed by Willis. The idea of using unconformities to explain puzzling contacts was common at that itme within this group of geologists; thus Campbell (1894) explained by unconformities certain peculiar map patterns in southwest Virginia that are now explained as windows and half-windows along the Pulaski thrust fault.

Nevertheless some doubts began to be expressed, perhaps stemming from C. Willard Hayes (see next paragraph). A note on a map in Willis' treatise on The Mechanics of Appalachian Structure (Willis, 1893, Pl. 58) reads: "This are is occupies by rocks of Saffords Ocoee, of undetermined age.

They are here colored as Nashville, or later, with doubt." On the Knoxville folio (Keith, 1895), although he assigned all the strata of the Chilhowee Mountain succession (right down through the Sandsuck) to the Lower Cambrain, Keith classed the Ocoee formations as "of unknown age".

In the Cleveland folio (Hayes, 1895), southwest of the Knoxville folio against the Georgia line, Hayes encountered the same Chilhowee and Ocoee rocks as Keith; indeed his quadrangle included part of Safford's type locality in the Ocoee River gorge. Hayes used Keith's Chilhowee units and some of the Ocoee unites in his own mapping (though admitting uncertainty in correlating the latter), but in contrast to Keith he used the terms Chilhowee series and Ocoee series as formal names to group the respective formations. Moreover, he mapped a continuous thrust fault between the two series and, although earlier he had accepted the Willis-Keith view that the Ocoee rocks are "Silurian" (Hayes, 1891, p. 149), in the folio he adopted Safford's view that they are older than the Chilhowee, for in the text he specifically classified the Ocoee series as "probably Algonkian"; i.e., later Precambrian.

When Keith mapped in northeastern Tennessee (see references below), he found reasonably continuous sections from the base of the Cambrian carbonates down through a great thickness of clastic strata (Safford's Chilhowee and Ocoee) to an unconformity over granite and gneiss (the rocks that Safford had thought "most likely are" older than the Ocoee group), and from then on Keith consistently classified all these clastic strata as Lower Cambrian. In the Cranberry folio (Keith, 1903), he named three new formations to cover these strata, but on the correlation chart (p. 9) he specifically equated them to formations he had named on the Knoxville folio for the succession on Chilhowee Mountain and to Safford's Chilhowee sandstone. Yet he too mentioned (p. 4) the basalt layers in the lower part of the succession, which Safford had placed in the Ocoe. In the Asheville folio (Keith, 1904), located between the Knoxville and Cranberry folios, Keith used his names from Chilhowee Mountain, but he also introduced four new names for what are clearly the Ocoee rocks he had previously classified as "of unknown age"; he equated them too (except for the lowest) with is Chilhowee units, and he assigned all these units to the Lower Cambrian.

Finally, in the Nantahala folio (Keith, 1907a), covering the area directly south of the Knoxville folio, he proposed six more names, for the succession in the Murphy syncline, and his correlation table (p. 11; reproduced here as the first four columns of Talbe 1) shows how at that time he equated all these names with each other and with Safford's Chilhowee and Ocoee (except for the three names he had proposed in the Cranberry folio and for three others; for these see the last column of Table 1 and the footnotes).

By this time therefore, Keith had accepted Safford's placement of the Ocoee beneath the Chilhowee, for he and the others had realized that the superposition of the Ocoee strata on the Knox dolomite in the three Great Smoky coves is tectonic; the covers are windows in "overthrust" sheets. It was Hayes (1891) who introduced the idea of great "overthrusts" to the southern Appalachians, and that idea quickly replaced the idea that unconformities best explain the relations. Much of this history has been recounted by George W. Stones (Stose and Stose. 1944 p. 373 ff.), who played a role in the reversal of ideas about the stratigraphic posiiton of the Ocoee strata (fascinating hints are also provided in the annual Director's Reports of the U. S. Geological Survey for 1898 – 1902).

Of course the idea of "overthrusts" was unknown to Safford who, following the Rogers brothers, thought in terms of "upthrusts". Nevertheless it is worth quoting his discussion of the problem posed by the coves (Safford, 1869, p. 186 – 187): "In Blount and Sevier Counties, its strata [the Ocoee] enclose the interesting coves described in the First Part of this Report [1869, p. 51 – 52], but these do not properly belong to this formation. They are based, mostly, on the rocks of the Knox Formation, and owe their origin to the fact that great patches of the Knox strata, were, during the period of disturbance, cut off, and entangled among the Ocoee beds. These patches of softer rocks, by subsequent denudation, have been hollowed out into the coves, as we now find them." Safford's discussion of the "the period of disturbance" (p. 136 ff.) is likewise remarkable for its time.

Although Keith now agreed that Safford was right to place the Ocoee beneath the Chihowee, he classified all the post-basement units listed on his chart as Lower Cambrian (Keith, 1907a, p. 3), and he apparently thought it unnecessary to recognize a separate Ocoee group. As a result, the term Ocoee was officially "rejected for use in the classification of the U. S. Geological Survey" (Wilmarth, 1938, p. 3, 1528), whereas Chilhowee (p. 430) remained acceptable. (Later Butts, 1926, p. 60, reported that Keith accepted the correlation of the Talladega group of Alabama with the "Ocoee", though not the Algonkian age assignment.

THE REVIVAL OF THE OCOEE

Although Keith never explicitly used the term Chilhowee group for the Lower Cambrian clastic strata, such a usage gradually became established during the succeeding decades, not only in Tennessee but also northeastward into Virginia, first as far as Roanoke (Woodward, 1932, p. 28 – 30) to cover Keith's three Cranberry names, which were extended to that region, and then right across the state (Butts, 1940, p. 25 ff.) to include still another group of four names coined by Keith (1894) along the Potomac River. As time went on, Chilhowee came to stand for the whole basal clastic group from Tennessee to New Jersey.

As for the term Ocoee, officially consigned to oblivion by the Federal Survey, it only began to resurface some 25 years later, especially in the work of George Stose and Anna

Jonas, later Mrs. Stose. Joans's first idea (1932, p. 240 – 241, Fig. 1) was to split the thick clastic sequence, which Keith had lumped together as Lower Cambrian, along a major thrust fault (part of her "Blue Ridge overthrust") that essentially followed the boundary Safford (1869, map) had drawn between his Ocoee and his Metamorphic Group. Safford's Ocoee northwest of this fault she called "quartzite and slate" and retained in the Lower Cambrain (she never mentioned the term Ocoee); the rocks to the southeast she called "crystalline schist of low-rank metamorphism indicative of retrogression" (Fig. 1) and "phyllonites" (p. 240), and she assigned them to the late Precambrian (Algonkian?) Glenarm series (another term with a long and tortured history, which she imported from Pennsylvania and Maryland). This interpretation was followed by Geoffrey Crickmay in his studies of the metamorphic rocks of Georgia (1936; 1952 – a report actually written in the late '30s), but be used the name Ocoee series for the rocks northwest of the fault and Talladega series for those southeast of it. These ideas were embalmed on the Geologic Map of the United States published at that time (Stose and Ljungstedt, 1932) and not superseded till 1974.

In a series of three later articles (Stose and Stose, 1944, 1947, 1949), the Stoses renounced this fault and reunited the two sets of rocks across it in the Ocoee series, which they regarded as of late Precambrian age, older than and virtually everywhere separated by faults from the Lower Cambrian Chilhowee group. They divided the Ocoee into a number of formations; at first they used a mixture of Keith's old and new names, but then they began to introduce new names of their own. Unfortunately most of their conclusions were based on very broad reconnaissance and have not been confirmed by later detailed work.

The Stoses were well aware that the Ordovician carbonates in the three coves north of the Great Smoky Mountains (and in couple of others nearby, equally known to Safford-1869, p. 188) are in tectonic windows. Moreover they were the first to recognize three other major windows in the region – the Taylors Valley or Mountain City window, the Grandfather Mountain window, and the Hot Springs window, all shown already on the Geologic Map of the United States (Stose and Ljungstedt, 1932) but first described in detail 12 years later (Stose and Stose, 1944, p. 383 – 386). They seem to have concluded therefore that no carbonate rocks can belong to the Ocoee, that all are in windows, although Safford (1869, p. 188, 189, 193) had recognized beds of limestone, "calcareous puddiingstone", "breccia limestone", and dolomite within the Ocoee successions, and Hayes and Keith had also described them (Hayes, 1895, p. 2; Keith, 1895, p. 2; 1904, p. 5, map). In 1944 the Stoses (Fig. 2A and p. 378) suggested that the whole Murphy marble belt is an extremely elongate window; in 1949, while they no longer mentioned the window hypothesis for the Murphy marble, they placed virtually every other carbonate body in the Ocoee belt either in a window or within a discontinuous strip up to 8km wide along the north side of the belt of finer grained, mainly salty rocks that underlies the northern foothills of the Great Smoky Mountains (south of Chilhowee Mountain). They transferred the rocks in this strip bodily from the Ocoee to the "Tellico[1]" formation of Middle Ordovician age, reporting a couple of Middle Ordovician fossil localities along the northwest edge of the strip (p. 297), and they drew a large thrust fault to separate the strip from the rest of the Ocoee. Thus they seemed to be repeating the Willis-Keith challenge to Safford's stratigtraphy, not for the whole Ocoee but for some of the finer grained northern part that Safford (and Keith) had considered to underlie the great thickness of conglomerate in the main range of the Great Smoky Mountains.

The next major piece of work mainly concerned with the Ocoee rocks was the study of the geology of the Great Smoky Mountains National Park, which produced a series of comprehensive reports (Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965). Philip B. King had been working during the Second World War on manganese deposits in residuum of the Shady dolomite immediately above the highest beds of the Chilhowee group, first in the Elkton area in northern Virginia (King, 1943, 1950) and then in northeast Tennessee (King and others, 1944; King and Ferguson, 1960). During this work King had become thoroughly familiar with the Chilhowee strata and what lay beneath them in those regions, and he was fascinated by the stratigraphic and structural problems they present. After the war, he accepted the assignment as Chief of Party for the survey of the Great Smoky Park; the field work lasted for ten seasons, from 1946 to 1955, and involved fourteen geologists. I had been a field assistant to King in both Virginia and northeast Tennessee; I did not join the Smoky party, but I was in close touch with their work as it developed (my reports of that period – Rodgers 1953, 1956 – reflect stages in that development but do not have the authority of King's articles or the final reports).

Early in the Smoky work, King (1949) published an excellent summary of the age relations of the Chilhowee and Ocoee strata; he listed (Table 2, p. 623) ten different interpretations of the age of the Ocoee, ending with his own. Striking is the absence of any entry between 1907 and 1932. (At this point, moreover, he persuaded the U.S. Survey to lift its ban on the word Ocoee and to reinstate it as a "provincial series"; he also brought the Sandsuck shale back into the Ocoee).

1.The name Tellico (Keith, 1895) has a checkered career, partly described by Rodgers (1953, p. 69, 70-71, 75, 78-79, 79-80), who wanted to abandon it. Neuman (1955) revived the unit however, expanding it fourfold (see his Plate 27, right end) by adding thick bodies of strata above and below what Keith had mapped as Tellico at the type locality along the Tellico River in Monroe County, Tennessee.

King emphasized particularly the differences in sedimentary character between the Chilhowee and Ocoee strata, contrasting the quartzite and arkose affinities of the Chilhowee with the graywacke of the Ocoee. He tended to regard the Chilhowee as lying unconformably upon the Ocoee (there was tentative but somewhat equivocal evidence in that direction), as well as upon other post-basement but pre –"quartzite" rock groups, such as the Mount Rogers volcanic group in southwest Virginia and adjacent Tennessee and North Carolina and the Catoctin greenstone and underlying sediments in northern Virginia and Maryland; in this he followed Jonas and Stose (1939). The unconformity or at least the sharp change in depositional conditions between Chilhowee and Ocoee he proposed to take as the base of the Cambrian System in the southern Appalachians.

As the Smoky work progressed, the true complexity of the Ocoee – stratigraphic, structural, and metamorphic – became clearer and clearer. In addition to the obvious graded graywacke and graywacke-conglomerate that uphold the main range of the Great Smoky Mountains (and that had been called the Great Smoky conglomerate since Keith, 1904) two other major associations of strata could be distinguished. One is dominated by arkose and feldspathic siltstone and includes much of Keith's Snowbird formation (also named in 1904). The other is generally finer grained, consisting of slate, siltstone, pure and impure sandstone, and conglomerate and including the carbonate beds noticed long before by Safford, Hayes, and Keith. As an introduction to the final reports, King and his colleagues (King and others, 1958) published a stratigraphic summary of the Ocoee, which they continued to class as a series and of which these three associations were formally recognized as groups, along with certain unclassified formation that "do not fit conveniently into these groups" (p. 951). By admitting the dominantly arkosic Snowbird group into the Ocoee, however, King considerably decreased the contrast between Ocoee and Chilhowee on which he had insisted in 1949.

Because of the many large thrust faults, of a least two generations (pre- and post-metamorphic), the interrelations of the three groups were by no means clear. It seemed that the finer grained association in the northern foothills, which they named the Walden Creek group, overlies the Arkosic Snowbird group, but that on other thrust sheets a much thinned equivalent of the Snowbird underlies the main body of the graywacke Great Smoky group; whether the Great Smoky and Walden Creek groups are facies equivalents of each other or were deposited in separate basins could not be determined. In any case, the detailed mapping of the Smoky party disposed of the Stoses' proposal that any considerable part of the fine-grained rocks in the northern foothills belt should be removed to the Middle Ordovician Tellico formation; those rocks are thrust over the adjacent Ordovician strata (and they over Mississippian) along the post – metamorphic Great Smoky thrust fault (named by Keith, 1927), and the fossil localities the Stoses had cited lie beneath that fault. This detailed field work thus removed the second challenge to Safford's stratigraphy. At the same time, the position of the finer grained strata of the foothills beneath the coarse conglomerates of the main range was shown to be not stratigraphic, as Safford and Keith had thought, but tectonic, to this extent vindicating the Stoses.

SOUTHWARD INTO GEORGIA

The preceding discussion has emphasized work in the central area of the Ocoee in and around the Great Smoky Mountains or to the northeast, but the same rocks continue southwest to the region around the Ocoee River (the type locality after all), where they underlie the southeastern corner of Tennessee and the adjacent southwestern corner of North Carolina – here they also include rocks that Safford had placed in his Metamorphic Group – and they have been mapped well beyond, into northern Georgia. Starting from the Cleveland quadrangle (Hayes, 1895), Hayes mapped tw0 30' quadrangles on to the south, the Dalton and Cartersville, both in Georgia; he prepared maps and manuscripts for the folio series, but the folios were never published. In them he carried the name Ocoee and some of its formations as far as Cartersville. Similarly, mapping of the Murphy marble belt, begun by Keith in southwestern North Carolina (Nantahala folio, 1907a), was carried southwest into Georgia by LaForge and Phealan (1913) and by Bayley (1928), using many of Keith's formation names (see Table 1, column 3) but not the overall term Ocoee.

Since then a variety of structural interpretations have been proposed for the Murphy marble belt (listed by Hurst, 1955, p. 1; I have already mentioned the window interpretation), but Vernon Hurst's careful napping (1955) of a small area in northernmost Georgia astride the Murphy belt and the Toccoa River (the name for the Ocoee River in Georgia) demonstrated that the belt's structure is synclinal and that Keith's stratigraphy needed only minor modification. In particular Hurst added a Mineral Bluff formation at the top of Keith's section and divided the Great Smoky group (which Hurst called a group before King and others, 1958) into four formations. He too mentioned neither Ocoee nor Chilhowee, but he considered that the main break in sedimentary conditions – "the base of the Cambrian" – lies at the (gradational and probably conformable) contact between the Great Smoky and the Nantahala (Hurst, 1955, p. 8, 43 – 45), and King and others (1958, p. 951) agreed. Further work to the west and northwest, including the Ocoee River gorge in Tennessee (Hurst and Schlee, 1962), indicated that the Nantahala formation reappears there above the Great Smoky group on the far side of the Ducktown anticlinorium, the major fold next northwest of the Murphy syncline; later Hurst (1973, p. 650 – 652) tended to correlate that formation with the Walden Creek group of King and others (1958). The descriptions of the section in the Ocoee gorge by Safford (1869, p. 183 – 185 and figure on p. 185) and by Hurst and Schlee (1962) can easily be related; I must point out however that by Hurst's chain of reasoning a good half of Safford's carefully chosen and described type section of the Ocoee Conglomerates and Slates would be removed from the Ocoee (series or supergroup).

Recently James Tull and his students (Tull and Guthrie, 1985; Tull and Groszos, 1988) have assembled evidence in the Murphy belt to show that the Mineral Bluff formation (which for them includes the Nottely quartzite as a member) lies unconformably across all the underlying formations from the Andrews schist down to the Dean formation at the top of the Great Smoky group. Moreover, they have specifically correlated the Mineral Bluff with the Talladega group – Smith's typical section along Talladega Creek, mentioned above – which in recent years (Shaw and Rodgers, 1963; Rodgers and Shaw, 1963; Shaw, 1970; Tull 1982; Tull and others, 1988) has been shown to lie unconformably above dated Lower Ordovician strata (upper part of Sylacauga marble) and to bevel down as far as Chilhowee and perhaps Ocoee equivalents. Thus the correlation of the Ocoee with the type Talladega has proven to be incorrect; if Ocoee strata are present at all in Alabama, they are not in the Talladega group but in the Kahatchee Mountain and Columbiana Mountain areas and to the southwest, beneath strata (Weisner quartzite) of Chilhowee type.

A CONTINUOUS SECTION OF OCOEE BETWEEN BASEMENT AND CHILHOWEE

From 1943 to 1945 (before the start of the Great Smoky project), Herman W. Ferguson, a principal collaborator in and the representative of the Tennessee Division of Geology on the manganese project in northeast Tennessee (King and others, 1944), mapped a large area on both sides of the French Broad River where it crosses the belt of Chilhowee rocks that extends discontinuously from northeast Tennessee to Chilhowee Mountain north of the Great Smokies. The purpose of this mapping was to provide the geologic setting for a study of the manganese and barite deposits in that region (Ferguson and Jewell, 1951), both kinds of deposits being associated chiefly with rocks of Chilhowee type; hence the report is concerned mainly with the Chilhowee strata, for which Ferguson employed the northeast Tennessee names (the "Cranberry" names; see Table 1, column 6). But along the south side of this area, Ferguson encountered, mapped, and described the upper part of a very thick section of Ocoee strata lying beneath the Unicoi formation of the Chilhowee group, and he divided it into the Sandsuck and Snowbird formations. Reconnaissance work by Ferguson and myself in the next few years strongly suggested that a continuous section could be pieced together in the region between the French Broad and Big Pigeon Rivers (Including Snowbird Mountain), from a basal unconformity over older Precambrian granite and gneiss (recognized long ago by Keith) up to the Chilhowee strata along the French Broad. This reconnaissance work is reflected in a section published by King (1949, Fig. 8, Section A) and in my description of the Ocoee rocks northeast of the Big Pigeon River (Rodgers, 1963, p. 24 – 25, Plates 10,11). By the time Ferguson's work had begun; for a time Ferguson was a member of the Smoky party, and he cited Kings' 1949 article in his report.

Later, other geologists mapped areas between Ferguson's area and northeast Tennessee (Oriel, 1950; Lowry, ms. 1951; Shekarchi, ms. 1959; Bearce, 1969), and they too encountered Ocoee-like rocks beneath the Chilhowee; they followed Ferguson's terminology. Thus the Ocoee "series" was extended northeastward into rocks that King and others (1944) had included in the Chilhowee group (this change is partially reflected in Plates 4, 5, and 10 of Rodgers, 1953).

The Big Pigeon River bounds the Great Smoky Mountains on the northeast, and Jarvis B. Hadley and his assistants, working in the eastern part of the park, studied and mapped the well displayed section along that river south of Snowbird Mountain, which became the standard section for the Snowbird group (King and others, 1958, p. 954; Hadley and Goldsmith, 1963, p. 24 – 25). The land between the rivers (Big Pigeon and French Broad) was not mapped in detail at that time, but in the later 1960's Hadley visited it in reconnaissance and used his findings in compiling the Knoxville 2° quadrangle (Hadley and Nelson, 1971, which includes the area of 5 published and 2 unpublished folios by Keith). Although the area is crossed by several major faults, Hadley's reconnaissance, like that of Ferguson and Rogers, suggested that the stratigraphic sequence was originally continuous from the base of the Snowbird group through the Walden Creek group into the overlying Chilhowee. In some areas Hadley drew the base of the Chilhowee group considerably higher than Ferguson had done, including the lower part of Ferguson's Unicoi in the Sandsuck formation, and he transferred the upper part of what Ferguson had called Snowbird, especially a unit of calcareous sandstone, sandy limestone, and limestone-conglomerate, to the redefined Wilhite formation, both Wilhite and Sandsuck being assigned to the Walden Creek group of the Ocoee series.

In the mid 1970's, Fred B. Keller mapped the critical area between the rivers in detail (Keller, 1980; ms. 1980); his work confirmed the stratigraphic continuity of the Ocoee from the basement to the Chilhowee. Like Hadley, he transferred the lower part of Ferguson's Unicoi to the Sandsuck formation of the Walden Creek group; for the rest of the Unicoi, remaining in the Chilhowee group, he used the name Cochran formation (though for the higher Chilhowee units he retained the "Cranberry" names). These decisions were agreed on by Ferguson, Keller, and myself at his field maps and notes for the southern part of the Del Rio area). Keller also recognized the Wilhite formation in what had been

TABLE 1. Keith's last published correlations of the stratigraphic units he named in the U. S. Geological Survey folios, 1896-1907. The first four columns are directly from the correlation table in the Nantahala folio (Keith, 1907a); the last two columns are arranged from the table in the Roan Mountain folio (Keith, 1907b). Footnotes sere added by JR.

<table>
<tr><th>Safford, 1869</th><th>Knoxville folio (16)-Keith, 1895</th><th>Nantahala folio (143)-Keith, 1907a</th><th>Asheville folio (116)-Keith, 1904</th><th colspan="2">Roan Mountain folio (151)-Keith, 1907b</th></tr>
<tr><td rowspan="8">Chilhowee sandstone</td><td rowspan="3"></td><td>Nottely quartzite</td><td rowspan="3">Shady limestone</td><td rowspan="3">Shady limestone</td><td rowspan="3">also: Cranberry folio (90)-Keith, 1903
Shady limestone</td></tr>
<tr><td>Andrews schist</td></tr>
<tr><td>Murphy marble</td></tr>
<tr><td>Hesse sandstone</td><td>Valleytown formation</td><td>Hesse quartzite</td><td>Hesse quartzite</td><td>Erwin quartzite</td></tr>
<tr><td>Murray shale</td><td>Brasstown schist</td><td>Murray slate</td><td>Murray slate#</td><td rowspan="3">Hampton shale#</td></tr>
<tr><td>Nebo sandstone</td><td>Tusquitee quartzite</td><td>Nebo quartzite</td><td>Nebo quartzite#</td></tr>
<tr><td>Nichols shale</td><td>Nantahala slate+</td><td>Nichols slate
Nantahala slate</td><td>Nichols slate</td></tr>
<tr><td>Cochran conglomerate*</td><td rowspan="5">Great Smoky conglomerate</td><td rowspan="5">Cochran conglomerate

Great Smoky conglomerate</td><td rowspan="5">Cochran conglomerate</td><td rowspan="8">Unicoi formation</td></tr>
<tr><td rowspan="6">Ocoee group</td><td>Clingman conglomerate</td></tr>
<tr><td>Hazel slate+</td></tr>
<tr><td>Thunderhead conglomerate</td></tr>
<tr><td>Cades conglomerate</td></tr>
<tr><td>Pigeon slate°</td><td rowspan="2">Hiwassee slate</td><td rowspan="2">Hiwassee slate*</td><td rowspan="2">Hiwassee slate</td></tr>
<tr><td>Wilhite slate°</td></tr>
<tr><td colspan="3"></td><td>Snowbird formation**</td><td>Snowbird formation</td></tr>
</table>

*On the correlation table in the Asheville folio, the Hiwassee slate is equated with the Sandsuck shale, a unit that Keith mapped onthe Knoxville folio at the base of the Chilhowee succession directly below the Cochran conglomerate but that he omitted here.

+Along the mutual border of the Nantahala and Knoxville folios, Keith mapped the Nantahala slate into the Hazel slate.

° Keith has here omitted the Citico conglomerate, which he mapped on the Knoxville folio between the Pigeon and Wilhite slates.

**The Snowbird formation appears below the Hiwassee slate on the correlation table in the Asheville folio but not in the corresp onding column on the table in the Nantahala folio.

#On the correlation table in the Cranberry folio and in the text of the Roan Mountain folio, Keith equated the Murray and Nebo with the lower Erwin (correctly, it now appears), but on the correlation table and map legend in the Roan Mountain folio, he equated them with the uper Hampton, as here shown.

classed before as Sandsuck and Snowbird; he showed indeed that in one area the Wilhite carbonate units intertongue with upper Snowbird strata. The Great Smoky work had already shown that facies changes are rapid and large in the Ocoee strata (e.g., Hadley and Goldsmith, 1963, Fig. 10, p. 35, showing facies changes within the Snowbird group).

Keller also investigated in detail the sedimentary petrography and sedimentation of the whole Ocoee sequence and showed that they reflect a consistent pattern of sedimentation, readily explained if the very thick sequence was deposited in growing rift-basins that preceded the establishment of the passive-margin shelf represented by the overlying Paleozoic deposits. Such an interpretation was abroad at that time; I think the first to propose it was John M. Bird, for strata in about the same stratigraphic position in New York State (oral communication, about 1962, but see also Neuman and Nelson, 1965, p. 67-68), and it was worked out by Rankin (1975) and others for pre-Chilhowee strata in the central and southern Appalachians (for a recent model, see Rast and Kohles, 1986). Most important, perhaps, was the discovery of acritarchs in Walden Creek strata in the northern foothills of the Great Smoky Mountains; they were determined by Andrew Knoll as probably of Vendian – latest Precambrian – age (Knoll and Keller, 1979). More recently, Knoll (Knoll and Swett, 1987, p. 911; oral communication, July 1991(has recognized that the acritarch in question (Sphaerocongregus, formerly attributed to Bavlinella) can occur, in small numbers, with Lower Cambrian fossils, although when it is numerous and alone it is commonly of Vendian age. Some of the acritarchs found by Knoll and Keller were figured by Walker and Driese (1991, Fig. 5E,F).

I would like to suggest that the mixed stratigraphic terminology used by Keller is applicable not only in his and Ferguson's areas but throughout northeast Tennessee and probably into southwest Virginia. In those areas the Unicoi formation has been divided into lower and upper parts by several workers (King and Ferguson, 1960, p. 38-39; Ordway, 1959; Lowry, ms. 1951, the type locality; Simpson and Sundberg, 1987), and the basalt layers (described first by Safford, then by Keith, then in subsequent reports) – or certain of those layers, generally the lowest or the highest – have been taken as a convenient and traceable boundary (though such layers were not observed by Ferguson, Oriel, or Keller near the French Broad River). I suggest that a more rational boundary would be a little higher, at the base of the thick, resistant, and continuous zone of (generally strongly feldspathic) conglomerate and pebbly quartzite that is a major ridge-maker in northeast Tennessee (e.g., Iron Mountain, parts of Stone Mountain, Buffalo Mountain, Unaka Mountain). In my opinion, the lower Unicoi in these areas is equivalent not to the Cochran but to the Sandsuck; the conglomerate layers are much more lenticular than in the upper Unicoi and Cochran. Thus the lower Unicoi, including the basalt layers, would be returned to the Ocoee where Safford originally placed it. I would retain only the upper Unicioi in the Chilhowee group, along with the correlative Cochran conglomerate; both are characterized by continuous layers of conglomerate and pebbly quartzite. These units too Safford certainly included in the Ocoee at some places, as on Chilhowee Mountain itself, but in the Chilhowee at others, as in the Doe River gorge; as however they have been consistently assigned to the Chilhowee group for nearly a century, it is not possible nor prudent to reverse that assignment now.

I further suggest that the Unicoi basalt layers are the feather edges of the Catoctin metabasalt or greenstone of central and northern Virginia (see King, 1949, p. 522-525, esp. Fig. 3); in this suggestion I am following Bloomer and Werner (1955, Fig. 4), who in a rather thin Unicoi along the James River in central Virginia found basalt layers that they correlated with the Catoctin. What may be an intermediate link between the Catoctin, Mount Rogers, and Ocoee units is exposed as the Grandfather Mountain formation in the Grandfather Mountain window (Bryant and Reed, 1970, p. 73-96). The Montezuma member of that formation (ibid., p. 93-94 and Fig. 56), a unit of metabasalt that appears to reach several hundred meters in thickness but that thins out southwestward, could well represent the Catoctin (and also the much thinner Unicoi basalt layers). The main body of the Grandfather Mountain formation, which is several kilometers thick, might represent the lower Unicoi, the Mount Rogers (felsic volcanics are present but much less abundant than in the Mount Rogers), the Walden Creek group (calcareous sandstone and sandy marble are present locally; Bryand and Reed, 1970, p. 82, 84), or the Snowbird group, or parts of several of these units.

Some of these questions were raised already by Hadley (1970) in his excellent discussion of the Ocoee problem as it stood twenty years ago.

THE CURRENT CHALLENGE

The discovery of aritarchs in the Walden Creek group showed that microfossils can be found at least in the little metamorphosed parts of the Ocoee, and the most recent development in the Ocoee's up-and-down history is the discovery of shelly microfossils by Unrug and Unrug (1990), also in the Walden Creek group. The Unrugs' discovery led them to challenge once again the pre-Chilhowee position of the Ocoee. Moreover, even before those fossils were discovered Unrug and LePain (1988) had called into question the age of the Walden Creek group and indeed of the Ocoee Supergroup as a whole. From studies of the carbonate rocks in the Wilhite formation, they concluded.

1. that the presence of limestone olistoliths demands the existence somewhere nearby of a carbonate platform or bank in this they agreed with Keller (ms. 1980, p. 171, 174-175; see also King, 1964, p. 63), who also held that the limestone-conglomerates and limestone turbidites are evidence of redeposition from a nearby bank or shelf – and
1. 2) that that platform or bank could only have been Paleozoic – shady or Knox (they preferred Knox) – whereas Keller (ms. 1980, p. 310-311 and Fig. 5-1) and Rast and Kohles (1986, p. 605-607) suggested that carbonate banks could well have formed in the late Precambrian on uplifted blocks beside the rift-basins in which the deeper water Ocoee sediments were deposited, or for that matter whenever the rift-basins were forming.

Unrug and LePain maintained that the carbonate in the Wilhite is all in olistoliths, but this conclusion does not seem to hold from some of it, for the carbonate turbidites for example, and even less for the stratiform bodies of sandy limestone and limy sandstone hundreds of meters thick and holding up ridges several kilometers long that have been mapped by Ferguson (Ferguson and Jewell, 1951) and Keller (ms. 1980, see Fig. 2-14); these last are more readily explained as large sand-flows from a nearby quartz-sandy carbonate platform. But of course Unrug and LePain's inference of deep-water deposition beside a carbonate platform is entirely compatible with this different interpretation.

Unrug and Unrug's microfossils (1990) were found at two localities in the Wilhite formation, in close association with carbonate olistoliths but in the accompanying shale, not in the carbonate; Raphael Unrug (written communication, 1989) reports further discoveries along many kilometers of the same outcrop belt. These discoveries appear to be within the stratigraphic interval containing the aritaarchs reported by Knoll and Keller (1979), though farther southwest. The presence of shelly fossils in the Wilhite is exceedingly important, for clearly it brings some of the Ocoee strata up into the Paleozoic.

But the Unrugs further maintained that the fossils, at least the agglutinated Foraminifera (p. 1043), prove a Silurian age; in the fossils imaged by scanning electron microscope in their Figure 4, they identified seven species in seven different genera, by comparison with Foraminifera described from the central United States and Europe. I must respectfully disagree. These minute fossils, at least those figured, seem to me not well enough preserved to permit such close identification; until they can be shown to be different from Ordovician and Cambrian agglutinated Foraminifera, such as the Lower Cambrian forms recently discovered with other microfossils in flat-lying strata in West Africa (Culver and others, 1990; see also Culver, Pojeta, and Repetski, 1988), they do no more than force the "base of the Cambrain" down from somewhere in the lower Chilhowee group (below the lowest strata with Skolithus) to somewhere in the upper Ocoee. The assignment of some of the other fossils to orders or suborders of Bryozoa, Ostracoda, and Trilobita also seems premature to me, especially in view of the minute size of the fossils, such as the putative bryozoans. Moreover, the lowest know fossiliferous (pretrilobite) stage of the Cambrian (the "Tommotian") is notorious for the variety of its diminutive shelly fossils, many of groups incertae sedis and without known descendants. I suggest that the Unrugs' fauna may represent that stage. This in itself is a major discovery but not one that requires throwing out the window a great deal of painstaking geological mapping and measuring of sections by a number of geologists, work indicating that the Walden Creek group lies in sequence below the Chilhowee group. Until better evidence is forthcoming, I must conclude that the Silurian age of the Wilhite formation is not proven.

I have been struck by the close resemblance's between the carbonate rocks in the Wilhite, as seen in the field, and the limestone-conglomerates and related rock-types long known along the western margin of the Taconic klippen in eastern New York, southeastern Quebec, and western Newfoundland. In the northern Appalachians these rock-types are well dated and by now well understood as bank-foot deposits, in exactly the same paleogeographic setting that Keller and the Unrugs have inferred for the Wilhite rocks. But in the north they are fossiliferous, not abundantly so to be sure, but megafossils have been known in New York and Quebec for more than a century (Ford, 1871; Ruedemann, 1901) and in Newfoundland for many decades (Schuchert and Dunbar, 1934; Kindle and Whittington, 1958). The fossils, found in both the limestone clasts and the encompassing deep-water turbidites and shales, range from Lower Cambrian to Middle Ordovician (perhaps only from Middle Cambrian in Newfoundland). If the Wilhite carbonates were similarly derived from an Ordovician or Lilurian carbonate bank, I find it hard to believe that no megafossils would have been found in them, and only microfossils in the accompanying shales.

The current debate sparked by these fossils shows however that challenges to Safford's Ocoee are still possible and that the last word on the subject will not be written soon, if ever.

ACKNOWLEDGEMENTS

This article was prepared at the suggestion of Stephen A. Kish, and I thank him for his encouragement. The article was reviewed by him, Dan Walker, Leroy Odum, and James Tull, and I am grateful to each of them for their valuable comments. I also would like to thank Danny Rye for converting my original computer-diskette material into final form, especially Table 1.

REFERENCES

Bayley, W. S., 1928, Geology of the Tate quadrangle, Georgia: Geological Survey of Georgia Bulletin 43, 170p.

Bearce, D. N., 1969, Geology of the southwestern Bald Mountains in the Blue Ridge Province of Tennessee: Southeastern Geology, v. 11, p. 21-36.

Bloomer, R. O., and Werner, H. J., 1955, Geology of the Blue Ridge region in central Virginia: Geological Society of America Bulletin, v. 66, p. 579-606.

Bryant, Bruce, and Reed, J. C., Jr., 1970 [1971], Geology of the Grandfather Mountain window and vicinity, North Carolina and Tennessee: United States Geological Survey Professional Paper 615, 190p.

Butts, Charles, 1926, The Paleozoic rocks: Geological Survey of Alabama Special Paper 14, p. 41-230.

Butts, Charles, 1940-1941, Geology of the Appalachian Valley of Virginia: Virginia Geological Survey Bulletin 52. Part I, 568 p.; Part II, 271p.

Campbell, M. R., 1894, Paleozoic overlaps in Montgomery and Pulaski counties, Virginia: Geological Society of America Bulletin, v. 5, p. 171-190.

Crickmay, G. W., 1936, Status of the Talladega series in southern Appalachian stratigraphy: Geological Society of America Bulletin, v. 47, p. 1371-1392.

Crickmay, G. W., 1952, Geology of the crystalline rocks of Georgia: Georgia Department of Mines, Mining and Geology, Geological Survey, Bulletin 58, 56 p.

Culver, S. J., Pojeta, John, Jr., and Repetski, J. E., 1988, First record of Early Cambrian shelly microfossils from west Africa: Geology, v. 16, p. 596-599.

Culver, S. J., Repetski, J. E., Pojeta, John, Jr., and Hunt, D., 1990, Early Cambrian Foraminifera and metazoan shelly fossils from West Africa: Geological Society of America Abstracts with Programs, v. 22, no. 7, p. 221.

Emmons, Ebenezer, 1838, Report of the 2nd geological district of the State of New York: New York Geological Survey Annual Report, 2nd, p. 185-252.

Ferguson, H. W., and Jewell, W. B., 1951, Geology and barite deposits of the Del Rio district, Cocke County, Tennessee: Tennessee Division of Geology Bulletin 57, 235p.

Ford, S. W., 1871, Notes on the Primordial rocks in the vicinity of Troy, N. Y.: American Journal of Science, 3rd series, v. 2, p. 32-34. Also many short articles in the Journal during that decade.

Hadley, J. B., 1970, The Ocoee Series and its possible correlatives, in Fisher, G. W., Pettijohn, F. J., Reed, J. C. Jr., and Weaver, K. N., Studies of Appalachian Geology, Central and Southern (Cloos volume), p. 247-259.

Hadley, J. B., and Goldsmith, Richard, 1963, Geology of the eastern Great Smoky Mountains, North Carolina and Tennessee: United States Geological Survey Professional Paper 349-B, 118p.

Hadley, J. B., and Nelson, A. E., 1971, Geologic map of the Knoxville quadrangle, North Carolina, Tennessee, and South Carolina: United States Geological Survey Miscellaneous Geologic Investigations, Map I-654.

Hamilton, Warren, 1961, Geology of the Richardson Cove and Jones Cove quadrangles, Tennessee; United States Geological Survey Professional Paper 349-A, 55p.

Hayes, C. W., 1891, The overthrust faults of the southern Appalachians: Geological Society of America Bulletin, v. 2, p. 141-154.

Hayes, C. W., 1895, Description of the Cleveland sheet: United States Geological Survey Geologic Atlas, folio 20, 4 p., 4 maps, 1 chart.

Hurst, V. J., 1955, Stratigraphy, structure, and mineral resources of the Mineral Bluff quadrangle, Georgia: Georgia Department of Mines, Mining and Geology, Geological Survey, Bulletin 63, 137 p.

Hurst, V. J., 1973, Geology of the southern Blue Ridge belt: American Journal of Science, v. 273, p. 643-670.

Hurst, V. J., and Schlee, J. S., 1962, Field excursion: Ocoee metasediments, north-central Georgia – southeast Tennessee: Georgia Department of Mines, Mining and Geology, Geological Survey, Guidebook 3, 28 p.

Jonas, A. I., 1932, Structure of the metamorphic belt of the southern Appalachians: American Journal of Science, 5th series, v. 24, p. 228 – 243.

Jonas, A. I., and Stose, G. W., 1939, Age relation of the pre-Cambrian rocks in the Catoctin Mountain – Blue Ridge and Mount Rogers anticlinoria in Virginia: American Journal of Science, v. 237, p. 575 – 593.

Keith, Arthur, 1892, Geology of Chilhowee mountain, in Tennessee: Philosophical Society of Washington Bulletin, v. 12, p. 71-88.

Keith, Arthur, 1894, Description of the Harpers Ferry sheet: United States Geological Survey Geologic Atlas, folio 10, 5p., 4 maps.

Keith, Arthur, 1895, Description of the Knoxville sheet: United States Geological Survey Geologic Atlas, folio 16, 6 p., 4 maps, 1 chart

Keith, Arthur, 1903, Description of the Cranberry quadrangle: United States Geological Survey Geologic Atlas, folio 90, 9 p., 4 maps 1 chart.

Keith, Arthur, 1907a, Description of the Nantahala quadrangle: United States Geological Survey Geologic Atlas, folio 143, 11p., 1 plate, 4 maps.

Keith, Arthur, 1907b, Description of the Roan Mountain quadrangle: United States Geological Survey Geologic Atlas, folio 151, 12p., 4 maps, 2 plates.

Keith, Arthur, 1927, Great Smoky overthrust (abstract): Geological Society of America Bulletin, v. 38, p. 154 – 155.

Keller, F. B., 1980, Wilhite Formation (Ocoee Supergroup): late Precambrian shelf-to-basin transition in the southern Appalachians: Geological Society of America Abstracts with Programs, v. 12, p. 460.

Keller, F. B., ms. 1980, Later Precambrian stratigraphy, depositional history, and structural chronology of part of the Tennessee Blue Ridge: Ph. D. dissertation, Yale University, 353 p.

Kindle, C. H., and Whittington, H. B., 1958, Stratigraphy of the Cow Head region, western Newfoundland: Geological Society of America Bulletin, v. 69, p. 315 – 342.

King, P. B., 1943, Manganese deposits of the Elkton area, Virginia: United States Geological Survey Bulltin 940 (B), p. 15 – 55.

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., 1950, Geology of the Elkton area, Virginia: United States Geological Survey Professional Paper 230, 82 p.

King, P. B., 1964, Geology of the central Great Smoky Mountains, Tennessee: United States Geological Survey Professional Paper 349-C, 148p.

King, P. H., and Ferguson, H. W., 1960, Geology of northeasternmost Tennessee: United States Geological Survey Professional Paper 311, 136 p.

King, P. B., Ferguson, H. W., Craig, L. C., and Rodgers, John, 1944, Geology and manganese resources of northeastern Tennessee: Tennessee Division of Geology Bulletin 52, 283 p.

King, P. B., Hadley, J. B., Neuman, R. B., and Hamilton, Warren, 1958, Stratigraphy of Ocoee series, Great Smoky Mountains, Tennessee and North Carolina: Geological Society of America Bulletin, v. 69, p. 947 – 966.

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, Keene, 1987, Microopaleontology across the Precambrian – Cambrian boundary in Spitsbergen: Journal of Paleontology, v. 91, p. 898 – 926.

LaForge, Laurence, and Phelan, W. C., 1913, Description of the Ellijay quadrangle: United States Geological Survey Geologic Atlas, folio 187.

Lowry, Jean, 1951, The southwest end of the Mountain City window, northeastern Tennessee: Ph. D. dissertation, Yale University, 147 p.

Neuman, R. B., 1955, Middle Ordovician rocks of the Tellico-Sevier belt, eastern Tennessee: United States Geological Survey Professional Paper 274 (F), p. 141-178.

Neuman, R. B., and Nelson, W. H., 1965, Geology of the western Great Smoky Mountains, Tennessee: United States Geological Survey Professional Paper 349-D, 81 p.

Ordway, R. J., 1959, Geology of the Buffalo Mountain-Cherokee Mountain area, northeastern Tennessee: Geological Society of America Bulletin, v. 70, p. 619-635.

Oriel, S. S., 1950, Geology and mineral resources of the Hot Springs window, Madison County, North Carolina: North Carolina Division of Mineral Resources Bulletin 60, 70p.

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.

Rast, Nicholas, and Kohles, K. M., 1986, The origin of the Ocoee Supergroup: American Journal of Science, v. 286, p. 593-616.

Rodgers, John, 1953, Geologic map of East Tennessee with explanatory test: Tennessee Division of Geology Bulletin 58, Part II, 168 p.

Rodgers, John, 1956, The clastic sequence basal to the Cambrian System in the Central and Southern Appalachians: International Geological Congress, 20th, Ciudad Mexico 1956, El Sistema Cambrico, su paleogeograffia y el problema de su base, v. 2, p. 385-413.

Rodgers, John, and Shaw, C. E., Jr., 1963, Age of the Talladega Slate of Alabama (abstract): Geological Society of America Special Paper 73, p. 226-227.

Ruedemann, Rudolf, 1901, Trenton conglomerate of Rysedorph Hill Rensselaer County N. R. and its fauna: New York State Museum Bulletin 49, p. 1-114.

Safford, J. M., 1856, A geological reconnaissance of the State of Tennessee: State Geologist First Annual Report, 164 p.

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

Schuchert, Charles, and Dunbar, C. O., 1934, Stratigraphy of western Newfoundland: Geological Society of America Memoir 1, 123p.

Shaw, C. E., Jr., 1970, Age and stratigraphic relations of the Talladega Slate: Evidence of pre-Middle Ordovician tectonism in central Alabama: Southeastern Geology, v. 11, p. 253-267.

Shaw, C. E., Jr., and Rodgers, John, 1963, Subdivisions of the Talladega Slate of Alabama (abstract): Geological Society of America Special Paper 73, p. 239-240.

Shekarchi, E., ms. 1959, The geology of the Flag Pond Quadrangle, Tennessee-North Carolina: Ph. D. dissertation, University of Tennessee, 140 p.

Simpson, E. L., and Sundberg, F. A., 1987, Early Cambrian age for syn-rift deposits of the Chilhowee Group of southwestern Virginia: Geology, v. 15, p. 123-126.

Smith, E. A., 1875, Report of progress for 1874: Geological Survey of Alabama, 139 p.

Smith, E. A., 1876, Report of progress for 1875: Geological Survey of Alabama, 220 p.

Smith, E. A., 1888, Report of progress for the years 1884-1888: Alabama Geological Survey Report of Progress, 24 p.

Stose, G. W., and Ljungstedt, O. A., 1932, Geologic map of the United States [scale, 1:2,500,000]: Unites States Geological Survey.

Stone, G. W., and Stose, A. J., 1944, The Chilhowee group and Ocoee series of the Southern Appalachians: American Journal of Science, v. 242, p. 387-390, 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, v. 60, p. 267-300.

Tull, J. F., 1982, Stratigraphic framework of the Talladega slate belt, Alabama Appalachians: 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: Georgia Geological Society, 23rd Annual Field Trip, Ellijay 1988, Guidebook (v.8, no. 1), p. 35-74.

Tull, J. F., and Guthrie, G. M., 1985, Proposed stratigraphic linkages between the Talladega slate belt and the Appalachian migeocline – tectonic implications: Alabama Geological Society, 22nd Annual Field Trip, Sylacauga 1985, Guidebook, p. 1-10, 87-92.

Tull, J. F., Harris, A. G., Repetski, J. E., McKinney, F. K., Garrett, C. B., and Bearce, D. N., 1988, New paleontologic evidence constraining the age and paleotectonic setting of the Talladega slate belt, southern Appalachians: Geological Society of America Bulletin, v. 100, p. 1291-1299.

Unrug, Raphael, and LePain, D. L., 1988, Carbonate olistoliths in the Ocoee series; implications for North American craton margin evolution: Geological Society of America Abstracts with Programs, v. 20, p. 320.

Unrug, Raphael, and Unrug, Sophia, 1990, Paleontological evidence of Paleozoic age for the Walden Creek Group, Ocoee Supergroup, Tennessee: Geology, v. 18, p. 1041-1045.

Walcott, C. D., 1891, Correlation papers – Cambrian (The Cambrian group of rocks in North America) United States Geological Survey Bulletin 81, 447p.

Walker, Dan, 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.

Willis, Bailey, 1893, The mechanics of Appalachian structure: United States Geological Survey Annual Report, 13th, part 2, p. 211-281, plates 46-96.

Wilmarth, M. G., 1938, Lexicon of geologic names of the United States (including Alaska): United States Geological Survey Bulletin 896, 2396 p.

Woodward, H. P., 1932, Geology and mineral resources of the Roanoke area, Virginia: Virginia Geological Survey Bulletin 34, 172 p.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 13-23

Problems of Stratigraphic Correlation Between the Great Smoky, Snowbird, and Walden Creek Groups Between the Great Smoky Mountains National Park, Central East Tennessee and Ocoee Gorge, Southeastern Tennessee

John O. Costello[1] and Robert D. Hatcher, Jr.[2]

[1]Atlanta Testing & Engineering 11420 Johns Creek Parkway, Georgia 30135; [2]Department of Geological Sciences, University of Tennessee, Knoxville, Tennessee 37996-1410, and Environmental Sciences Division, MS 6352, Oak Ridge National Laboratory,P.O. Box 2008, Oak Ridge, Tennessee 37831*

ABSTRACT

Rocks exposed in the eastern parts of Ocoee Gorge and eastward into the Ducktown basin in southeastern Tennessee, have been historically assigned to the Great Smoky conglomerate (now the Great Smoky Group of the Ocoee Supergroup). In contrast, the formation assignment and regional correlation of rocks west of the Great Smoky Group downstream of Short Creek westward to Greasy and Sylco Creeks in the western part of the gorge has been to either the Walden Creek Group or the Snowbird Group. Those who extend the Snowbird Group into southeastern Tennessee have also projected the Greenbrier fault south of the Great Smoky Mountains through Ocoee Gorge and into Georgia.

In the Great Smoky Mountains, the Greenbrier fault emplaced mountain-forming Great Smoky Group onto Snowbird Group, Walden Creek Group, and unclassified Ocoee rocks of the foothills belt to the west. In the eastern Great Smoky Mountains, the Snowbird Group is known to stratigraphically underlie the Great Smoky Group, but this relationship is not preserved to the west and southwest. The Walden Creek Group in the Great Smoky Mountain is only known to lie in tectonic contact with the Great Smoky Group which has lead to uncertainty regarding their stratigraphic relationships.

Extension of the Greenbrier fault into southeastern Tennessee is inconsistent with contact relationships along the western side of the Great Smoky Group both in Ocoee Gorge and along the Hiwassee River to the north. We have not found evidence of a major fault along this boundary in either place. In Ocoee Gorge, the overturned stratigraphically uppermost Great Smoky Group sandstone, conglomerate, and gray slate sequence of the Buck Bald Formation lies in conformable and gradational contact with a siltstone and greenish gray slate sequence that contains roundstone polymictic conglomerate, and sandy carbonate along strike. Primary structures in riverbed outcrops within the contact zone clearly indicate that the interval is overturned and that the predominantly fine-grained sequence stratigraphically succeeds the Buck Bald uninterrupted by faulting. These rocks are part of a conformable, stratigraphically higher sequence that regionally contains characteristic Walden Creek Group liithofacies (e.g., roundstone [Citico-type] conglomerate and sandy carbonate). We therefore correlate the sequence west of and stratigraphically above the Great Smoky Group in southeastern Tennessee with the Walden Creek Group rather than the Snowbird Group and maintain that the Greenbrier fault dies out near the Great Smoky Mountains National Park to the north.

The truth is rarely pure, and never simple.
Oscar Wilde

INTRODUCTION

Although Ocoee Gorge in southeastern Tennessee (Fig. 1) is the type area of the Ocoee Supergroup (Ocoee conglomerate and slate of Safford [1856], first order subdivisions of the Ocoee throughout the region were made by King and others (1958) from type areas about 100 km to the northeast (Table 1) in the Great Smoky Mountains. This usage may have led some geologists to import correlations and structural interpretations into the gorge based on relationships worked out in greater detail farther north.

For more than a century, geologists have studied rocks that are now commonly accepted as Great Smoky Group south of the Great Smoky Fountains in and near the Unicoi Mountains of eastern Tennessee (including the eastern part of Ocoee Gorge) and western North Carolina and extending along strike into northern Georgia (e.g., Keith, 1904, 1907; LaForge and Phalen, 1913; Stose and Stose, 1944, 1949; Rodgers, 1953; Hardeman, 1966; Hadley and Nelson, 1971; North Carolina Geological Survey, 1985). On the other hand, foothills belt rocks (Ocoee slate of Safford [1856] to the west (including the western part of Ocoee Gorge) have been correlated with either the Snowbird Group (e.g., Wiener and Merschat, 1878; Wiener and Merschat, 1981; Merschat and Hale, 1983; Gair and Slack, 1982; Slack and others, 1982) or the Walden Creek Group (e.g., Hadley, 1970; Sutton, 1971, Holcombe, 1973; Hatcherand Milici, 1986).

Although detailed geologic mapping of the foothills belt between the Great Smoky Mountains and Ocoee Gorge will eventually settle this dispute, we believe that headway can be made toward resolving the controversy by comparing foothills belt rocks in and along strike from Ocoee Gorge with type area Snowbird and Walden Creek Group lithofacies 100 km to the north (Fig. 1)

This paper relates Ocoee Supergroup lithostratigraphy

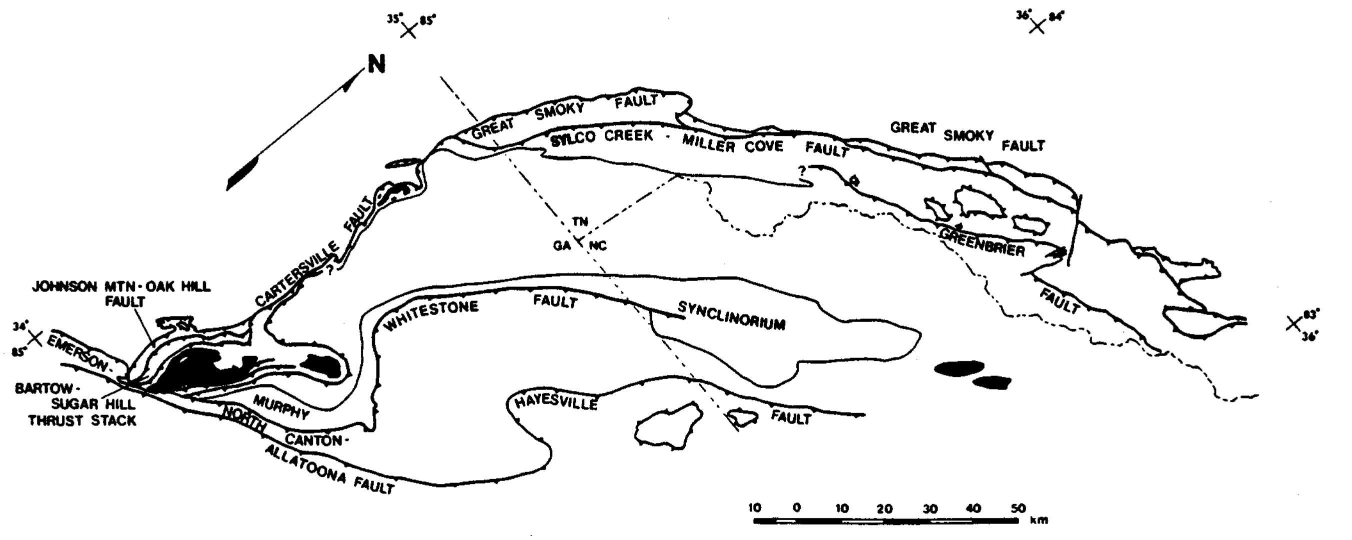


FIGURE 1. The frontal thrust zone and major western Blue Ridge structures in southeastern Tennessee, northern Georgia and southwestern North Carolina. Black areas are basement massifs. Shading denotes the Ocoee Gorge area.

that is well established in the Great Smoky Mountains to the less well understood stratigraphy in the Ocoee Gorge region. As a result, we correlate rocks stratigraphically above the Great Smoky Group in Ocoee Gorge with the Walden Creek Group of the Great Smoky Mountains. We also acknowledge the vision of Hurst and Schlee (1962) who recognized lithologic similarities and potential for correlations between sequences in Ocoee Gorge and in the Murphy syncline farther east.

REGIONAL GEOLOGIC SETTING

The Ocoee Supergroup was originally defined as the Ocoee Series by Kin and others (1958). The Ocoee is a Late Proterozoic sequence of variably metamorphosed, predominantly turbidite-dominated, immature clastic sedimentary rocks with volumetrically minor carbonate. Felsic and mafic volcanic rocks and banded iron formation (exhalite), related to stratabound massive sulfide deposits in the Ducktown, Tennessee area, have been reported by Abrams (1987), but these and similar rocks south of the Great Smoky Mountains probably constitute only a small percentage of the Ocoee Supergroup.

The Ocoee Supergroup is the most extensive lithostratigraphic sequence in the western Blue Ridge of Tennessee, North Carolina, and Georgia (Hadley, 1970). The Ocoee outcrop belt extends along strike almost 300 km from near the Nolichuky River at the Tennessee-North Carolina border (Rodgers, 1953) to the northeastern Talladega Salte belt southwest of Cartersville, Georgia (King, 1964; McConnell and Costello, 1982). The greatest outcrop width of 80 km and stratigraphic thickness of at least 9100 m occurs roughly at the midpoint of the belt across western North Carolina and central eastern Tennessee (King and others, 1958; Hardeman, 1966; Hadley, 1970; North Carolina Geological Survey, 1985). Farther east, Ocoee rocks may be exposed in the Brasstown Bald and Shooting Creek windows (Fig. 1)in the Hayesville thrust sheet (Hatcher and others, 1990), suggesting that the eastern limits of the Ocoee basin are concealed beneath the eastern Blue Ridge allochthon.

The Ocoee Supergroup lies nonconformably on Middle Proterozoic (Grenvillian) basement (Keith, 1907; Stose and Stose, 1949; King and others, 1958; Odom and others, 1973) that was a partial source of the clastic detritus (e.g., 1140 ma zircons [Carroll and others, 1957], blue quartz, microcline, and local granitoid clasats) that comprises the sequence. The Ocoee, in turn, is conformably overlain by rocks of the Murphy belt (Nuttall, 1951) to the east and the Chilhowee Group (Neumann and Nelson, 1965; Walker and Driese, 1990) to the west.

A well-defined, basin-wide, internal Ocoee lithostratigraphic scheme has not been recognized, most likely of complexities in the original depositional setting and the effects of Paleozoic deformation. Additionally, comprehensive, high-resolution geologic mapping, necessary for such definition is limited to the Great Smoky Mountains National Park (Hamilton , 1961; Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965). Farther south, detailed mapping covers several widely spaced, smaller areas (e.g., Hurst, 1955; Merschat and Hale, 1983; and Hernon; 1964, 1968).

The most extensive, systematically executed detailed mapping project in the western Blue Ridge was conducted in the Great Smoky Mountains by the U. S. Geological Survey. During the U. S. G. S. investigation, King and others (1958), elaborated Safford's (1856) Ocoee Conglomerate and Slate into the Ocoee Series. They divided Ocoee rocks of the Great

Table 1. Geographic Origins of Ocoee Supergroup Unit Names (place names may not coincide with type areas).

Walden Creek Group	Walden Creek, Walden Creek and Pigeon Forge, TN quadrangles.
Sandsuck Formation	Sandsuck Branch, Walden Creek, TN quadrangle.
Wilhite Formation	Richardson Cove and Jones Cove, TN quadrangles.
Yellow Breeches Member	Yellow Breeches Creek, Jones Cove, TN quadrangle.
Dixon Mountain Member	Dixon Mountain, Jones Cove, TN quadrangle.
Shields Formation	Shields Mountain, Pigeon Forge and Richardson Cove, TN quadrangles.
Licklog Formation	Licklog Hollow, Richardson Cove, TN quadrangle.
Unclassified formations	
Cades Sandstone	Cades Cove, Cades Cove, TN - NC quadrangle.
Webb Mountain & Big Ridge rocks	Webb Mountain and Big Ridge, Richardson Cove and Jones Cove, TN quadrangles.
Rich Butt Sandstone	Rich Butt Mountain, Hartford, TN quadrangle.
Great Smoky Group	Great Smoky Mountains, TN & NC.
	(Great Smoky Mountains)
Anakeesta Formation	Anakeesta Ridge, Mt. Le Conte, TN - NC quadrangle.
Thunderhead Sandstone	Thunderhead Mountain, Thunderhead Mountain, TN - NC quadrangle.
Elkmont Sandstone	Elkmont community, Gatlinburg, TN quadrangle.
	(eastern Ducktown District and northern Georgia)
Dean Formation	Dean Ridge, Mineral Bluff, GA - NC quadrangle.
Hothouse Formation	Hothouse Creek, Mineral Bluff, GA - NC quadrangle.
Hughes Gap Formation	Hughes Gap, Mineral Bluff, GA - NC quadrangle.
Wehutty Formation	Wehutty community, NC, Isabella, TN - NC quadrangle.
Copperhill Formation	Copperhill, TN, Epworth, GA - TN quadrangle.
	(western Ducktown District and Ocoee Gorge)
Buck Bald Formation	Buck Bald, Farner, TN - NC quadrangle.
Boyd Gap Formation	Boyd Gap, Ducktown, TN quadrangle.
Farner Formation	Farner community, Farner, TN - NC quadrangle.
Snowbird Group	Snowbird Mountain, Waterville, NC - TN quadrangle.
Metcalf Phyllite	Metcalf Bottoms, Wear Cove, TN quadrangle.
Pigeon Siltstone	Little Pigeon River and West Fork of the Little Pigeon River, Pigeon Forge, Richardson Cove, Gatlinburg, and Cartertown, TN quadrangles.
Roaring Fork Sandstone	Roaring Fork, Cartertown, TN quadrangle.
Longarm Quartzite	Longarm Mountain, Cove Creek Gap, NC quadrangle.
Wading Branch Formation	Wading Branch Ridge, Cove Creek Gap, NC quadrangle.

Smoky Mountains into the Snowbird, Great Smoky, and Walden Creek Groups (each with constituent formation subdivisions that were mostly named using the stratigraphic nomenclature of Keith [1895, 1896, 1904, and 1907]) and the unclassified Cades and Rich Butt Sandstones and Webb Mountain and Big Ridge rocks (see Tables 1 and 2). Also, the Greenbrier fault (now recognized as the Greenbrier-Dunn Creek fault system [see Woodward and others, this volume]) was reported (in the first guidebook of the Carolina Geological Society) by King and others (1952) as the oldest major structure to affect Ocoee rock unit distribution throughout the Great Smoky Mountains from Snowbird Group, unclassified formations, and Walden Creek Group of the foothills area to the west.

In an attempt to reconcile internal Ocoee relationships, King and others (1958) tentatively correlated the Great

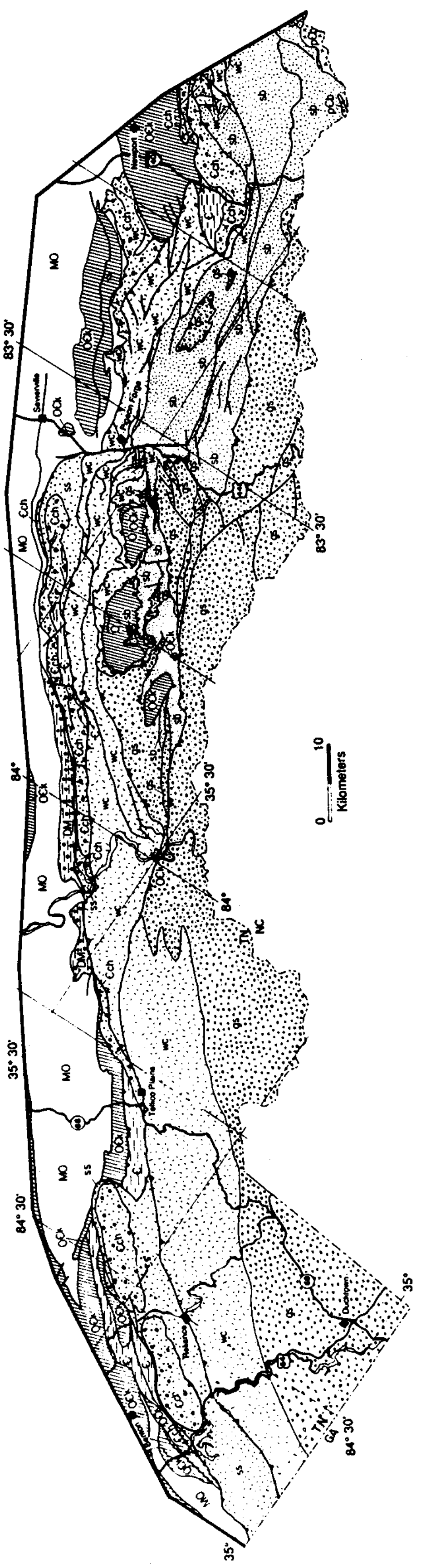


FIGURE 2. Simplified geologic map of the western Blue Ridge and adjacent parts of the Valley and Ridge showing the major thrust faults and gross western Blue Ridge lithostratigraphic belts (modified from Hardeman, 1966). Solid- teeth line – Great Smoky fault. Open-teeth line –Miller Cove and related faults. Double solid-teeth line Greenbrier fault. Gs- Great Smoky Group (mountains belt sequence). Sb – Snowbird Group and wc – Walden Creek Group (foothills belt sequence). Ss – Sandsuck Formation, Cch – Chilhowee Group and C – Shady Dolomite and Rome Formation on Chilhowee Mountain, Blunt and Sevier Counties (frontal Blue Ridge fault block sequence). C. Cambrain rocks (predominantly Shady Dolomite, Rome Formation and Conasauga Group) of the Valley and Ridge. OCk – Knox Group. 0 – Ordovician rocks (Ordovician Knox Group and lower Middle Ordovician rocks. MO – Middle Ordovician rocks. DM – Devonian and Mississippian rocks.

Smoky Group east of the Greenbrier fault with the unclassified Ocoee formations and the Walden Creek Group to the west. Recently, a model was conceived by Rast and Kohles (1986) to explain compositional differences and west-to-east thickness variations in the Ocoee Supergroup that are now telescoped by the Greenbrier and younger faults. They suggested that contrasts in Ocoee lithostratigraphy across the Greenbrier fault were caused by deposition of a southeastward tapering Snowbird Group wedge in a half-graben that was later broken into two separate grabens by an intervening (Unaka) horst. According to the hypothesis of Rast and Kohles, this resulted in the deposition of the Snowbird Group – Great Smoky Group – Murphy belt succession east and south of the horst and the Snowbird Group – unclassified Ocoee formation – Walden Creek Group succession to the west and north.

Unfortunately, neither of these hypotheses is totally sound. A problem with the correlation of King and others (1958) is that at no place, in either the Great Smoky Group or the Walden Creek Group, are characteristic lithofacies of one assemblage present in the other. Rast and Kohles (1986) advanced a plausible explanation for the west-to-east Ocoee Supergroup variations in the Great Smoky Mountains, but their model is not substantiated by preservation of vestiges of the Unaka horst. Therefore, stratigraphic relationships between the Walden Creek Group and the Great Smoky Group in the Great Smoky Mountains remain unclear.

COMPARISION OF LITHOLOGIES

The following section describes foothills belt rocks in Ocoee Gorge and type-area Snowbird Group and Walden Creek Group rocks in the Great Smoky Mountains. Our correlation is based primarily on lithologic similarity and to a lesser degree on limited detailed and reconnaissance mapping in the intervening area.

Paleozoic low to medium grade Barrovian metamorphism and deformation have not significantly modified primary sedimentary structures in the foothills and westernmost mountains belt. Although metamorphism is important, the emphasis of this field trip is on stratigraphic relationships. We, therefore, feel it is appropriate to describe the rocks in sedimentary terms.

OCOEE GORGE LITHOSTRATIGRAPHY

Rodgers (1953) subdivided the western Blue Ridge in general geologic/physiographic elements: 1) the frontal Blue Ridge fault blocks; 2) the foothills belt to the east; and 3) the mountains belt farther to the east. These divisions can be generally traced from the Great Smoky Mountains southward through Ocoee Gorge using strike-parallel toporaphy (Fig. 2).

The frontal Blue Ridge fault blocks contain subgreen-

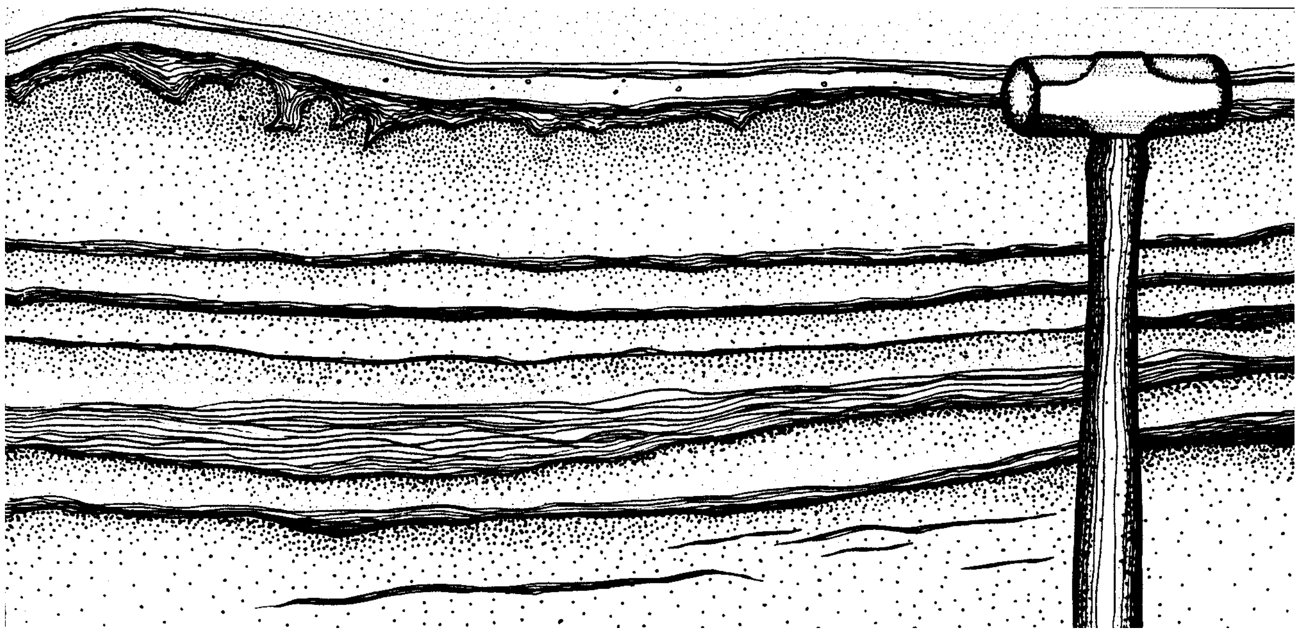


FIGURE 3. Sketch of outcrop in Great Smoky Group – Walden Creek Group contact zone, Ocoee riverbed about 2 km southwest of Ocoee No. 2 Dam. Sedimentary load and flame structures preserved in interbedded dark slate and lighter siltstone to fine-grained sandstone (stipple pattern) indicate the sequence is overturned and west facing. Hammer head is 12.7 cm long.

schist-facies, locally pencil-cleaved Late Progerozoic Sandsuck Formation shale and siltstone, succeeded by Lower Cambrian rift to shelf facies sedimentary rocks (Chilhowee Group, and locally Shady Dolomite and Rome Formation). The frontal blocks overlie the Great Smoky fault in southeastern Tennessee and contain either open synclinal or uniformly east-dipping monoclinal structures that form major ridges, including Chilhowee, Bean, Chestnut, and Starr Mountains in Polk and Monroe Counties and Chilhowee and English Mountains in Blount, Sevier, and Cocke Counties, Tennessee.

The foothills belt consists of predominantly greenschist-facies (chlorite grade), slaty cleaved fine-grained Ocoee rocks that lie east of and above the Sylco Creek – Miller Cove fault system, but west of predominantly coarse-grained Great Smoky Group rocks. Foothills belt rock are commonly fine-grained clastics with minor conglomerate and carbonate. Hayes (1895) correlated the rocks in the easternmost part of the foothills belt with Pigeon Slate, Citico Conglomerate, and Wilhite Slate mapped in the Knoxville quadrangle by Keith (1895). Much of Keith's (1895) Pigeon, Citico, and Wilhite was incorporated into the Walden Creek Group by King (1964, p. 45).

Mountain-forming (e.g., the Great Smoky and Unicoi Mountains) coarse-grained, chlorite-to- biotite grade Ocoee clastic rocks interlayered with dark pelite crop out in the upper reaches of Ocoee Gorge. Mountains belt rocks comprise the westernmost part of the Great Smoky Group strike belt in southeastern Tennessee. Wiener and Mershat (1978, 1981) subdivided the Great Smoky Group in upper Ocoee Gorge into the Boyd Gap Formation overlain by Buck Bald Formation. These rocks are similar in composition to higher (garnet to staurolite) grade, but generally finer-grained quartzo-feldspathic clastic rocks to the east in the Ducktown Basin (Hernon, 1968).

Ocoee Gorge Foothills Belt

The westernmost foothills belt was emplaced against the eastern border of the frontal Blue Ridge Bean and Starr Mountains allochthon along the Sylco Creek-Miller Cove fault system (Hardeman, 1966; Hatcher and others, 1990). The most abundant foothills belt rock types in Ocoee Gorge are greenish-gray banded slate, variegated sandstone, and dark pyritic slate. From Greasy Creek eastward to Madden Branch, gray-green laminated to thin-bedded sericite-quartz-chlorite slate interlayered with incipiently transposed, rippled silty carbonate (ankerite). Cleavage-bedding relationships and locally preserved sedimentary structures indicate this sequence contains the youngest rocks in the Sylco Creek hanging-wall sequence. To the east and stratigraphically below this interval is a sequence of calcareous and feldspathic fine-grained sandstone, graywacke, and fine conglomerate interlayered with greenish slate through a gradational contact. Sandstone beds generally range from 5 cm to > 1 m thick.

Stratigraphically below the sandstone and slate sequence across a gradational contact is a succession of locally pyritic and carbonaceous, dark green to gray laminated phyllite and slate interlayered with buff to light tan siltstone and fine-grained sandstone. This sequence passes eastward and stratigraphically downward through a gradational contact zone into the Buck Bald Formation of the Great Smoky Group just west of Short Creek (about 2 km downstream from the Ocoee No. 2 dam). We have not seen evidence of major faults between the Sylco Creek – Miller Cove fault and the Great Smoky Group either in Ocoee Gorge or along the Hiwassee River to the north.

The contact zone between the Buck Bald Formation and stratigraphically overlying rocks is well exposed in the Ocoee riverbed during peak electrical power demand, when water is routed through the wooden flume along the south wall of the gorge. Well-preserved load and flame structures occur in interbedded dark slate and lighter siltstone to fine-grained sandstone (Fig. 3) of the uppermost Buck Bald Formation. These structures reinforce other sedimentary and tectonic facing criteria in this section of the gorge that indicate the mountains belt-foothills belt rock sequence youngs to the west.

Grain-support to matrix-supported polymictic conglomerate and various carbonates occur within the foothills belt sequence along strike, but are not conspicuous in Ocoee Gorge. These important rocks are interlayered with the slate and siltstone to fine sandstone sequence north of the gorge through Polk and Monroe Counties, Tennessee and to the south into Murray County, Georgia (Salisbury, 1961).

North of Ocoee Gorge, variably thick, lenticular beds of polymictic rounddstone conglomerate with a distinctive greenish-gray to medium gray sandy matrix occur in sequences of dull green to medium gray phyllitic slate. Clasts in the conglomerate are composed of milky white to light pink quartz, argillite, dolostone, limestone, and (rarely) granitoid. This rock is strikingly similar to the Citico-type conglomerate of Keith (1895) and the Shields Formation described by Hamilton (1962). The conglomerate is exposed in roadcuts and outcrops and railroad cuts along the Hiwassee River near the Apalachia Powerhouse (McFarland, Tennessee quadrangle), and in roadcuts near the crest of Tellico Mountain on Tennessee Highway 68 (Tellico Plains, Tennessee quadrangle). Roundstone conglomerate also occurs farther north along the Little Tennessee River at Chilhowee Dam.

Interlayered conglomerate and slate have also been mapped south of Ocoee Gorge in roadcuts north of Taylor Branch (Tennga, Georgia-Tennessee quadrangle). At this locality, the conglomerate contains well-rounded, cobble-size dolostone clasts and ubiquitous milky quartz pebbles.

Sandy limestone and angular limestone clast conglomerate (breccia) also locally occur in this sequence. The fresh limestone is typically medium to dark gray. Weathering produces a dusty gray color and etched, high-relief surfaces where quartz grains and relatively insoluble Ooliths and pisoliths are conspicuous.

About 13 km north of Ocoee Gorge, carbonate crops out beyond the Hiwassee River along Childers Creek at the southern end of Pond Mountain (McFarland, Tennessee quadrangle). The rock at this locality is locally highly deformed. Insoluble-rich layers stand out on weathered surfaces and clearly portray folds and other small-scale structures. In contrast, only 100 m northeast of this exposure relatively unstrained and unrecrystallized limestone contains preserved rounded detrital quartz sand grains and Ooids.

About 4.5 km farther north, at the end of a southwest-trending spur of Hankins Mountain east of Springtown (McFarland, Tennessee quadrangle), limestone, Oolith – and pisolith-bearing limestone, and angular limestone clast conglomerate are exposed in and near an abandoned quarry (privately owned). The carbonate at each of these localities is concordant with and locally gradational into the surrounding, dominantly pelitic rocks.

We have not mapped carbonates in the foothills belt immediately south of the Ocoee River, but three outcrops of argillaceous, locally sandy "metalimestone" in northern Murray County, Georgia (Tennga, Georgia – Tennessee quadrangle) were reported in rocks tentatively correlated with the Sandsuck Formation by Salisbury (1961). Sandy limestone farther south in the Cartersville district, Georgia has been correlated with the Wilhite Formation of the Walden Creek Group (Costello and others, 1982, p. 38).

Great Smoky Mountains Lithostratigraphy

Information summarizing Ocoee Supergroup nomenclature is presented in Tables 1 and 2. In many cases, the most representative or "type" exposures of Ocoee rock units are located apart from features for which they were named. For instance, the Snowbird Group is named for Snowbird Mountain, northeast of the Great Smoky Mountains (Keith, 1904; King and others, 1958), but the Pigeon River Gorge along Interstate Highway 40 in Tennessee and North Carolina contains the most complete section (Hadley and others, 1974) and may be a better reference section. Snowbird Group internal subdivisions, however, are named for localities in the Great Smoky Mountains (Table 2). The Walden Creek Group is named for a tributary of the northeastern end of Chilhowee Mountain (King and others, 1958). Walden Creek internal subdivisions are named for nearby foothills belt localities. The Great Smoky Group was named by Hurst (1955) after the Great Smoky conglomerate of LaForge and Phalen (1913) who followed Keith's (1904, 1907) usage.

Snowbird Group

The Snowbird Group is comprised of the Wading Branch Formation, the Longarm Quartzite, and the Roaring Fork Sandstone, which are present in both the Greenbrier fault hanging wall and footwall sequences (King and others, 1958; King 1964). Pigeon Siltstone and Metcalf Phyllite are also assigned to the Snowbird, but are known to occur only

Table 2. Origins of Ocoee Supergroup Stratigraphic Nomenclature (Great Smoky Mountains to Ocoee Gorge area)

Walden Creek Group (King and others, 1958)
- Sandsuck Formation (King and others, 1958 after Keith, 1895)
- Wilhite Formation (King and others, 1958 after Keith, 1895)
  - Yellow Breeches Member (King and others, 1958)
  - Dixon Mountain Member (King and others, 1958)
- Shields Formation (King and others, 1958)
- Licklog Formation (King and others, 1958)

Unclassified Formations (probably Great Smoky Group equivalents)
- Cades Sandstone (King and others, 1958 after Keith 1895)
- Webb Mountain and Big Ridge rocks (King and others, 1958)
- Rich Butt Sandstone (King and others, 1958)

Great Smoky Group (Hurst, 1955 after La Forge and Phalen, 1913 and Keith, 1904)

(Great Smoky Mountains)
- Anakeesta Formation (King and others, 1958)
- Thunderhead Sandstone (King and others, 1958 after Keith, 1895)
- Elkmont Sandstone (King and others, 1958)

(eastern Ducktown District & northern Georgia)
- Dean Formation (Hurst, 1955)
- Hothouse Formation (Hurst, 1955)
- Hughes Gap Formation (Hurst, 1955)
- Wehutty Formation (Hernon, 1968)
- Copperhill Formation (Hurst, 1955)

Western Ducktown District & Ocoee Gorge)
- Buck Bald Formation (Wiener and Merschat, 1978)
- Boyd Gap Formation (Wiener and Merschat, 1978)
- Farner Formation (Wiencer and Merschat, 1978)
- Copperhill Formation (Hurst, 1955)

Snowbird Group (King and others, 1958 after Keith, 1904)
- Metcalf Phyllite (King and others, 1958)
- Pigeon Siltstone (King and others, 1958 after Keith, 1895)
- Roaring Fork Sandstone (King and others, 1958)
- Longarm Quartzite (King and others, 1958)
- Wading Branch Formation (King and others, 1958

west of the Greenbrier fault (King, 1964). The Metcalf Phyllite is largely fault bound and isolated from most other Snowbird rocks, but was mapped by King (1964) in stratigraphic contact with the Pigeon Siltstone in the Gatlinburg and Pigeon Forge, Tennessee, quadrangles.

The basal Snowbird Group, the Wading Branch Formation, consists of dark sandy pelite, siltstone, and coarse, poorly sorted, micaceous feldspathic sandstone and pebble conglomerate (King and others, 1958). South of the Pigeon River in the eastern Great Smoky Wading Branch (interpreted as a former regolith) lies nonconformably on basement (Hadley and Goldsmith, 1963).

The Longarm Quartzite lies conformably above the Wading Branch (King and others, 1958). The Longarm contains resistant beds of clean feldspathic quartzite, arkose and darker, predominantly fine-grained sandstone that exhibit cross stratification, current bedding, and other primary structures (Hadley and Goldsmith, 1963).

The Roaring Fork Sandstone which is composed of thickly bedded, light to dark, coarse – to tine-grained greenish-gray sandstone and interbedded dark slate and phyllite conformably overlies the Longarm Quartzite on the Pigeon River (King and others, 1958). In the type area, however, the basal Roaring Fork contact is faulted, but the conformable contact with the overlying Pigeon Siltstone is preserved.

The Pigeon is characterized by laminated, light to dark siltstone which is locally interbedded with lenticular fine-grained sandstone (King, 1964). A dull gray to greenish siltstone containing iron-bearing carbonate (ankerite) layers near the top of the Pigeon along the West Prong of the Little Pigeon River is described by King (1964, p. 24).

The Metcalf Phyllite is a locally highly deformed sequence of green to gray phyllite with interlayered, minor siltstone and feldspathic sandstone (King, 1964). The Metcalf compositionally resembles parts of the Pigeon Siltstone and Roaring Fork Sandstone, but it is locally strongly foliated and fault bound except at its northeastern limits, thwarting correlation with any Snowbird Group members other than the Pigeon Siltstone.

In summary, the Snowbird Group is a relatively clean, feldspathic, predominantly medium – to fine-grained clastic metasedimentary sequence with sparse conglomerate and carbonate. Reconstructions show the Snowbird to have formed a northwesterly thickening sedimentary prism (King and others, 1958). South of the Great Smoky Mountains, Snowbird Group rocks thin and pinch out or truncate against faults (King and others, 1958; Hadley and Goldsmith, 1963, plate 1; King, 1964, plate 1; Neuman and Nelson, 1965, plate 2).

Walden Creek Group

King and others (1958) established the Walden Creek Group to integrate rocks mapped by Keith (1895, 1904) as Wilhite Slate, Citico Conglomerate, Pigeon Slate and Hiwassee Slate. The foothills belt Walden Creek succession in the Great Smoky Mountains consists of Licklog Formation, Shields Formation, Wilhite Formation (subdivided into the lower, Dixon Mountain Member and upper, Yellow Breeches Member), and the Sandsuck Formation.

The Licklog Formation, which is only locally exposed, consists of dark gray, laminated to crudely layered micaceous siltstone and shale. In places, the fine-grained Licklog sequence is interbedded with coarse-grained rocks that mimic parts of the overlying Shields Formation.

The Shields Formation consists of sandstone and a distinctive conglomerate that contains predominantly well rounded, white vein quartz pebbles with less abundant lithic clasts (e.g., quartzite, granite, chert, siltstone, and limestone). The Shields also contains dark gray to green shale, siltstone, and sandstone that are interbedded with the conglomerate lithofacies. Contact relationships between the Shields Formation and the overlying Wilhite Formation are obscured by deformation, but King (1965) interpreted the transition as conformable.

The Wilhite Formation is divisible in the type area into a lower Dixon Mountain Member and upper Yellow Breeches Member. The Dixon Mountain Member consists of micaceous, sandy siltstone with carbonate laminations that is locally interbedded with light gray sandstone. The Yellow Breeches member is characterized by sandy and conglomeratic limestone and dolostone. The carbonates, which locally exceed a 30 m thickness, are interbedded with dull green to gray argillaceous to feldspathic sandy clastic rocks.

The Wilhite Formation has been mapped through the Great Smoky Mountains foothills belt (King and others, 1958), but Neuman and Nelson (1965) did not recognize Hamilton's (1961) two-member succession in the western Great Smoky Mountains. Neuman and Nelson (1965) describe Wilhite lithologies recognized in the type area including Shields Formation conglomerate lithofacies, which they show as Walden Creek conglomerate on their maps.

King and others (1958) considered the Sandsuck Formation interbedded gray to greenish shale and siltstone with minor coarse sandstone and quartz pebble conglomerate sequence to be disconformable with the overlying Chilhowee Group. Neuman and Nelson (1965), however, reported Sandsuck-Chilhowee contact relationships near the Little Tennessee River to be conformable. This relationship also appears to apply in the Bean Mountain – Starr Mountain area north of the Ocoee River.

The Miller Cove fault isolates "type" Sandsuck from the remainder of the Walden Creek Group (King, 1964; Neuman and Nelson, 1965). Hamilton (1961) reported that Sandsuck rocks in a small area south of English Mountain and north of Dixon Mountain stratigraphically succeed the uppermost Wilhite, although he further reported that the top of the Sandsuck is not preserved. If the Sandsuck sequence south of English Mountain is equivalent to part of the Chilhowee Mountain Sandsuck sequence, the Early Cambrian age (Walcott, 1891; Laurence and Palmer, 1963) for the Chilhowee versus the Siluro-Devonian age reported by Unrug and Unrug (1990) for the Walden Creek Group represents a geologic enigma.

DISCUSSION

The Snowbird Group was originally correlated with the Ocoee Gorge foothills sequence by Wiener and Merschat (1978, 1981). In keeping with this, Slack and others (1982) and Gair and Slack (1982) assigned foothills rocks along strike farther south to the Snowbird. In contrast, characteristic Walden Creek lithologies (e.g., Citico-type [Shields Formation] conglomerate and Yellow Breeches-type carbonate) have been recognized south of the Great Smoky Mountains via reconnaissance and local detailed mapping along strike to the Hiwassee River and southward into Georgia.

We believe that reconnaissance mapping has its uses, but such work in only preliminary and should be aggressively superceded by detailed investigations. To confirm our hypothesis, it is essential that detailed geologic mapping be completed in the western Blue Ridge south of the Great

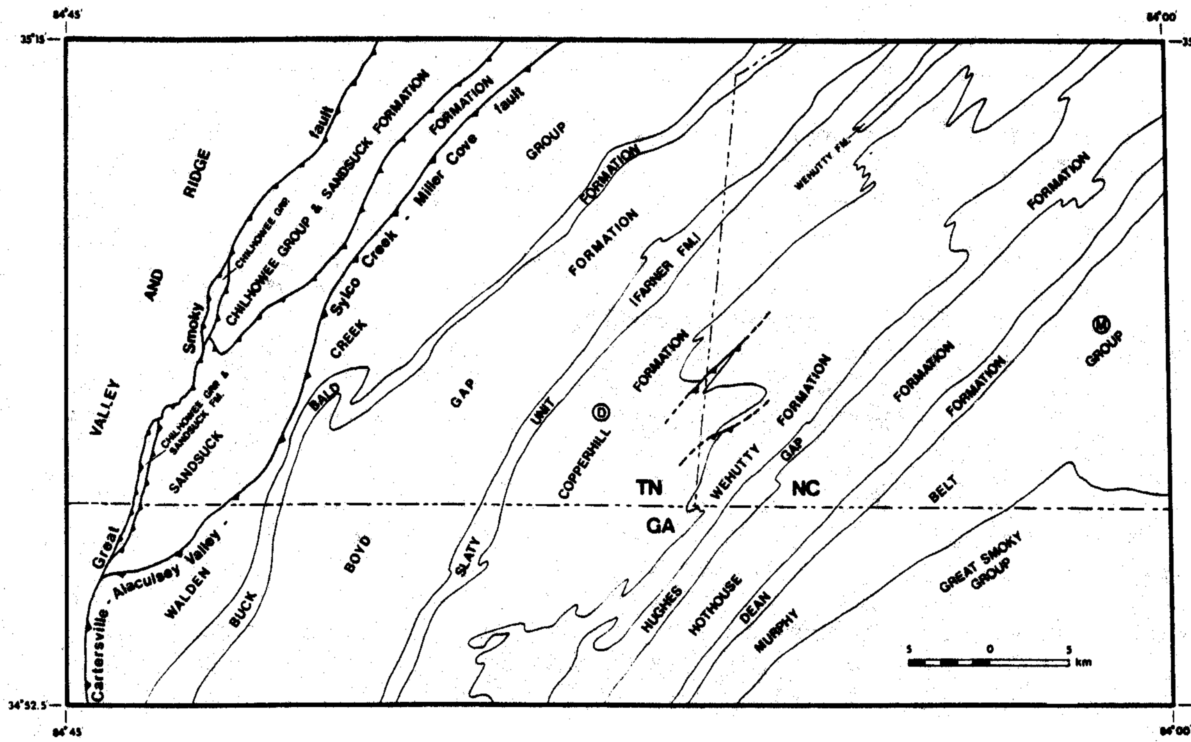


FIGURE 4. Geologic map of the Tennessee – North Carolina – Georgia boundary area. Circled D – Ducktown,Tennessee. Circled M – Murphy, North Carolina. Modified by JOC from Hurst and Schlee (1962), Hernon (1964) and Wiener and Merschat (1981).

Smoky Mountains.

We also feel that either sedimentary petrological investigations similar to the Carroll and others (1957) or Hanselman (1972) studies, or geochemical investigations, may provide inroads to realizing the unique characteristics of grossly similar Blue Ridge rocks. For instance, Hadley (1970) reported that the Great Smoky Group and Walden Creek Group contain detrital tourmaline that is absent from the Snowbird Group. He also observed that bulk compositions of Great Smoky Group rocks indicate derivation from a predominantly granitic source, whereas Snowbird Group rocks accumulated from a more mafic source. Lastly, Hadley (1970) acknowledged the Walden Creek Group as the most compositionally diverse of the three major Ocoee Supergroup units, but clearly unique as containing the most significant carbonate. The foundation for future work has been built.

CONCLUSIONS

1.The Snowbird Group unit that most closely resembles the fine-grained Ocoee Gorge foothills rocks is the Pigeon Siltstone. Interlayered dark greenish gray laminated phyllitic slate and light gray fine sandy siltstone exposed in cuts across U. S. Highway 64 from Ocoee Powerhouse No. 2 slightly resemble laminated and crossbedded Pigeon Siltstone (see Hamilton, 1961, Fig. 3), but the rocks more closely resemble greenish gray dark banded argillite and siltstone interlayered with lighter colored fine-grained sandstone reported by Neuman and Nelson (1965, Fig. 5) in the Wilhite Formation. Furthermore, the Snowbird Group contains minor coarse clastic rocks and carbonates, but it does not contain lithofacies that are compositionally equivalent to the Shields/Citico-type conglomerate or the characteristic Yellow Breeches-type sandy to conglomeratic limestone. While these lithofacies are rare in Ocoee Gorge, they are abundant in the foothills along strike to the north.

Our reconnaissance and local detailed mapping between Ocoee Gorge and the Little Tennessee River, coupled with observed similarities in lithologic character and stratigraphic sequence in the foothills between the western Great Smoky Mountains and Ocoee Gorge, strongly support the correlation of widely separated rocks along strike. We therefore correlate the Ocoee Gorge foothills sequence with the Walden Creek Group rather than the Snowbird Group.

2.A conformable contact between the Great Smoky Group and the Walden Creek Group in Ocoee Gorge, plus the absence of a major fault elsewhere between the Great Smoky Group and the Sylco Creek – Miller Cove fault, precludes extending the Greenbrier fault, or any equivalent structure through the Gorge. In the southwestern Great Smoky Mountains, the Greenbrier fault is truncated by the younger Mannis Branch fault (Gatlinburg fault family of King, 1964) and the Great Smoky Group strikes into the largely reconnaissance mapped Tennessee – North Carolina – Georgia Blue Ridge south of the Great Smoky Mountains National Park. We believe that our scant knowledge of this region conceals the termination of the Greenbrier fault.

3. Hurst and Schlee (1962) recognized the top of the Great Smoky Group in Ocoee Gorge and reported the transition with fine-grained rocks to the west as an overturned, but conformable contact. They also subtly concluded that rocks stratigraphically above the Great Smoky Group in Ocoee Gorge correlate with rocks in the core of the Murphy syncline farther east (Fig. 4). In our view, lithologic similarity and conformable contact relationships between the Buck Bald Formation (uppermost Great Smoky Group) and lowermost Murphy belt sequence permit direct correlation.

4. We are not certain how either the recent Unrug and Unrug (1990) Wilhite Formation paleontologic data or the rediscovery of soft-bodied metazoans in the Late Proterozoic Sandsuck Formation (see Broadhead and others, this volume) bear on western Blue Ridge chronostratigraphy, but, until either the Unrug and Unrug (1990) data re replicated or the Sandsuck Formation is proven not to stratigraphically overlie the Wilhite Formation, we regard the uppermost Walden Creek Group as no younger than Early Cambrian.

ACKNOWLEDGEMENTS

We gratefully acknowledge support by National Science Foundation grant EAR-8406949 to RDH for field work in the western Blue Ridge by J. O. Costello. Critical and thought-provoking reviews by Carl Merschat, Leonard Wiener, and Jim Tull helped clarify early versions of this paper and are very much appreciated. We thank Steve Kish and Ken Gillon for additional helpful comments and suggestions.

REFERENCES CITED

Abrams, C. E., 1987, Base metal mines and prospects of the southwest Ducktown District, Georgia: Georgia Geologic Survey Information Circular 78, 61 p.

Carroll, D., Neuman, R.B., and Jaffee, H.W., 1957, Heavy minerals in arenaceous beds in parts of the Ocoee Series, Great Smoky Mountains, Tennessee: American Journal of Science, v. 255, p. 157-193.

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, 40 p.

Gair, J.E. and Slack, J.F., 1982, Geologic maps of the Cohutta Wilderness and the Hemp Top Roadless Area, northern Georgia and southeastern Tennessee: U.S. Geological Survey Miscellaneous Field Studies Map MF-1415-A, scale 1:48,000.

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, 188p.

Hadley, J.B., King, P.B., Neuman, R.B., and Goldsmith, R., 1955, Outline of the geology of the Great Smoky Mountains area, in Russell, R.J., ed., Guides to southeastern geology: Geological Society of America, p. 390-411.

Hadley, J.B. and Nelson, A.E., 1971, Geologic map of the Knoxville quadrangle, North Carolina, Tennessee, and South Carolina: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-654, scale 1:250,000.

Hadley, J.B., Wiener, L.S., Merschat, C.E., Maher, S.W., Royster, D.L., Aycock, J.H., and McElrath, J.P., 1974, Geology along Interstate 40 through Pigeon River Gorge, Tennessee – North Carolina: Tennessee Academy of Science Geology – Geography Section and Safford Centennial Society Spring Field Trip, 20 p.

Hamilton, W.B., 1961, Geology of the Richardson Cove and Jones Cove quadrangles, Tennessee: U.S. Geological Survey Professional Paper 349-A, 55 p.

Hanselman, D.H., 1972, Depositional environment in the Upper Precambrian Ocoee Series of central eastern Tennessee [Ph.D. thesis]: Columbia, University of South Carolina, 87 p.

Hardeman, W.D., 1966, Geologic map of Tennessee: Tennessee Division of Geology, scale 1:250,000.

Hatcher, R.D., Jr. and Milici, R.C., 1986, Ocoee Gorge, Appalachian Valley and Ridge to Blue Ridge transition, in Neathery, T.N., ed., Southeastern Section of the Geological Society of America Centennial Field Guide, v. 6, p. 265 – 270.

Hatcher, R.D., Jr., Osberg, P.H., Drake, A.A., Robinson, P., and Thomas, W.A., 1990, Tectonic map of the U.S. Appalachians – Plate 1, in Hatcher, R.D., Jr., Thomas, W.As., 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.

Hayes, C.W., 1895, Description of the Cleveland sheet: U.S. Geological Survey Geologic Atlas, Folio 20, 12 p.

Hernon, R.M., 1964, Geologic maps and sections of the Ducktown, Isabella and Persimmon Creek quadrangles, Tennessee and North Carolina: Open File, U.S. Geological Survey, scale 1:24,000.

________1968, Geology Geology of the Ducktown, Isabella and Persimmon Creek quadrangles, Tennessee and North Carolina: Open File, U.S. Geological Survey, 71 p.

Holcombe, R.J., 1973, Mesoscopic and microscopic analysis of deformation and metamorphism near Ducktown, Tennessee [Ph.D. thesis]: Palo Alto, Stanford University, 225p.

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 – southeast Tennessee (Geological Society of America, Southeastern Section Annual Meeting, Guidebook no. 3): Georgia Department of Mines, Mining and Geology, 28 p.

Keith, A., 1895, Description of the Knoxville sheet (Tennessee and North Carolina): U.S. Geological Survey Geologic Atlas, Folio 16, 6 p.

________1896, Description of the Loudon sheet (Tennessee): U.S. Geological Survey Geologic Atlas, Folio 25, 6 p.

________1904, Description of the Asheville quadrangle (Tennessee and North Carolina): U.S. Geological Survey Geologic Atlas, Folio 116, 10 p.

________1907, Description of the Nantahala quadrangle (North Carolina and Tennessee): U.S. Geological Survey Geologic Atlas, Folio 143, 11 p.

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. Hadley, J.B., and Neuman, R. B., 1952, Guide book of excursion in the Great Smoky Mountains: Carolina Geological Society Guidebook No. 1, 60 p.

King, P.B., Hadley, J.B., and 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.

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 Murray Shale and Hessee Quartzite on Chilhowee Mountain, Blount County, Tennessee: U.S. Geological Survey Professional Paper 475-C, p. C53 – C54.

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 Talladega and Carolina slate belts, southern Appalachian orogen: Geological Society of America Special Paper 191, p. 19 – 30.

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.

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.

North Carolina Geological Survey, 1985, Geologic map of North Carolina: North Carolina Department of Environment, Health, and Natural Resources, scale 1:500,000.

Nuttal, B.D., 1951, The Nantahala-Ocoee contact in north Georgia [M.S. thesis]: Cincinnati, University of Cincinnati, 32 p.

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 Abstract with Programs, v. 5, p. 425.

Rast, N. and Kohles, K.M., 1986, The origin of the Ocoee Supergroup: American Journal of Science, v. 286, p. 593 – 616.

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.

Salisbury, J.W., 1961, Geology and mineral resources of the northwest corner of the Cohutta Mountain quadrangle: Georgia Geological Survey Bulletin 71, 61 p.

Slack, J.F., Gazdik, G.C., and Dunn, M.L., 1982, Mineral resources of the Big Frog Wilderness Study Area and additions, Polk County, Tennessee, and Fannin County, Georgia: U.S. Geological Survey Bulletin 1531, 25 p.

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.

_________1949, Ocoee Series of the southern Appalachians: Geological Society of America Bulletin, v. 60, p. 267 – 320.

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.

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.

Walcott, C.D., 1891, Correlation papers, Cambrian: U.S. Geological Survey Bulletin 81, 447p.

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.

Wiener, L.S. and Merschat, 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 Hatcher, R.D., Jr., Merschat, C. E., Milici, R.C., and Wiener, L.S., Field Trip

1-A transect in the southern Appalachians, Tennessee and North Carolina, in Milici, R.C., and Wiener, L.S., Field Trip 1-A transect in the southern Appalachians, Tennessee and North Carolina, in Milici, R.C., ed., Field Trips in the southern Appalachians, Tennessee Division of Geology Report of Investigation No. 37, p. 23 – 29.

Wiener, L.S. and Merschat, C.E., 1981, Provisional geologic map of southwest North Carolina, southeast Tennessee and north Georgia: North Carolina Geological Survey Open File Map, scale 1:250,000.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 25-34

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

Raphael Unrug, Sophia Unrug and Stephen L. Palmes
Department of Geological Sciences, Wright State University, Dayton, Ohio 45435

ABSTRACT

New Microfossil finds in the Little Tennessee River Valley indicate that the age of the Walden Creek Group is Late Devonian – Famennian to earliest Mississippian. The carbonate rocks present as clasts and olistoliths in the siliciclastic rocks of the Walden Creek Group are of Silurian to Late Devonian – Frasnian age. The thrust sheet stacking and regional metamorphism of the Western Blue Ridge province of the Southern Appalachians, postdating the deposition of the Walden Creek Group, is post-earliest Mississippian.

INTRODUCTION

The discovery of fossils and microfossils in the Walden Creek Group (Unrug and Unrug, 1990) established the Paleozoic age of this uppermost unit of the Ocoee Supergroup in the Western Blue Ridge tectonic province of the Southern Appalachians (Fig. 1). The Walden Creek Group can no longer be considered part of a Late Proterozoic rift basin fill, preceding the opening of the Iapetus ocean.

Unrug and Unrug (1990) presented evidence for a Silurian or younger age of the Walden Creek Group, and interpreted the Walden Creek sedimentary basin to be a post – Taconic successor basin, correlative to the Talladega Group basin.

Presently, we have fossil material found along the entire outcrop belt of the Walden Creek Group from Hot Springs, North Carolina, to the Ocoee River Gorge, Tennessee. In this paper we focus on outcrops in the Little Tennessee River Valley that indicate the older and younger age limits for the Walden Creek Group. The occurrences of fossils in various types of carbonate rocks allow to establish the relationship of the older, carbonate-dominated sedimentary basin and the younger, siliciclastic-dominated sedimentary basin of the Walden Creek Group. A full description of the fossil material of the Walden Creek Group will be presented in a forthcoming paper.

THE WALDEN CREEK GROUP

Siliciclastic Rocks

The Walden Creek Group consists of coarse-to fine-grained siliciclastic sedimentary rocks, some slightly metamorphosed. The facies characteristics indicate deposition of the Walden Creek Group sediments in a deep-water marine basin, in a base of slope sedimentary environment, along a tectonically active basin margin (Unrug and Unrug, 1990)

The lithologic types present include quartz conglomerates, polymict conglomerates, feldspathic sandstones, siltstones, and slaty shales, accompanied by debris-flow breccia beds consisting of quartz pebbles and shale clasts in a coarse-sand matrix. The conglomerate and sandstone beds are graded, often with repetitive grading. Channelized beds are common but not uniformly distributed. In some outcrops, notably at the Chilhowee Dam on the Little Tennessee River, channelized beds are predominant (Fig. 5).

Carbonate Rocks

Carbonate rocks occur in the Walden Creek Group as:

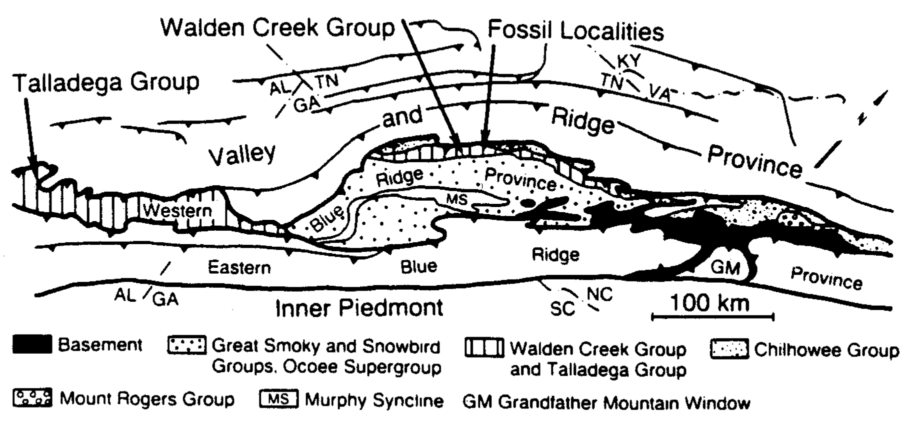


Figure 1. Generalized geologic map of the western Blue Ridge province and adjacent areas of the Southern Appalachians, showing the areas of occurrence of the Ocoee Supergroup and the Talladega Group. Fire from Unrug and Unrug (1990).

- carbonate olistoliths, some containing carbonate debris-flow breccia beds, and enclosed by siliciclastic rocks;
- carbonate debris-flow breccia beds intercalated in siliciclastic rocks;
- graded carbonate conglomerate beds intercalated in siliciclastic rocks;
- carbonate clasts in polymict conglomerates;
- graded calcarenite and calcilutite beds intercalated in siliciclastic rocks.

Carbonate Olistoliths

Olistoliths in the Walden Creek Group are blocks of carbonate, or carbonate and shale lithology, tens to hundreds of metres long and up to a hundred metres thick. The olistoliths blocks are sitting in siliciclastic rocks that underlie and overlie them. Bottom, top and lateral contacts of the carbonate rocks are unconformable with the siliciclastic enveloping rocks. The olistolith blocks can be mapped and walked around on siliciclastic float. The olistolith blocks are interpreted to be emplaced in the sedimentary basin of the Walden Creek Group by gravity transport of large blocks produced by collapse of active fault scarps. Olistolith blocks of comparable and larger size are produced by collapse of oversteepened slopes at basin margins in tectonically stable environments in passive margin settings (Cook and Mullins, 1983) and in tectonicaly unstable environments in active margin settings (Robertson, 1987), both in ancient and recent sediments.

Excellent and easily accessible examples of olistolith blocks sitting in siliciclastic rocks of the Walden Creek Group are exposed in road cuts near the southern end of the Foothills Parkway linking the US Highway 129 and US 321 roads (Fig. 2), 7 ½ minute Tallassee quadrangle, UTM coordinates Zone 16, $_{7}$7161E $_{39}$4082N. Three olistoliths of thin-bedded black limestone alternating with black shale are present in these outcrops. Another olistolith, cropping out on present in these outcrops. Another olistolith, cropping out on the slope some 150 m stratigraphically higher in the section consists of medium bedded limestone containing microfossils. The dimensions of the largest olistolith as revealed by detailed mapping at 1:10,000 scale are: 450 x 200 x 75 m.

The attitude of bedding in the olistoliths is discordant with regard to the attitude of bedding in the enclosing siliciclastic sediments. We interpret this as indication that the carbonate olistoliths traveled down the submarine slope as rigid blocks. The moving carbonate blocks rotated and came to rest with their internal stratification at an angle to the depositional surface of the enclosing siliciclastic sediment.

Incipient sliding of semi-consolidated beds produced local folds seen in several places in the olistoliths. The and cleavage planes in the fold hinges are absent

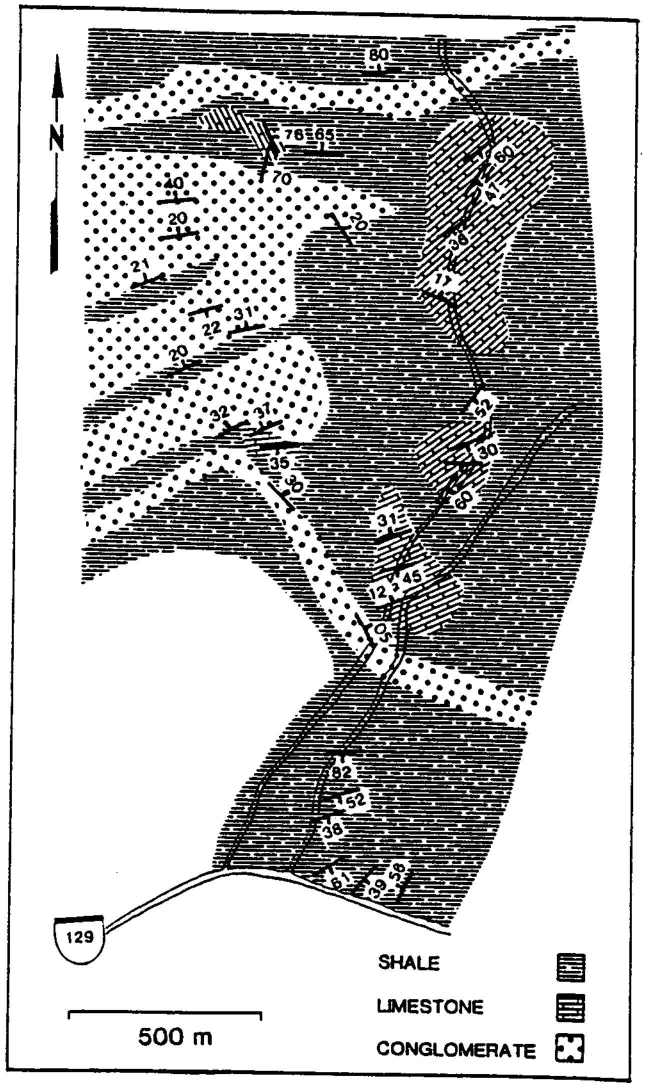


Figure 2. Geologic map of the area near the southwest end of the Foothills Parkway illustrating the relations of the carbonate olistoliths and enclosing siliciclastic sediments.

Carbonate Debris-flow Breccia Beds Within Olistoliths

A carbonate debris-flow breccia bed is intercalated among the thin bedded limestone and black shale (Fig. 3) of an olistolith exposed along the Foothills Parkway. The breccia contains clasts of lithologically varied carbonate rocks in a sandy carbonate matrix. Infrequent clasts of an older carbonate breccia are present. A bed of black shale with grey-weathering siltstone laminae underlies the breccia bed.

A large boulder of carbonate breccia at the southern end of the road cut contains clasts of limestone rich in microfossils. More breccia boulders are present in the stream below and east of the Foothills Parkway. In some blocks a conspicuous sub-parallel fabric of flat carbonate clasts is present.

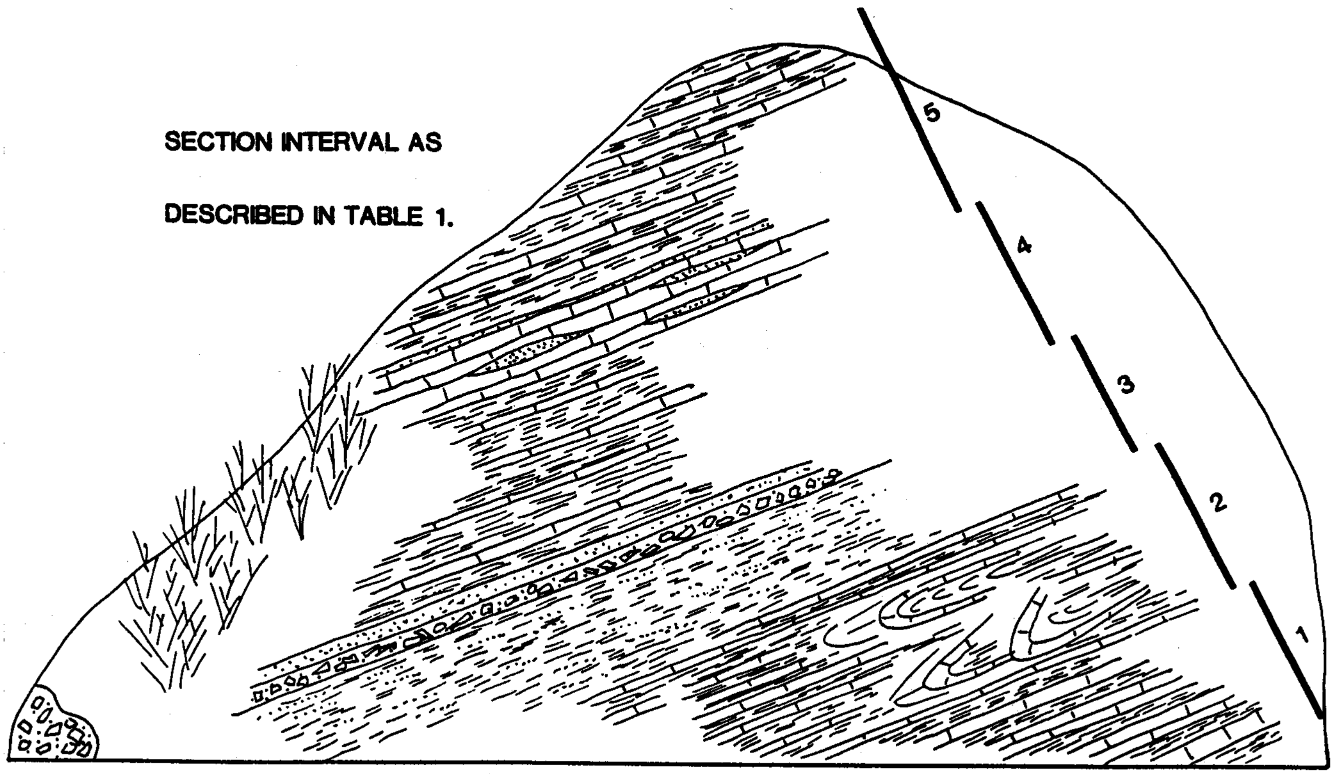


Figure 3. Outcrop sketch of an olistolith exposed along the Foothills Parkway showing sedimentological relationships between bedded limestone, debris-flow breccia, siltstone and shale. Section intervals 1-5 are described in Table 1.

TABLE 1. Description of section intervals described in Figure 3.

UNIT	THICKNESS	DESCRIPTION
5	7.8 m	Black thin-bedded limestone 2-10 cm thick with no shale intercalations, containing lenses of sand and fine-grained breccia with clasts up to 1 cm across. Uppermost beds of this unit contains shales 3-5 cm thick intercalated with 10-25 cm thick limestone beds.
4	5.7 m	Alternating black shale and limestones beds 10-20 cm thick.
3	4.4 m	Black shale with 1-4 cm thick intercalations 8-15 cm apart of light tan weathering siltstone, overlain by a 66 cm limestone breccia horizon containing 3-15 cm tabular elongate clasts in a muddy matrix.
2	5.6 m	Bedded limestones 2-5 cm thick with sandy laminae 2-3 mm thick at base of bedding planes. This unit contains a limestone and shale horizon which was folded as soft sediment.
1	5.2 m	30-50 cm thick dark grey limestone beds, some containing clasts of breccia, interbedded with finely laminated shales 1-10 cm thick.

This fabric is characteristic for translational slides on basin margin slopes (Cook and Mullins, 1983).

In the valley of Citico Creek, a south bank tributary of the Little Tennessee River, (7 ½ minute Tallassee quadrangle, UTM coordinates $_{7}$6260E $_{39}$3310N), an olistolith of bedded dark grey limestone alternating with black shale is exposed in a abandoned quarry. A breccia bed consisting of large clasts several metres across is intercalated in the bedded limestone and shale. Clasts of oolite and of grapestone with algal debris are present. Obviously, the breccias contain clasts of shallow water sediments. A nearby outcrop is in an olistolith of stromatolite and stromatolite-encrusted breccia.

We interpret the thin-bedded black limestone alternating with black shale, and containing intercalations of carbonate debris-flow and slide breccia, as sediments of a basin-margin facies deposited on a submarine slope. The bedded carbonates were locally subject to gravity induced sliding and deformation of semi-consolidated sediment producing the soft-sediment folds. Translational sliding rupturing the beds led to the formation of slide breccias. Occasionally the deposition of the evenly bedded carbonate sediment was interrupted by turbidity current depositing the silty laminated shales, and by debris flows depositing breccias that contain clasts of shallow water carbonate sediments.

Carbonate Debris-flow Breccia Beds Intercalated in Siliciclastic Rocks

A large outcrop of a debris-flow breccia bed consisting of carbonate clasts in a matrix of quartz sand and calcareous mud, intercalated in shale and siltstone is present in a road cut along US Highway 129, west of the junction with Foothills Parkway (Fig. 4) (7 ½ minute Calderwood quadrangle, UTM coordinates Zone 17, 22869E 393786N). The breccia bed is 3.5 m thick, and consists of angular clasts of several lithologic types of carbonate rocks including clasts of older breccia. Some clasts in this breccia bed contain microfossils. The breccia forms a planar bed of considerable extent, as no changes of thickness are seen in the large outcrop. The section in the described outcrop is overturned, as determined on graded bedding attitude in stratigraphically overlying beds to the west of the debris-flow breccia.

We interpret the breccia bed as a deposit of debris-flow that carried carbonate clasts of shallow water origin into a deep water basin accumulating predominantly siliciclastic sediment.

Graded Carbonate Conglomerate Intercalated in Siliciclastic Rocks

One bed of graded carbonate conglomerate is exposed in the road cut of US Highway 129, 1.7 kilometers east of the junction with Foothills Parkway (7 ½ minute Calderwood quadrangle, UTM coordinates 22828E 393862N). The bed, approximately 40 cm thick, intercalated among slaty shales, is folded into a recumbent anticline with spectacular axial plane cleavage. The bed consists of carbonate clasts, up to 2-3 cm across, that are highly strained, but graded bedding is clearly visible. This bed is a turbidity current deposit. The nature of the carbonate material is obscured by recrystallization.

Carbonate Clasts in Polymict Conglomerates

Pebble-to boulder-size clasts of carbonate rocks in polymict conglomerates are present in various position in the stratigraphic column of the Walden Creek Group. The best example of this mode of occurrence is in the Chilhowee Dam outcrop (Fig. 5), in the road cut along US Highway 129, 7 ½ minute Tallassee quadrangle, UTM coordinates 76747E 393755N. The polymict conglomerate beds are up to several meters thick, and contain carbonate clasts of diverse lithologies, including clasts of carbonate breccia, and clasts of fossiliferous limestones.

Calcarenite Beds

Nine calcarenite beds are exposed in the road cut on US Highway 129, in the same outcrop as the debris-flow breccia bed described above (7 ½ minute Tallassee quadrangle, UTM coordinates 77076E 393864N). The calcarenite beds alternate with siltstones and shales and stratigraphically overlie the debris-flow breccia bed (Fig. 5). The calcarenite beds, 3 to 10 cm thick, consist of small ooids, coated grains, microfossils, and quartz sand grains set in sparry calcite

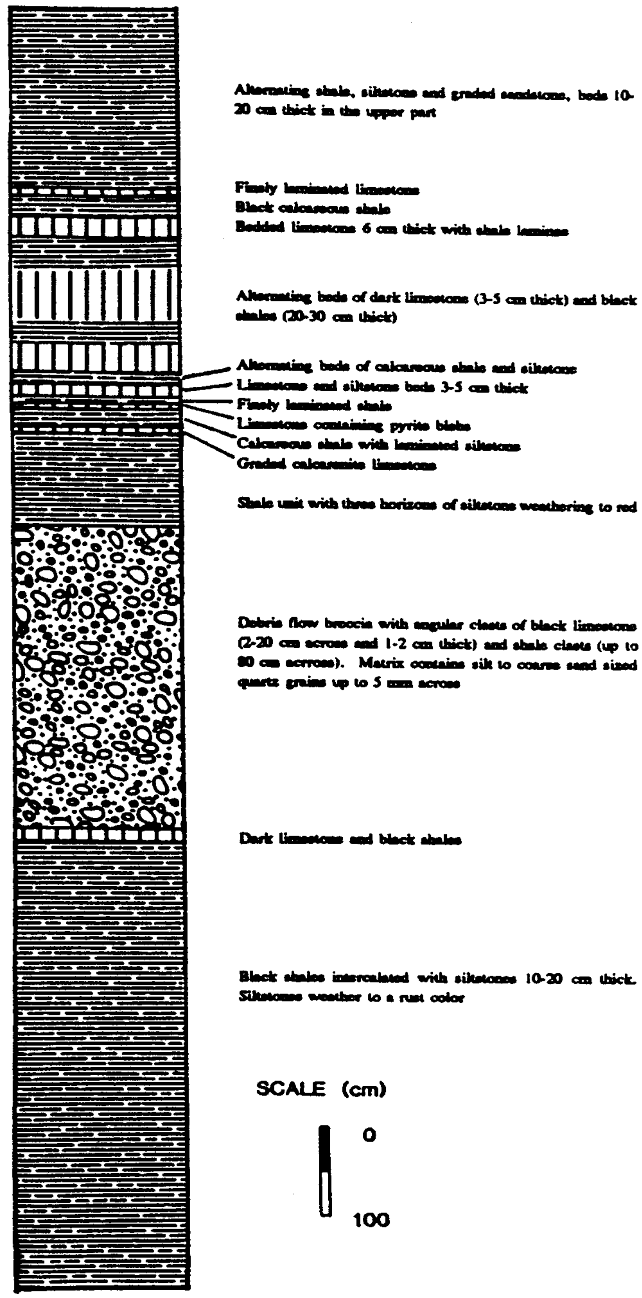


Fig. 4. Stratigraphic section measured along US 129 road just west of the intersection with the Foothills Parkway. This figure shows a carbonate debris-flow breccia and calcarenite beds interbedded with siliciclastic sediments of the Walden Creek Group.

cement. The beds show a graded distribution of grain sizes, and a faint lamination. We interpret the calcarenite beds as deposits of turbidity currents.

FOSSIL OCCURRENCES

An assemblage of Paleozoic fossils and microfossils has been obtained from the Walden Creek Group. Unrug and Unrug (1990) reported the presence of metazoan fragments and agglutinated foraminifers. New fossil discoveries broaden the assemblage to include also calcareous foraminifers and calcispheres.

Metazoan Fragments

Metazoan fragments have been obtained from shale of the Wilhite Formation enclosing the olistoliths exposed along the Foothills Parkway, from limestone boulders in the debris-flow breccia at the Citico Creek quarry, and from the limestone pebbles in the polymict conglomerate of the Chilhowee Dam outcrop. The metazoan assemblage consists of trilobite (Plate 1, K), bryozoan (Plate 1,L), ostracod (Plate 1, J), and microcrinoid (Plate 1, M) fragments. The metazoan fragments are not sufficient to support a precise age determination, but they place the age of the Walden Creek Group in the Paleozoic, and because of the presence of bryozoan fragments – younger than Cambrian. For a more detailed description of this material, see Unrug and Unrug (1990).

Agglutinated Foraminifers

Agglutinated foraminifers were found in shales alternating with bedded limestone in the olistolith at the Citico Creek quarry and in the limestone pebbles of the breccia bed at US Highway 129. The foraminiferal assemblage includes three families and eight genera in the suborder *Textulariina* (Unrug and Unrug, 1990). *Sorosphaera tricella* Moreman (Moreman 1930), (Plate 1,D) common in sandy limestone in the Little Tennessee River Valley area, brings the total number of general to nine. The families *Psammosphaeridae, Saccamminidae* and *Hemisphaeramminidae* all appeared in the Ordovician and range to the Holocene (Tappan and Loeblich, 1988). All but one of the species found appeared first in the Silurian. The agglutinated foraminifers are described in detail by Unrug and Unrug (1990) with the exception of *Sorosphaera tricella,* found recently and illustrated here.

Calcispheres

Abundant discrete spherical bodies were found in thin sections of limestone clasts from the debris-flow breccia exposed along Foothills Parkway. They consist of an inner chamber of variable diameter (90-360 um) filled with sparry calcite, and confined by a dark, thin layer of microgranular calcite (Plate 1, B). Some forms have an outer layer of sparry calcite 40-80 um wide, surrounded by a second thin dark layer, and appear to be double walled (Plate 1, A). In some forms the inner chamber is bound by spines or tightly packed calcitic prisms with pyramidal termination (Plate 1, C). These forms are classified as calcispheres (the genus Calcisphaera was established by Williamson, 1880, as quoted by Conil et al. 1979), but their systematic position is unknown. Stanton (1963) suggested they represent some form of plant spore or reproductive organ. Wray (1977) related them to Dasycladacea. Toomey and Mamet (1979) interpreted them as algal spore cyst. Calcispheres are known from Upper Paleozoic rocks, and are common in Upper Devonian to Middle Carboniferous rocks (Derville, 1951; Reytlinger, 1957; Conil and Lys, 1964; Rich, 1965). Stanton (1967) indicated that calcispheres with distinctive spinose to prismatic outer wall, termed radiosphaerid calcispheres, are common in Upper Devonian – Frasnian of North America, and can be used as index microfossils, but mentioned the possibility of pre-Frasnian and Mississippian occurrences. Toomey et al (1970) reported radiospherid calcispheres from Frasnian limestones of Alberta, Canada, and Brencle (1973) from the Lower Pensylvannian of Nevada. Calcispheres are reported from the Lower Pensylvannian of Nevada. Calcispheres are reported from shallow water, restricted, low-energy marine sedimentary environments (Wray, 1977).

Calcareous Foraminifers

Two distinctive assemblages of calcareous foraminifers are recognized in thin section: one in the limestone clasts of debris-flow breccias, then other in the valcarenite limestones interbedded with shales.

Limestone clast in the debris-flow breccia beds intercalated within the carbonate olistolith, and intercalated in siliciclastic rocks, contain specimens of foraminifers belonging to the families.

Parathuramminidae – Cribrosphaeroides (Cribrosphaeroides) simplex (Reytlinger) (Plate 1, I), described from the Upper Devonian of the western part of the Russian platform (Reytlinger, 1954).

Uslonidae – Uslonia permira Antropov, (Plate 1, E), described from the Upper Devonian of the Russian platform (Lipina, 1950).

Geinitzinidae – Lunucamina cf. Devonica (Lipina) described from the Upper Devonian of the Russian platform (Lipina, 1950).

The tests of these forms are very simple, unilocular, globular or irregular, built of microgranular calcite described as “secreted calcareous test” by Tommey and Mamet (1979). Coiled or separated forms were not observed. A very similar assemblage was described from Frasnian strata of Turkey by Dil (1976). Toomey and Mamet (1979) suggested that this assemblage indicates Middle Devonian – Late Givetian to Late Devonian – Frasnian age. The age determination is supported by the presence of calcispheres and radiosphaerid cal-

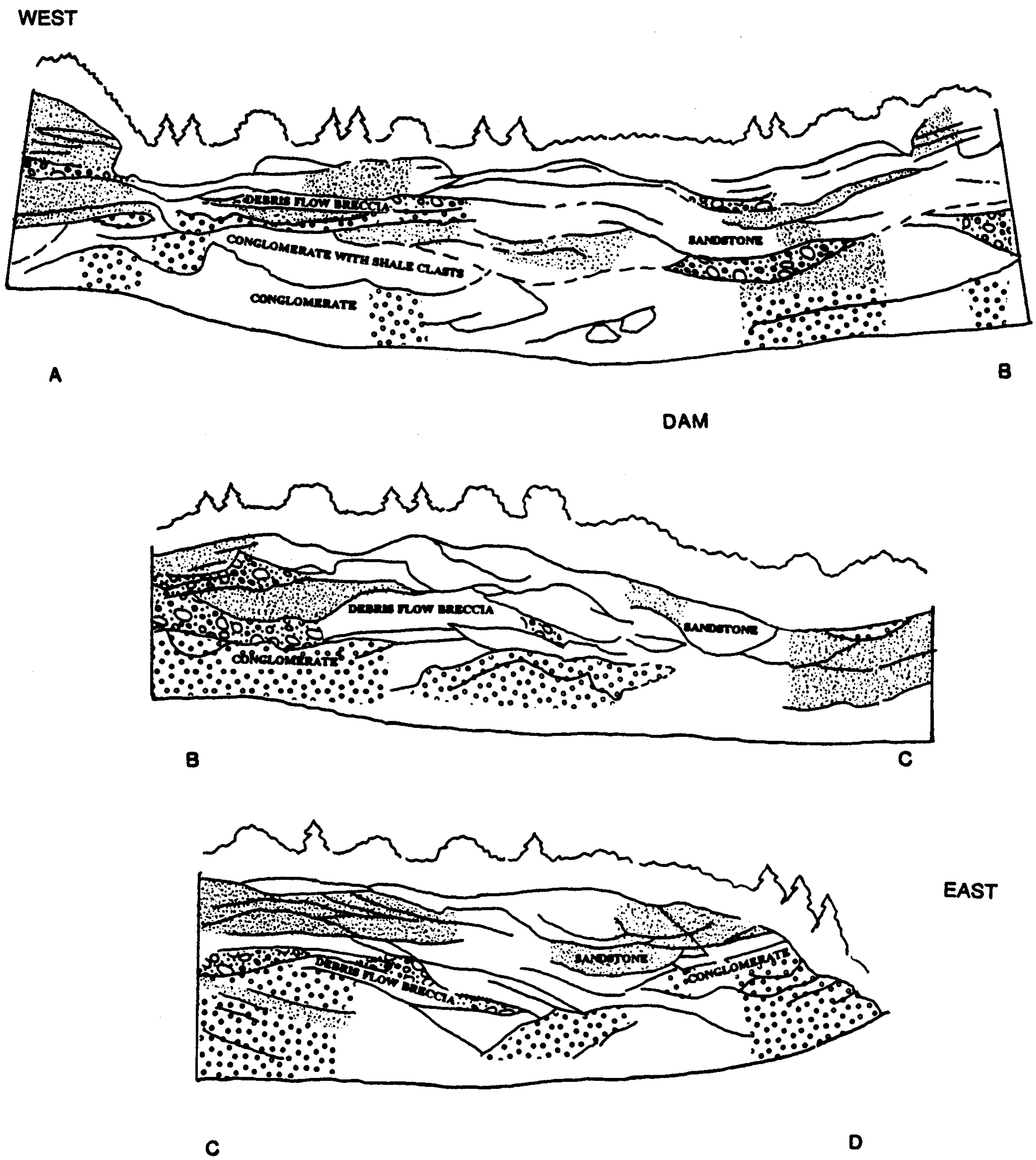


Figure 5. Road cut along U.S. Highway 129, Little Tennessee River Valley, at the Chilhowee Dam, exposing channelized beds of quartz and polymictic conglomerate, sandstone, and siliciclastic debris-flow breccia. After a strip photograph. The height of the exposure is approximately 12 meters.

cisphaeres in the same carbonate rocks of the Walden Creek Group.

The calcarenite limestone, examined in 29 thin sections, is composed mainly of ooids and foraminiferal fragments. The ooids are circular or ovoid in shape with diameters ranging from 0.29 to 0.69 mm. Their concentric internal structure include one to ten calcitic envelopes. The thickness of the envelopes is not constant and thins over irregularities of the nuclei. The nucleus is often composed of foraminiferal fragments. Both coated and non-coated foraminifers show abrasion effects, and identification can be done only at the genus level. The following genera were recognized:

Paratikhinella (Plate 1, F), (Reytlinger, 1954), with stratigraphic range from Upper Devonian – Fransnian to Lower Carboniferous – Avonian (Loeblich and Tappan, 1988)

Koskinotextularia (Plate 1, G), (Eickhoff, 1968), with stratigraphic range from Lower Carboniferous – Visean to

Upper Carboniferous (Loeblich and Tappan, 1988)

Septatournayella (?) (Plate 1, H), (Lipina, 1955) with stratigraphic range from Upper Devonian – Famennian to Lower Carboniferous – Visean, (Loeblich and Tappen, 1988) occurring usually as "ghost" forms.

DISCUSSION

Age Relationships of Carbonate and Siliciclastic Rocks

The carbonate rocks that occur as olistoliths and as clasts in conglomerates and breccias are older than the enclosing siliciclastic sedimentary rocks. The olistoliths, transported by gravity as rigid blocks, resulted from collapse of lithified rocks. The debris-flow breccias contain clasts of lithified limestones, that were eroded some time after their deposition. These breccia form intercalations in thin-to-medium-bedded limestones in the olistoliths. The breccias record a sequence of events as follows: deposition of the limestones, a collapse event forming the clasts, deposition of debris flow breccia, and finally, destruction of the carbonate basin and emplacement of the olistoliths containing the breccias in the siliciclastic sediments of the Walden Creek Group.

The carbonate clasts in the debris-flow breccia beds intercalated in siliciclastic rocks and in the polymict conglomerate were formed by erosion of lithified carbonate rocks. The presence of clasts of carbonate breccia in debris flow breccias and in polymict conglomerate indicates multiple events of breccia sedimentation preceding the erosion events that resulted in the deposition of the breccia and conglomerate beds.

The age of carbonate rocks present as clasts in the breccias and the polymict conglomerates, and the age of rocks in the olistoliths determined on microfossils do not indicate the age of the Walden Creek Group siliciclastic rocks: the carbonates are older.

In contrast, the calcarenites containing ooids and calcareous foraminifers tests consist of biogenic material and chemical sediment that was still unconsolidated at the time of redeposition by turbidity currents. Only this material indicate the true age of sedimentation of the Walden Creek Group.

Model for the Carbonate Sedimentary Basin

The relations of the carbonate and siliciclastic rocks indicate the existence of a pre-Walden Creek carbonate-dominated sedimentary basin. The carbonate rocks deposited in this basin, exposed in outcrops in the Little Tennessee River Valley, are grouped in three facies assemblages. The facies assemblages represent two sedimentary environments.

Facies assemblage A includes stromatolite, carbonate breccia encrusted by stromatolite, algal-grapestone limestone, oolitic limestone, and massive sandy limestone. The sandy limestone contains well rounded quartz grains with frosted surfaces of coastal dune and beach sediment affinities. Assemblages A represents sediments of a shallow water, low- to high-energy carbonate platform. Facies assemblage B consists of thin- to medium-bedded black or dark gray sulfidic limestone interbedded with black or gray shales. Facies assemblage C includes carbonate debris flow breccia and slide breccia intercalated in the bedded limestone and shale of facies assemblage B. The facies assemblages B and C represents sediments of the carbonate platform slope to base-of-slope. In facies assemblage C debris-flow breccia formed by failure of the carbonate platform margin and the slide breccias by failure of the carbonate platform slope.

The presence of well rounded quartz grains including blue quartz in the sandy limestones of facies assemblage A indicates either some basement rock exposure near the carbonate basin or reworking of older clastic rocks. The rounding of quartz grains and absence of feldspars suggest subdued topography allowing for weathering of unstable minerals and abrasion of quartz grains. The conditions in the younger siliciclastic basin were completely different: the coarse grain and immature sediments, feldspar-rich and containing poorly rounded quartz, indicate pronounced relief. The great thickness of coarse-grained sediments indicate rapid vertical movements, both uplift of source areas and subsidence of the basin as recognized already by King et al. (1958). All these feature and the presence of the carbonate olistoliths suggest the change from the carbonate – dominated basin to the siliciclastic-dominated basin was the result of block-faulting.

Age of the Carbonate Basin and of the Siliciclastic Basin.

The age determinations of the older, pre-Walden Creek Group carbonate basin and of the younger, siliciclastic Walden Creek Group basin are based on microfossils: foraminifers and calcispheres, and on the general sedimentological and stratigraphic relationships of the carbonate and siliciclastic rocks.

The age of the older, pre-Walden Creek Group carbonate basin is determined on microfossil content within olistoliths and clasts in conglomerates and breccias as Silurian to Late Devonian. The older age limit, indicated by the assemblage of agglutinated foraminifers in shale from a shale-limestone olistolith in the Citico Creek Valley (Unrug and Unrug, 1990) is maximum age possible: all but one of the species in the foraminiferal assemblage appeared first in the Silurian. The younger age limit, determined on calcareous foraminifers and calcispheres found in clasts of carbonate breccias in olistoliths in the Little Tennessee River Valley, is Late Devonian – Frasnian.

The siliciclastic basin of the Walden Creek Group is younger than the carbonate basin, as indicated by sedimentological relationships. The age of the Walden Creek Group basin is determined on the foraminiferal assemblage in the calcarenite limestone beds that are intercalated in the siliciclastic rocks of the Walden Creek Group. The presence of *Paratikhinella* and *Koskinotextularia* indicates an Late Devonian – Famennian to earliest Carboniferous (earliest Mississippian) age for the calcarenite beds that are interpreted as an integral part of the Walden Creek Group sedimentary megasequence.

The ooids and foraminifers of the calcarenite beds are redeposited from shallow water to deep water environment by turbidity currents. They accumulated originally on small shelf ledges along the coastline of the basin. The volume of the calcarenite beds in minuscule compared to the total volume of the Walden Creek sediments, yet these beds provide key evidence of the age of the Walden Creek Group.

REGIONAL CONSEQUENCES

Nature of the Walden Creek Sedimentary Basin

The new data presented above make necessary a are interpretation of the sedimentary basin of the Walden Creek Group. Rast and Kohles (1986) were first to recognize that the sedimentary history of the Ocoee Supergroup can not be explained in one sedimentary basin. Earlier, Hanselman (1972) and Hanselman et al. (1974) correctly recognized the shallow water character of some of the carbonate rocks present in the Walden Creek Group. However, their interpretation of the sedimentary environment of the entire Ocoee Supergroup as shallow marine to continental can not be sustained. The Ocoee Supergroup was deposited in a marine sedimentary basin, and facies characteristics of the Walden Creek Group are indicative of a base-of-slope sedimentary environment (Stanley and Unrug, 1972; Naylor and Follo, 1988). The model of an older, and carbonate-dominated basin, block-faulted and shedding clasts and olistoliths to a younger, siliciclastic turbidite-dominated basin explains the occurrence of shallow-water carbonate rocks in deep-water turbidites of the Walden Creek Group.

Regional Position of the Walden Creek Group

The newly determined Famennian – earliest Mississippian age relates the Walden Creek Group firmly to the Acadian orogeny. The complex shape of the North American plate margin (Thomas, 1977) accounts for local transtension and basin formation during the generally transpressive oblique convergence during the Early Devonian – Early Mississippian (Ferril and Thomas, 1988).

Tull and Groszos (1990) defined the Blue Ridge post-Taconic successor basins containing trubidite-dominated sequences. They considered the Walden Creek Group to represent the fill of one of the successor basins, and speculated it rests uncoformably on the Great Smoky Group.

Costello and Hatcher (1986) described the conformable contact of the Great Smoky Group and the Walden Creek Group in the Ocoee River gorge. A visit to the site leaves no doubt as to the validity of this observation. Consequently, the Walden Creek Group and the Great Smoky Group, and possibly the entire Ocoee Supergroup are likely to be Early Palezoic, rather than Late Proterozoic in age, and to represent the ill of a post-Taconic successor basin.

The Walden Creek Group previously thought to be correlative with the Lay Dam Formation, (Unrug and Unrug, 1990), appears now to be younger than the Lay Dam, which is overlain by the Butting Ram sandstone and Jemison chert containing Early Devonian shallow marine fossils (Butts, 1926; Tull et al., 1988). We speculate that perhaps the Great Smoky Group is correlative with the Lay Dam Formation.

We concur with Tull and Groszos (1990) that regional metamorphism affecting the Blue Ridge successor basins can not be associated with the Middle Ordovician Taconic orogeny as proposed by several authors (Bulter, 1972; Hatcher, 1972, 1978; Dallmayer 1979; Kish, 1989; Glover at al. 1983; Rast and Kohles, 1986; Drake et al., (1989). The metamorphism affecting the Walden Creek Group, and by extension, the other successor basins as well, is post-earliest Mississippian. The effects of the Taconic and Acadcian orogeny of the Western Blue Ridge of the Southern Appalachians need to be reassessed. In addition, the terranes of the Blue Ridge province need to be reevaluated, the terrane analysis taking into consideration sedimentologic, petrographic and stratigraphic data obtained from sedimentary rocks. The age of the Walden Creek Group is one of the key elements in the development of a better understanding of the evolution of the Blue Ridge Tectonic Province.

ACKNOWLEDGEMENTS

We thank J.O. Costello, R.G. Hatcher, Jr., R.B. Neuman and J.F. Tull for stimulating discussions in the field. Supported by NSF grant EAR 9017253 to R. Unrug, S.L. Palmes acknowledges the Geological Society of America grant-in-aid of graduate research No, 4763-91.

REFERENCES

Antropov, I.A., 1959, Foraminifera from the Devonian of Tatar: Isvestiya Kazanskogo Filiala, Akademiya Nauk SSSR, seriya Geologicheskikh Nauk, v. 7, p. 11-34 [in Russia].

Brenckle, P.L., 1973, Smaller Mississippian and Lower Pennsylvanian calcareous foraminifers from Nevada: Cushman Fundation for Foraminiferal Research. Special Publication no. 11, 82 p.

Butler, J.R., 1972, Age of Paleozoic regional metamorphism in the Carolinas, Georgia and Tennessee, southern Appalachians: American Journal of Science, v. 272, p. 319-333.

Butts, C. 1926, The Paleozoic rocks, in Adams, G.I., Butts, C. Stephenson, L.W., and Cooke, C.W., Geology of Alabama: Alabama Geological Survey Report 14, p. 40-223

Conil, R., and Lys, M., 1964, Materiaux pour l'etude micropaleontologique du Dinantien de la France (Avesnois). Premiere partie: Algues et Foraminiferes: Memoires de 1'Institut Geologique de 1'Universite de Louvain, v. XXIII, 296 p.

Conil, R., Longerstaey, P. J., and Ramsbottom, W. H. C., 1979, Materiaux pour 1'etude micropaleontologique du Dinantien de Grande-Bretagne: Memoires de 1'Institut Geologique de 1'Universite de Louvain, v. XXX, 187p.

Cook, H. E., and Mullins, H. T., 1983, Basin Margin Environment: in Scholle, P. A., Bebout, D. G., and Moore, C. H., Carbonate Depositional Environments, The American Association of Petroleum Geologists, Memoir 33, P. 539 – 618. Tulsa, Oklahoma.

Costello, J. O., Hatcher, R. D., Jr., 1986, Contact relationships between the Walden Creek Group and Great Smoky Group in Ocoee Gorge, Tennessee: Implication for the regional extent of the Greenbrier fault: Geological Society of America Abstracts with Programs, v. 18, p. 216.

Dallmeyer, R. D., 1979, $^{40}Ar/^{39}Ar$ dating: Principles, techniques, and applications in orogenic terrains, in Jager, R., and Hunziker, J. C., eds., Lectures in isotope geology: Belin, Springer-Verlag, p. 77 – 103.

Derville, H., 1951, Contribution a 1'etude des calcispheres du calcaired de Bachant: Annales de la Societe Geologique du Nord, v. 70, p. 273 – 283.

Dil, N., 1976, Assemblages caracteristiques de foraminiferes du Devonien Superieur et du Dinantien de Turquie (Bassin carbonifere de Zonguldak): Annales de la Societe Geologique de Belgique, v. 99, p. 373 –400.

Drake, A. A., Jr., Sinha, A. K., Laird, J., and Guy, R. E., 1989, The Taconic orogen, in Hatcher, R. D., Jr., Thomas, W. A., and Viele, G. W., eds., The Appalachian – Ouachita Orogen in the United States: Geological Society of America, The Geology of North America, v. F-2, p. 101 – 177. Boulder, Colorado.

Eickhoff, G., 1968, Neue Textularien (Foraminifera) aus dem Waldecker Unterkarbon: Palaontologische Zeitschrift, v. 42, p. 162 – 178, pl. 19-20.

Ferrill, B. A., and Thomas W. A., 1988, Acadian dextral transpression and synorogenic sedimentary successions in the Appalachians: Geology v. 16, p. 604-608.

Glover, L., III, Speer, J. A., Rusell, 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.

Hanselman, D. H., 1972, Depositional environments in the upper Precambrian Ocoee Series of central eastern Tennessee, Ph.D. Dissertation, University of South Carolina, 87p.

Hanselman, D. H., Connolly, J. R., and Horne, J. C., 1974, Carbonate environments in the Wilhite Formation of central eastern Tennessee: Geological Society of America Bulletin, v. 85, p. 45-50.

Hatcher, R. D., Jr., 1972, Developmental model for the southern Appalachians: Geological Society of America Bulletin, v. 83, p. 1735-1760.

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.

Kish, S. A., 1989, Igneous and metamorphic history of the eastern Blue Ridge, southwestern North Carolina: Georgia Geological Society Guidebook, v. 9, p. 41-55.

King, P. B., Hadley, J. B., Neuman, R. B., and Hamilton, W., 1958, Stratigraphy of Ocoee Series, Great Smoky Mountains, Tennessee and North Carolina: Geological Society of America Bulletin, v. 69, p. 947-966.

Lipina, O. A., 1950, Foraminifera of the Upper Devonian of the Russian Platform: Trudy Instituta Geologicheskikh Nauk, Akademiya Nauk SSSR, v. 119 p. 110-133 [in Russian].

Lipina, O. A., 1955, Foraminifera of the Tournaisian Stage and upper part of the Devonian of the Volgo-Ural district and western slope of the central Urals: Trudy Instituta Geologicheskik Nauk, Akademiya Nauk SSSR, v. 163, p. 1-96 [in Russia].

Loeblich, A. R., Jr., and Tappan, H., 1988, Foraminiferal genera and their classification. Van Nostrand Reinhold, New York, 970 p., 847 plates.

Moreman, W. L., 1930, Arenaceous Foraminifera from Ordovician and Silurian limestones of Oklahoma: Journal of Paleontology, v. 4, p. 42-59, p. 5-7.

Naylor, C. R., Jr., and Follor, M. F., 1988, Fan delta sedimentation in the Late Precambrian Wilhite Formation of the Great Smoky Mountains, eastern Tennessee: Geological Society of America Abstract with Programs, v. 20, p. A79.

Rast, N., and Kohles, K. M., 1986, The origin of the Ocoee Supergroup: American Journal of Science, v. 286 p. 593-616.

Reytlinger, E. A., 1954, Devonian Foraminifera of some sections in the eastern part of the Russian Platform: Trudy VNIGNI, Paleontologicheskii Sbornik, v. 1, p. 52-81 [in Russia].

Reytlinger, E. A., 1957, Spheres in the Devonian strata of the Russian Platform: Doklady Akademii Nauk SSSR, v. 115, p. 774-776 [in Russia].

Rich, M., 1965, "Calcisphaeres" from the Duperow Formation (Upper Devonian) in western North Dakota: Journal of Paleontology, v. 39, p. 143-145.

Robertson, A., 1987, The transition from a passive margin to an Upper Cretaceous foreland basin related to ophiolite emplacement in the Oman Mountains: Geological Society of America Bulletin, v. 99, p. 633-653.

Stanley, D. J., and Unrug, R., 1972, Submarine channel deposits, fluxoturbidites and other indicators of slope and base of slope environments in modern and ancient marine basins, in Rigby, J. K., and Hamblin, W. K., eds., Recognition of ancient sedimentary environments: Society of Economic Paleontologists and Mineralogists Special Publication 16, p. 287-340.

Stanton, R. J., Jr., 1963, Upper Devonian calcispheres from Redwater and South Sturgeon Lake Reefs, Alberta, Canada: Bulletin Canadian Petroleum Geology, v. 11, p. 410-418, pl. 1.

Stanton, R.J., Jr., 1967, Radiosphaerid calcispheres in North America and remarks on calcisphere classification: Micropaleontology, v. 13, p. 465-472.

Tappan, H., and Loeblich, A. R., Jr., 1988, Foraminiferal evolution, diversification and extinction: Journal of Paleontology, v. 65, p. 695-714.

Thomas, W. A., 1977, Evolution of Appalachian – Ouachita salients and recesses from reentrants and promontories in the continental margin: American Journal of Science, v. 277, p. 1233-1278.

Toomey, D. F., Mountjoy, E. W., and MacKenzie, W. S., 1970, Upper Devonian (Frasnian) algae and foraminifera from the Ancient Wall carbonate complex, Jasper National Park, Alberta, Canada: Canadian Journal of Earth Sciences, v. 7, p.

946-981.
Toomey, D. F., and Mamet, B. L., 1979, Devonian Progozoa, in M. R. House, C. T. Scrutton, and M. G. Basset (eds)., The Devonian System. Special Paper in Paleontology, no. 23, p. 189-232.
Tull, J. F., Harris, A. G., Repetzki, J. E., McKinney, F. K., Garrett, C. B., and Bearce, D. N., 1988, New paleotologic evidence constraining the age and paleotectonic setting of the Talladega belt, southern Appalachians: Geological Society of America Bulletin, v. 100, p. 1291-1299.
Tull, J. F., and Groszos, M. S., 1990, Nested Paleozoic "successor" basins in the southern Appalachian Blue Ridge: Geology, v. 18, p. 1046-1049.
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.
Wray, J. L., 1977, Calcareous algae. Elservier, Amsterdam, 185 p.

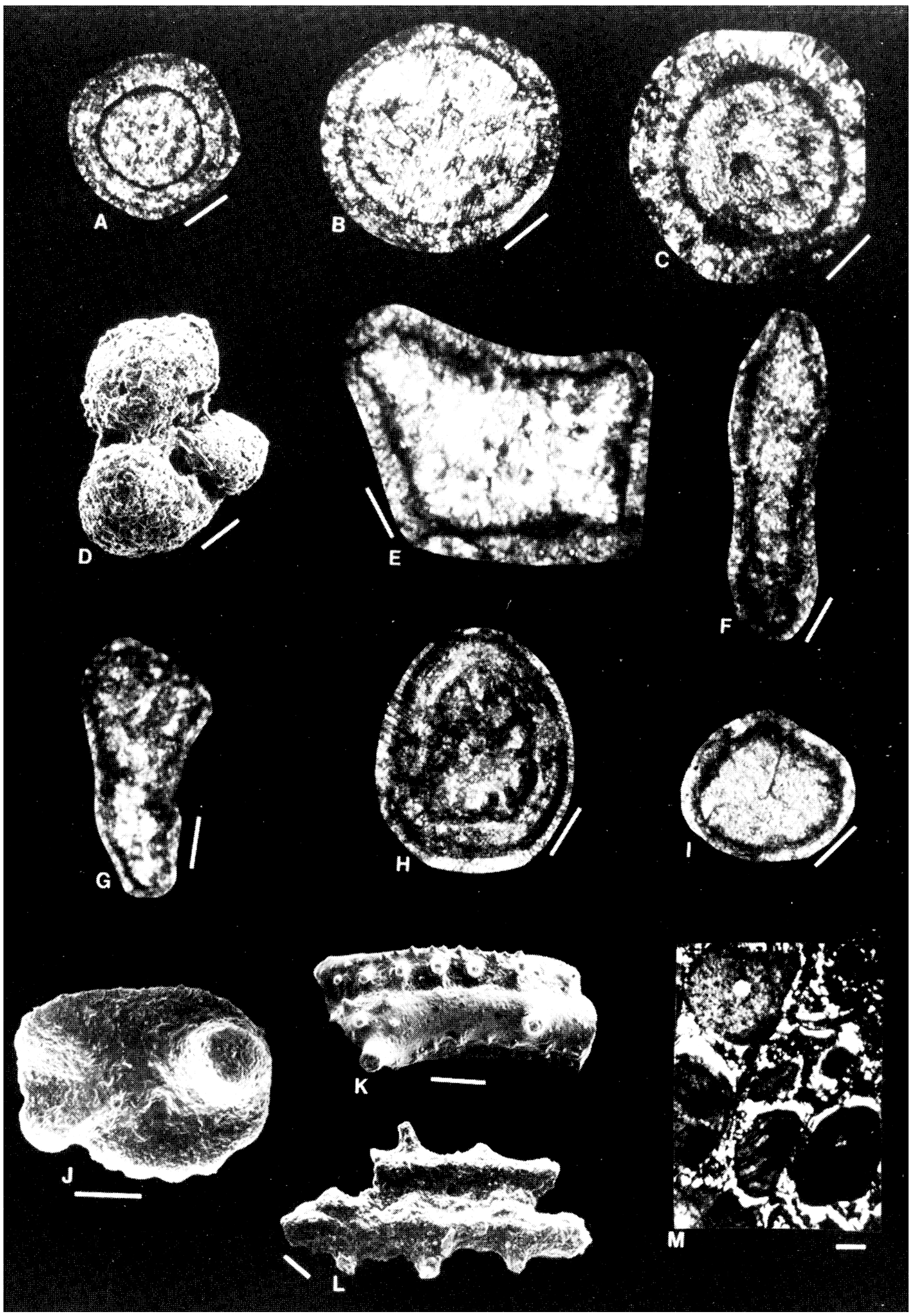


Plate 1. Fossils and microfossils from the Walden Creek Group rocks exposed in the Little Tennessee River Valley.
A-1 white bars represent 100 um. J-M white bars represent 250 um. D, J, K, L are scanning electron microscope photomicrographs. All others are optical photomicrographs. All others are optical photomicrographs of this sections.
A – Double-walled calcisphere.
B – Calcisphere.
C – Radiosphaerid calcisphere with tightly packed calcitic prisms with pyramidal terminations.
All from limestone clasts from debris-flow breccia boulder in olistolith outcrop on the Foothills Parkway.
D – agglutinated foraminifer *Sorosphaera tricella* Moreman.
E – calcareous foraminifer *Uslonia permira* Antropov.
I – calcareous foraminifer *Cribrosphaeroides* (*Cribrosphaeroides*) *simplex* (Reytlinger).
All from limestone clasts in carbonate debris-flow breccia bed on US highway 129.
F – calcareous foraminifer of the *Parathikinella* genus.
G – calcareous foraminifer of the *Koskinotextularia* genus.
H – ooid with test of calcareous foraminifer of the *Septotournayella* (?) genus as nucleus.
All from calcarenite beds exposed on US Highway 129. All show abrasion effects.
J – Ostracode valve fragment (*Paleocopida*?).
K – Trilobite fragment – cephalic (?) margin.
L – Bryozoan zoaria (*Cryptostomata*). All from shale on Foothills Parkway.
M – microcrinoid plates in thin section of a limestone clast in polymict conglomerate from the road cut on US Highway 129 at the Chilhowee Dam.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 35-40

TECTONIC AND STRATIGRAPHIC IMPLICATIONS OF MID-PALEOZOIC (?) FOSSILS FROM THE LATE PROTEROZOIC (?) WALDEN CREEK GROUP ROCKS IN THE FOOTHILLS BELT, EASTERN TENNESSEE

T.W. Broadhead[1], R.D. Hatcher, Jr.[2], and J.O. Costello[3]

[1]*Department of Geological Sciences, University of Tennessee, Knoxville, Tennessee 37996-1410*

[2]*Department of Geological Sciences, University of Tennessee, Knoxville, Tennessee 37996-1410, and Environmental Sciences Division, MS 6352, Oak Ridge National Laboratory *, P.O. Box 2008, Oak Ridge, Tennessee 37831*

[3]*Altanta Testing and Engineering, 11420 Johns Creek Parkway, Duluth, Georgia 30136*

ABSTRACT

Once comfortably held views of a Late Proterozoic age for the succession of sedimentary rocks composing the Ocoee Supergroup in the foothills belt of the western Blue Ridge and eastern Valley and Ridge have been challenged by Unrug and Unrug in their report of Paleozoic skeletal fossils from the Walden Creek Group. Lack, to date, of independent confirmation of the discovery, in addition to a lack of detailed taxonomic treatment of these fossils, have led to a continued disagreement concerning stratigraphic relationships within the Walden Creek Group and the implications of this discovery for the interpretation of evidence for timing of deformation and metamorphism. While the interpretation of the geometry of structures in the western Blue Ridge remains unchanged, the timing of the deformation and metamorphic events should all be Alleghanian in this region. The confirmed presence of a middle Paleozoic fauna would also contradict the interpretation of the Sandsuck Formation as the uppermost unit of the Walden Creek Group, but our appraisal of its biostratigraphic potential argues for a possible age as early as Middle Ordovician. Our rediscovery of large, C-shaped soft-bodied metazoan fossils in the Sandsuck Formation in sequence with fossiliferous Chilhowee Group rocks suggests that the Sandsuck is no younger than Early Cambrian, and may still be Late Proterozoic.

Search for fossils in metamorphic rocks needs a great amount of time and optimism, but the rewards are worthwhile.

.......A bad fossil is more valuable than a good working hypothesis.

R. Trumpy, 1971

INTRODUCTION

Fossil discoveries in structurally complex terranes have great potential for placing temporal limits on pretectonic geological histories, especially in those areas considered previously to be unfossiliferous. The mere presence of fossilized organic remains, however, does not guarantee an unambiguous solution to questions of geologic age. Fossils have been reported in the crystalline southern Appalachians several times during this century, and each time have been suggested to be Paleozoic remains. McCallie (1907, p.34) may have been the first, reporting an occurrence of organic remains from the Murphy Marble near Ellijay, Georgia, and indicated they were gastropods. McLaughlin and Hatheway (1973) reported the occurrence of gastropods form the Murphy Marble in the Hewitt Quarry in North Carolina. This led Wiener (1976) to speculate about a possible Paleozoic age of the Great Smoky Group and Murphy belt rocks. Although the Murphy belt gastropods were later reinterpreted as part of a Cenozoic cave filling (Chapman and Klatt, 1983), several geologists (e.g., Tull and Groszos, 1990) recently have concluded from stratigraphic data that the Murphy Marble is Paleozoic and that the upper part of the Murphy sequence unconformably overlies the lower part. The report by Unrug and Unrug (1990) of Paleozoic microfossils in the Walden Creek Group has generated renewed interest in western Blue Ridge geology (Fig, 1). The implications of their discovery reflect not only on the stratigraphy and age of the rocks, but alto on the timing of deformation and metamorphism in the western Blue Ridge.

The exposed Upper Proterozoic-Lower Cambrian sedimentary succession in the southern Appalachians consists predominantly of siliciclastic rocks of the Ocoee Supergroup and overlying Chilhowee Group. Previously known body fossils are limited to occurrences in argillaceous units of the middle to upper part of the Chilhowee and include a post-Adtabanian Lower Cambrian assemblage containing olenellid trilobites, obolellid brachiopods, hylolithids, the crustacean *Isoxys chilhoweana* (Walcott, 1890) and the ostracode *Indiana tennesseensis* (Laurence and Plamer, 1963). Earliest Cambrian (Tommotian-Adtabanian age) fossils predate trilobites and, although well known from Siberia, China, Morocco, Newfoundland, and other areas, are as yet unknown from the southern Appalachians. Our (Broadhead and others, Optional Field Trip Stop, this volume) rediscovery and study of softbodied metazoan macrofossils originally found by Phillips (1952) in the Sandsuck Formation (Late Proterozoic?) now marks one of the oldest known occurrences of body fossils in the southern Appalachians (see also Cloud et al., 1976). Although these fossils lack any obvious biostratigraphic utility, they occur in the Sandsuck Formation in stratigraphic continuity with the overlying Lower Cambrian Chilhowee Group. Furthermore, trace fossil assemblages, which occur throughout the marine facies of the Chilhowee (Walker and Driese, 1991), lack diagnostic taxa of the earliest Cambrian (sensu Crimes, 1987) that would permit a confident precise recognition of the Precambrian-Cambrian boundary. Thus our rediscovery of the Phillips (1952) locality and new collection there confirms that the Sandsuck is no younger than Early Cambrian and may be Late Proterozoic, as originally suggested by Kine et al. (1958). The methodology with the greatest potential for precise correlation of the base of the Cambrian appears to be quantitative analysis of residual $8^{13}C$ (A.H. Knoll, pers. Comm., 1991), which has proven to be useful in correlating other Prcambrian-Cambrian boundary sections (Kirschvink et al., 1991; Magaritz et al., 1991).

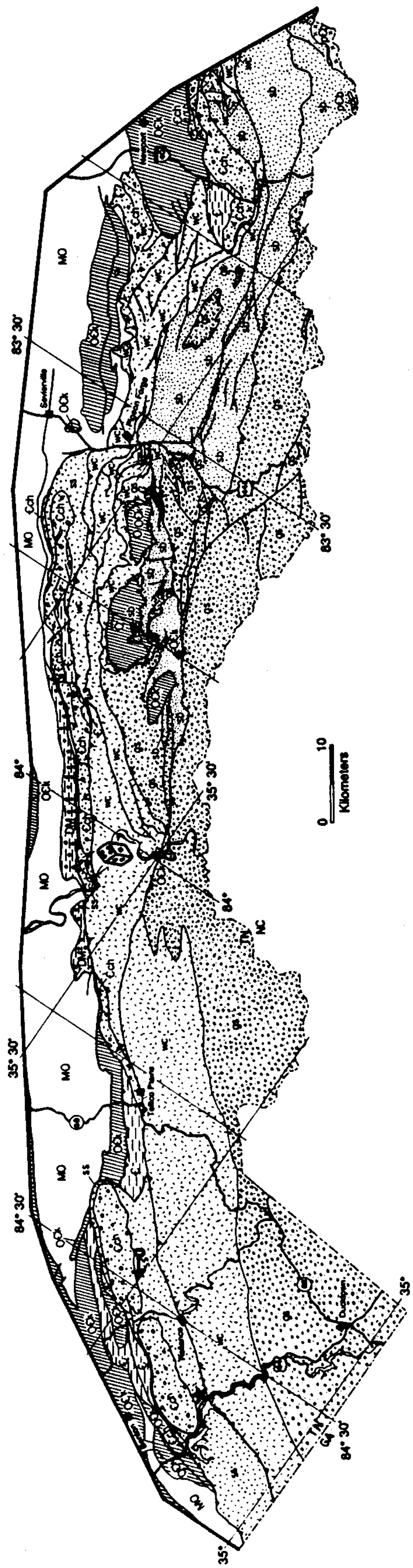
STRATIGRAPHY AND AGE RELATIONSHIPS

The western Blue Ridge in southeastern Tennessee and western North Carolina contains a dominantly clastic succession of deep-to shallow-water sedimentary rocks, the Ocoee Supergroup (Safford, 1856; Stose and Stose, 1944) that King et al. (1958) subdivided into three units: the Snowbird (shallow water), Great Smoky (deep water), and Walden Creek (deep to shallow water) Groups (Fig. 1). King et al. (1958) concluded that the Ocoee is a Late Proterozoic succession because: (1) these units are interrelated by sequence or facies; (2) originally they yielded no fossils; (3) at least one unit (the Snowbird Group) rests nonconformably on Grenville basement; and (4) at least part of the Walden Creek Group underlies the Lower Cambrian Chilhowee Group. They placed the Cambrian Precambrian boundary at the base of the Chilhowee Group, the oldest major unit containing Cambrian fossils. Hadley (1970) subsequently examined the possible correlatives of the Ocoee with other western Blue Ridge successions in North Carolina, northern Georgia, and eastern Tennessee, but also concluded that these, including the rocks of the Murphy belt, comprise a Late Proterozoic to Cambrian succession. Tull and Groszos (1990) from their work in the Murphy belt have inferred that a regional unconformity exists between the Mineral Bluff Formation, and the underlying rocks of the Murphy belt sequence, suggesting a later Paleozoic, successor basin-fill origin for the Mineral Bluff. They have applied a similar interpretation to part of the Walden Creek Group (based on the report of Unrug and Unrug, 1990) and to more quickly documented (Tull et al., 1988) fossiliferous strata of the Talladega belt.

nrug and Unrug (1990) disputed lithologic correlations of strata in the upper part of the Walden Creek Group, particularly between the Wilhite and Sandsuck Formations. Unrug and Unrug (1990, p. 1041) correctly emphasized that lithologic correlations, and hence usage of formations, correct application of lithostratigraphic unit names can only be done unambiguously at the stratotype sections. The stratotype for the Walden Creek Group occurs in the drainage of Walden Creek (King et al., 1958), located in the Miller Cove and Happy Hollow fault blocks. The stratotype for the Sandsuck Formation, the upper-most unit of the Walden Creek, is located in the Chilhowee Mountain block along Sandsuck Creek, a tributary of Walden Creek. In contrast, the stratotype for the Wilhite Formation is farther to the northeast in the Miller Cove block (see Hatcher et al., 1989), for explanation of revised fault terminology for these frontal thrust blocks). Although stratigraphic contact of the Sandsuck with the overlying Chilhowee Group makes its age somewhat less ambiguous, the report of middle Paleozoic fossils from rocks of the Wilhite Formation (Unrug and Unrug, 1990) would appear to negate any stratigraphic relationship between the Sandsuck and lower parts of the Walden Creek Group.

Any attempt to revise this stratigraphy, however, should take into account the fact that Hamilton (1961) mapped Sandsuck Formation in stratigraphic continuity with Dixon Mountain Member of the Wilhite Formation (Walden Creek Group) in the Richardson Cove and Jones Cove quadrangles. The Sandsuck is in turn overlain by Chilhowee Group rocks nearby in the English Mountain block, as well as to the southwest in the Chilhowee Mountain block. Either the strata mapped as Sandsuck in contintinuity with the Wilhite are not Sandsuck, or that in the Chilhowee Mountain block is not the same, or there is a problem with the Unrug and Unrug (1990) conclusions.

Hanselman et al. (1974) suggested that the Walden Creek Group rocks were deposited in a shelf-edge environment, with these rocks being the “most marine” of all the Ocoee Supergroup rocks. They interpreted the carbonates of the Walden Creek Group to have been deposited in subtidal to intertidal environments, based on study of the carbonate rocks and associated clastic facies along U. S. Highway 129 in southeastern Tennessee. Keller (1980) concluded from these rocks in central eastern Tennessee that most carbonate allochems and mud were transported from shallow, shelf or bank edge facies into deeper water. Unrug and Unrug (1990) suggested that most of the carbonate rocks in the Walden Creek Group occur as olistostromal blocks ranging up to several kilometers in lateral extent. Rast and Kohles (1986) have suggested that large parts of the Walden Creek and Talladega Groups, and Murphy belt rocks, contain olistostromal deposits. Whereas blocks (up to 2 m) of carbonate and other lithologies occur locally as block-in- matrix bodies in the Wilhite Formation further attesting to the stratigraphic similarity, careful mapping of the larger carbonate bodies in the Walden Creek Group by Hamilton (1961), King (1964), Neuman and Nelson (1965), Hanselman et al. (1974), and Wiener (unpublished data) reveals that most are tabular bodies that are integral – normally interlayered – parts of the predominantly siliciclastic sequence. Several blocks that terminate abruptly along strike do so because they are faulted. Other small outcrop-scale bodies of carbonate, such as one on Chilhowee Lake at the western end of the Great Smoky Mountains National Park (see Hatcher, Stop 6 this volume(,



are interlayered with the banded Wilhite Formation shale and are clearly part of the stratigraphic sequence. At that exposure, the carbonate pinches laterally, yet there is no doubt that it is a tabular body that increases in thickness from zero to about 1 meter within the exposure.

Distinctions between Cambrian and Proterozoic sedimentary rocks of the southern Appalachians relied in the past principally on the first occurrence of trilobites (Walcott, 1890, 1911).

Stratigraphic correlation, which relies on lithostratigraphy within parts of this interval, remains uncertain owing to diversity of contrasting depositional patterns and to structural complexities that obscure original sedimentary facies relationships. Knoll and Keller (1979) suggested a late Precambrian age for the Walden Creek Group based on the presence of aritarchs, particularly *Bavlinella faveolata* (Shepleva). This species now is known to range into the Cambrian (Knoll and Swett, 1985). A.H. Knoll (1991, personal commun.) believes it possible that *B. faveolata* may yet be shown to range higher, but notes that favorable taphofacies have not been observed in younger rocks. Nonetheless, the claim attributed to Knoll (Unrug and Unrug, 1990, p. 1042) that *B, faveolata* "is now believed likely to extend later into the paleozoic …" is somewhat overstated. Walker and Driese (1991) attempted to use ichnofossil biostratigraphic criteria proposed by Crimes (1987) to clarify Cambrian-Precambrian boundary relationships in Tennessee and Virginia. Their application of trace fossil data to interpreting the age of the base of the Chilhowee Group, however, is inconsistent with the model of Crimes (1987). For example, their (Figure 6) placement of the upper boundary of the Type I assemblages does not seem necessarily warranted nor is the assignment of the Nichols Shale and lower Nebo Sandstone to a Type II assemblage because elements of the Type II assemblage have not been observed in those rocks. That problem, plus the acknowledged unfavorable facies for the existence of tracemaking metazoans in the lower Chilhowee (contrasting with the Walker and Driese [1991, p. 278] statement that, "Such facies are not conducive to the recovery of

FIGURE 1. Simplified geologic map of the Blue Ridge and adjacent parts of the Valley and Ridge showing the major tectonic units and location of the rediscovered fossil locality in the Sandsuck Formation (modified from Hardeman, 1966). – Fossil locality. Star – carbonate in Sandsuck Formation in the Chilhowee mountain block exposed on Parksville Reservoir. – Approximate location of the Unrug and Unrug (1990) samples. Solid – teeth line- Great Smoky fault. Open-teeth line – Miller Cove and related faults. Double solid –teeth line- Greenbrier fault (Including the Dunn Creek). gs – Great Smoky Group. sb – Snowbird Group. wc – Walden Creek Group. ss – Sandsuck Formation. Cch – Chilhowee Group. C – Cambrian (predominantly Shady Dolomite and Rome Formation). OCk – Knox Group. O – Ordovician rocks (Ordovician Knox Group and lower Middle Ordovician rocks). MO – Middle Ordovician. DM – Devonian and Mississippian.

either trace or body fossils"), makes precise age assignments difficult.

The report by Unrug and Unrug (1990) of small skeletal fossils from rocks mapped as Wilhite Formation (Walden Creek Group) suggested a middle Paleozoic age for that unit based upon taxa of arenaceous foraminifera. The strongest, if somewhat equivocal, evidence for geologic age comes from calcareous fossils reported from shale beds. The generally small size ("up to a few millimetres long", p. 1043) is notable, particularly since many are fragments of larger organisms (crinoids, bryozoans, trilobites), and suggests the possibility that, sedimentologically, these beds may be distal parts of grain flows or distal tempestites. The Middle Ordovician or younger age of this assemblage is best indicated by the bryozoans (Ordovician-Recent), and dissepiment-bearing fenestrates (their Fig. 3D, E) that are first reported from the Middle Ordovician. The name *Fenestella elegans* Hall, however, is usually applied collectively to fenestrate zoarial fragments, and the subtriangular outline of sectioned zooecia (their Fig. 3E) indicates an assignment to a fenestrate genus other than *Fenestella s.s.* (F.K. McKinney, 1990, pers. Comm.). Similarly, crinoids with well-organized meric (their Fig. 3D) or holomeric stems (their Fig. 3C) are not known before the Ordovician. How much younger may be difficult to establish, owing to the difficulty of species level identification. The Unrug and Unrug (1990) "microcrinoid" (their Fig. 3A) is poorly oriented for identification, but bears at least a superficial similarity to the "kalimorphocrinid" ontogenetic stage of some disparid crinoids, the earliest reported example of this juvenile form being the recent discovery by Clement (1989) (Early Devonian, west-central Tennessee). The pentameric columnal (their Fig. 3B) is most common among Ordovician crinoids, but existed throughout the Paleozoic, characterizing only about six general younger than Silurian (Moore and Teichert, 1978). Trilobites are almost too fragmentary to speculate about, but the "ornamented spine" (their Fig. 3J) generally resembles those of small Middle Ordovician forms already known from the southern Appalachians (e.g., the ptychopariid *Glaphurus,* the odontoplurid *Ceratocephala).* The other trilobite fragments could easily belong to these or to cheirurine phacopids, which are common in the Ordovician and Silurian. Collectively, the observations and interpretations described above present difficulties in stratigraphic nomenclature, in addition to the more obvious problems of correlation and geologic history.

Several important questions remain concerning Paleozoic fossils reported by Unrug and Unrug (1990) from the Walden Creek Group. Among these are the apparent unfossiliferous nature of the carbonate units, which have now been interpreted (Unrug and Unrug, 1990; Tull and Grozos, 1990) as carbonate platform margin blocks transported downslope as "olistoliths". By middle Paleozoic time, marine biotas were sufficiently abundant and evolved that the remains of shelly biotas would be conspicuous and diverse in rocks of this facies. Similarly enigmatic is the absence of conodonts, which, although not ubiquitous, are common microfossils in Silurian and Devonian carbonate rocks of a wide variety of facies. Similarly enigmatic is the absence of conodonts, which, although not ubiquitous, are common microfossils in Silurian and Devonian carbonate rocks of a wide variety of facies developments. Finally, the report of Unrug and Unrug (1990) awaits both independent confirmation and a more careful taxonomic treatment of the fossils in order to determine their precise biostratigraphic significance as elements of a biota that could be as old as Middle Ordovician.

TECTONIC SETTING

Structural blocks, underlain by the Great Smoky fault, form a series of monoclinal, synclinal, and anticlinal structures at the Blue Ridge front from south western Virginia to northern Georgia. The significance of this frontal series of blocks is that they contain the Chilhowee Group succession and its presumed equivalents. Also, except for the shales (commonly uncleaved to weakly cleaved), few of these rocks are penetratively deformed or metamorphosed, and these relatively undeformed rocks are separated from the cleaved and greenschist facies-metamorphosed rocks of the Walden Creek Group by the Miller Cove fault (and equivalents). From just south of the Tennessee line in Georgia southwestward, the Great Smoky fault is eroded, except for small synclinal outliers and complex antiformal stack duplexes like those near Cartersville, Georgia. Thus the Miller Cove (Alaculsey Valley) fault and equivalents (Cartersville fault, Talladega fault) – not parts of the Great Smoky fault system – form the frontal fault of the Blue Ridge equivalent in most of Georgia and Alabama (Costello, 1984; Hatcher et al., 1989).

The internal structure of blocks underlain by the Great Smoky fault is relatively simply compared to the complicated structure of the zone immediately to the southeast. The Great Smoky fault system actually has more characteristics of Valley and Ridge faults than faults within the Blue Ridge. The Great Smoky fault, with its correlatives, is a true thin-skinned fault complex (probably the first Valley and Ridge fault system), whereas the Miller Cove-Cartersville fault system immediately southeast is a true basement fault system, because it propagated through and transported rocks already cleaved and metamorphosed by at least one earlier orogenic cycle (Hatcher et al., 1989).

In contrast to rocks of the frontal Chilhowee Mountain block (Great Smoky fault system), rocks southeast of the Miller Cove fault are clearly more deformed by earlier events and these older structures are truncated by Alleghanian faults. Despite this, for at least 3 to 5 km southeast of the Miller Cove fault, penetrative deformation and metamorphism have affected the pelitic rocks more than the carbonate and psammitic rocks in the Walden Creek Group. Aside from minor pressure solution, slight reorientation of pebbles, and locally cleaved zones (e.g., in the hinges of tight folds), neither outcrop scale exposures nor thin sections of thick bedded conglomerate and carbonate rocks reveal much of the penetrative deformation that is characteristic of the finer grained rocks. Recrystallization has produced fine grained micas and chlorite, but most detrital biotite and muscovite grains survive, and quartz microstructures consists primarily of subgrains, deformation lamellae, and other indicators of only incipient or localized effects of penetrative deformation and metamorphism. Manifestations of deformation and metamorphism increase rapidly toward the southeast as the biotite isograd is reached. Even at this metamorphic grade, delicate primary sedimentary structures survive, particularly in the coarser-grained rocks, commonly preserve delicate flame structures, laminae, and other features characteristic of fine grained sediments.

The report by Unrug and Unrug (1990) does not require reinterpretation of the geometry or kinematics of emplacement of any of the structures in the western Blue Ridge. Its importance is the implication for the interpretation of the age of the fossils for the timing of deformation and metamorphism in this area. If the Unrug and Unrug (1990) fossils are mid-Paleozoic as they have said- most of the radiometric age dates in the western Blue Ridge previously interpreted as Taconian must be abandoned as incorrect. All of the Paleozoic deformation and metamorphism must be Alleghanian, with only a remote possibility that some of the earliest deformation (e.g., the Hayesville, Greenbrier, and Dunn Creek faults)might be Acadian. Unrug and Unrug (1991) discussed the implications of their discovery and stated that all of the deformation and metamorphism in the Blue Ridge must be Alleghanian, along with the large premetamorphic faults, including the Hayesville. Tull and Groszos (1990, p. 1049) also recognized these implications, and suggested that – because they interpret the Mineral Bluff Formation, along with parts of the Talladega and Walden Creek Groups, as successor assemblages and not as parts of the Taconian clastic wedge – there is no evidence in the western Blue Ridge for the Taconian Blountian clastic wedge that is well developed immediately to the west in the Valley and Ridge. While we applaud their recognition of the Middle Ordovician unconformity in the Talladega and Murphy belts (and possibly in the Foothills belt), we disagree and, using the same stratigraphic data, prefer to interpret the clastic assemblage above the unconformity as part of the Middle Ordovician Blountain clastic wedge, and not a younger successor assemblage. Our interpretation is consistent with that of Tull et al. (1988) for theTalladega belt, and the correlation by Tull and Groszos (1990) of the stratigraphic sequences from the Talladega to the Murphy belt.

CONCLUSIONS

1. Discovery of possible middle Paleozoic fossils in rocks traditionally thought to be Late Proterozoic raises questions about correlations of units in the western Blue Ridge, some of which contain Cambrian fossils. The Sandsuck Formation resides in stratigraphic continuity with the Lower Cambrian Chilhowee Group, is now known to contain metazoan fossils, and was thought to be part of the Walden Creek Group. This correlation is impossible if the Walden Creek is middle Paleozoic.
2. Structural geometry of the western Blue Ridge is unchanged by the fossil discovery.
3. All radiometric age dates commonly cited to document Taconian or middle Paleozoic events in the Blue Ridge must be abandoned if the Unrug and Unrug fossil disvoery is reproduced.
4. Interpretation of parts of the Murphy and western Blue Ridge sequences as successor assemblages precludes occurrence of the Middle Ordovician clastic wedge in the western Blue Ridge. We interpret these same sequences in the Murphy belt as Middle Ordovician clastic wedge and correlative with similar sequences in the Talladega belt.

ACKNOWLEDGEMENTS

Support for field work by J.O. Costello in the western Blue Ridge was provided by National Science Foundation grant EAR-8406949 to RDH. Additional support has been provided RDH by the University of Tennessee Science Alliance Center of Excellence Distinguished Scientist stipend. We thank Pete Palmer, Bob Neuman, Leonard Wiener, Carl Merschat, and Dan Walker for their thorough reviews of this manuscript. Jim Tull and Steve Kish made additional comments that were also very helpful. Comments by all encouraged us to rewrite an earlier version into a more respectable scientific paper. Comments and editing of our field trip stops by Leonard Wiener and Carl Merschat were very helpful and are appreciated.

REFERENCES CITED

Chapman, J.J., and Klatt, E.A., 1983, Gastropod shells with the Murphy Marble: Geological Society of America Abstracts with Programs, v. 15, p. 52-53.

Clement, C.R., 1989, Echinoderm faunas of the Decatur Limestone and Ross Formation (Upper Silurian to Lower Devonian) of west-central Tennessee [Ph.D.thesis]: Knoxville, Tennessee, University of Tennessee, Knoxville, 365 p.

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.

Crimes, T.P., 1987, Trace fossils and correlation of late Precambrian and early Cambrian strata: Geological Magazine, v. 124,

p. 97 – 119.

Hadley, J.B., 1970, The Ocoee Series and its possible correlatives, in Fisher, G.W., Pettijohn, F.J., Reed, J.C., Jr., and Weaver, K.N., Studies of Appalachian geology: Central and southern: New York, Wiley-Interscience, p. 127 – 146.

Hamilton, W.B., 1961, Geology of Richardson and Jones Coves quadrangles, Tennessee: U.S. Geological Survey Professional Paper 349-A, 55p.

Hanselman, D.H., Conolly, J.R., and Horne, J.C., 1974, Carbonate environments in the Wilhite Formation of central eastern Tennessee: Geological Society of America Bulletin, v. 85, p. 45 – 50.

Hardeman, W.D., 1966, Geologic map of Tennessee: Tennessee Division of Geology, scale 1:250,000.

Hatcher, R.D., Jr., Thomas, W.A., Geiser, P.A., Snoke, A.W., Mosher, S., and Wiltschko, D.V., 1989, 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.

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., 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.

King, P.B., 1964, Geology of the central Great Smoky Mountains, Tennessee: U.S. Geological Survey Professional Paper 349-C, 148 p.

Kirschvink, J.L., Magaritz, M., Ripperdan, R.L., Zhuravlev, A. Yu., and Rozanov, A. Yr., 1991, The Precambrain/Cambrian boundary: Magnetostratigraphy and carbon isotopes resolve correlation problems between Siberia, Morocco, and South China: GSA Today, v. 1, p. 69 – 71, 87, 91.

Knoll, A.H., and Keller, F.B., 1979, Late Precambrian micro-fossils 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, Micropaleontologh of the Late Proterozoic Veteranen Group, Spitsbergen: Palaeontology, v. 11, p. 185.

Laurence, R.A., and Palmer, A.R., 1963, Age of Murray Shale and Hesse Quartzite on Chilhowee Mountain, Blount County, Tennessee: U.S. Geological Survey Professional Paper 475C, p. C53 – C54.

Magaritz, M., Kirschvink, J.L., Latham, A.J. Zhuravlev, A. Yu., and Rozanov, A. Yu., 1991, Precambrian/Cambrian boundary problem: Carbon isotope correlations for Vendian and Tommotian time between Siberia and Morocco: Geology, v. 19, p. 847 – 850.

McCallie, S.W., 1907, A preliminary report on the marbles of Georgia: Geological Survey of Georgia Bulletin 1, 126 p.

McLaughlin, R.E., and Hatheway, D., 1973, Fossils in the Murphy Marble: Geological Society f America, Abstracts with Programs, v. 5, p. 418 – 419.

Moore, R.C., and Teichert, C., (eds), 1978, Treatise on Invertebrate Paleontology, pt T (Echinodermata 2), Geological Society of America, Boulder.

Neuman, R.B., and Nelson, W.H., 1965, Geology of the western Great Smoky Mountains, Tennessee: U.S. Geological Survey Professional Paper 349-D, 81 p.

Phillips, H.E., 1952, The geology of the Starr Mountain area, southeast Tennessee [M.S. thesis]: Knoxville, University of Tennessee, 61 p.

Rast, N., and Kohles, 1986, The origin of the Ocoee Supergroup: American Journal of Science, v. 286, p. 593 – 616.

Safford, J.M., 1856, A geological reconnaissance of the State of Tennessee: Nashville, 1st Biennial Report of the State Geologist, 164 p.

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.

Trumpy, R., 1971, Stratigraphy in mountain belts: Quarterly Journal of the Geological Society of London, v. 126, p. 293 – 318.

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., Harris, A.G., Repetski, J.E., McKinney, F.K., Garrett, C., and Bearce, D.N., 1988, New paleontologic evidence constraining the age and paleotectonic setting of the Talladega slate belt, southern Appalachians: Geological Society of America Bulletin, v. 100, p. 1291 – 1299.

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., and Unrug, S., 1991, Paleozoic age for the Walden Creek Group, Southern Blue Ridge Province: Exploring the consequences: Geological Society of America, Abstracts with Programs, v. 23, p. 142.

Walcott, C.D., 1890, The fauna of the Lower Cambrian or Olenellus zone: U.S. Geological Survey 10th Annual Report, 1888 – 1889, pt. I, Geology, p. 509 – 763.

Walcot, C.D., 1911, Middle Cambrian holothurians and medusae: Smithsonian Miscellaneous Collections, v. 57, p. 41 – 68.

Walker, 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.

Wiener, L.S., 1976, Great Smoky Group and Murphy belt strata – Paleozoic or Precambrian deposits?: Geological Society of America, Abstracts with Programs, v. 8, p. 299.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 41-53

THE WALDREN CREEK GROUPS: IS IT PART OF THE OCOEE SUPERGROUP?

Dan Walker[1] and Nicholas Rast[2]

[1]*Kentucky Geological Survey, 228 Mining and Mineral Resources Building, University of Kentucky, Lexington, Kentucky 40506 – 0107,*
[2]*Department of Geological Sciences, 211 Bowman Hall, University of Kentucky, Lexington, Kentucky 40506-0059*

ABSTRACT

Recent paleontological data presented by Unrug and Unrug (1990) possibly provide evidence for a Silurian or younger age for the upper part of the Walden Creek Group. Body fossils were obtained from disaggregated shale and argillite interpreted by Unrug and Unrug (1990) as matrix enclosing limestone olistoliths. The body fossils included microcrinoids, fenestrate bryozoans, ostracodes, trilobites, and agglutinated Foraminifera, As these rocks are separated from the Chilhowee Group and underlying Sandsuck Formation in the area of Chilhowee Mountain by the Miller Cove fault, Unrug and Unrug (199) have stated that the shale overlying the Wilhite Formation southeast of English Mountain cannot be correlated with the Sandsuck Formation of the Chilhowee Mountain block, and that this shale, as well as the remainder of the Walden Creek Group which underlies it, is of Silurian or younger age.

Detailed examination of the geology in seven areas within the western Blue Ridge from Chilhowee Lake, Tennessee north of the Hot Springs area of North Carolina and Tennessee, however, shows that the findings of Unrug and Unrug (1990) are incompatible with much of the widely available, detailed geologic mapping. These data suggest that the general stratigraphic succession advanced by Safford (1856) and subsequently refined by King et al. (1958) should be considered valid until additional sampling and independent re-examination of the paleontology verify a post-Cambrian age for the Walden Creek Group.

INTRODUCTION

The outer Blue Ridge of the southern Appalachians is characterized by two major principally siliciclastic units: the Ocoee Supergroup and the Chilhowee Group. Until recently the general consensus had been that the former is upper Proterozoic, while the latter is uppermost Proterozoic to Lower Cambrian (Simpston and Sundberg, 1987; Rast, 1989; Hatcher, 1989; Walker and Driese, 1991). The discovery of a microfaunal assemblage by Unrug and Unrug (1990) from strata interpreted as a portion of the Walden Creek Group (uppermost Ocoee Supergroup; Neuman and Nelson, 1965) has challenged this consensus. The fauna, which Unrug and Unrug (1990)assign to the Silurian, consists of small crinoid ossicles, fragments of bryozoans, ostracods, and possibly trilobites, as well as several agglutinated foraminifers. This fauna at present does not appear to be absolutely diagnostic further than probably lower Paleozoic. Small crinoids are known from the Lower Cambrian onward, as indeed are trilobites. Foraminifera from the Lower Cambrian of West Africa have been reported by Culver et al. (1990). Bryozoans are known from the Ordovician onward (see Broadhead et al., this volume). Further collection and detailed examination of the fauna awaits work by other qualified paleontologists and is beyond the scope of this paper. The question is addressed here because of the close association of the Ocoee Supergroup with the Chilhowee Group, since the latter often overlies the former (King et al., 1958; Hardeman, 1966). The Chilhowee Group shows limited but almost incontrovertible evidence for being no younger than Early Cambrian (Walcott, 190-, 1891; Resser, 1938; Laurence and Palmer, 1963; Wood and Clendening, 1982; Simpson and Sundberg, 1987; Walker and Driese, 1991). Thus, faunal evidence tends to indicate a lower Paleozoic and even post-Cambrian age for the Walden Creek Group, yet its stratigraphic relationships to the Chilhowee imply the age is no younger than Early Cambrian. This paradox and its implications are the focus of this paper.

SUCCESSION AND DISTRIBUTION OF THE OCOEE SUPERGROUP

King et al. (1958) divided the Ocoee Supergroup into two different successions: 1) to the northeast and below the Greenbrier fault of Tennessee and North Carolina and 2) to the southeast and above this fault (Figs. 1 and 2). The former (A) succession includes the Snowbird Group below and the Walden Creek Group above, with several unclassified formations in between, while the latter (B) succession has the Snowbird Group directly overlain by the Great Smoky Group (Fig. 2). The relationships between the Walden Creek and Great Smoky Groups were left by King et al. (1958) indeterminate, while Rast and Kohles (1986) suggested that the two sequences were deposited in two half-grabens separated by a horst of Grenville basement. As a consequence of several episodes of deformation, Walden Creek and Great Smoky strata are now commonly in tectonic contact. Exposures in the Ocoee Gorge, however, indicate that in that area the Walden Creek conformably overlies the Great Smoky Group (Costello and Hatcher, 1986, this volume). In eastern Tennessee, the Great Smoky and the Walden Creek Groups form two separate belts of considerable continuity, with the Walden Creek belt lying to the northwest and the Great

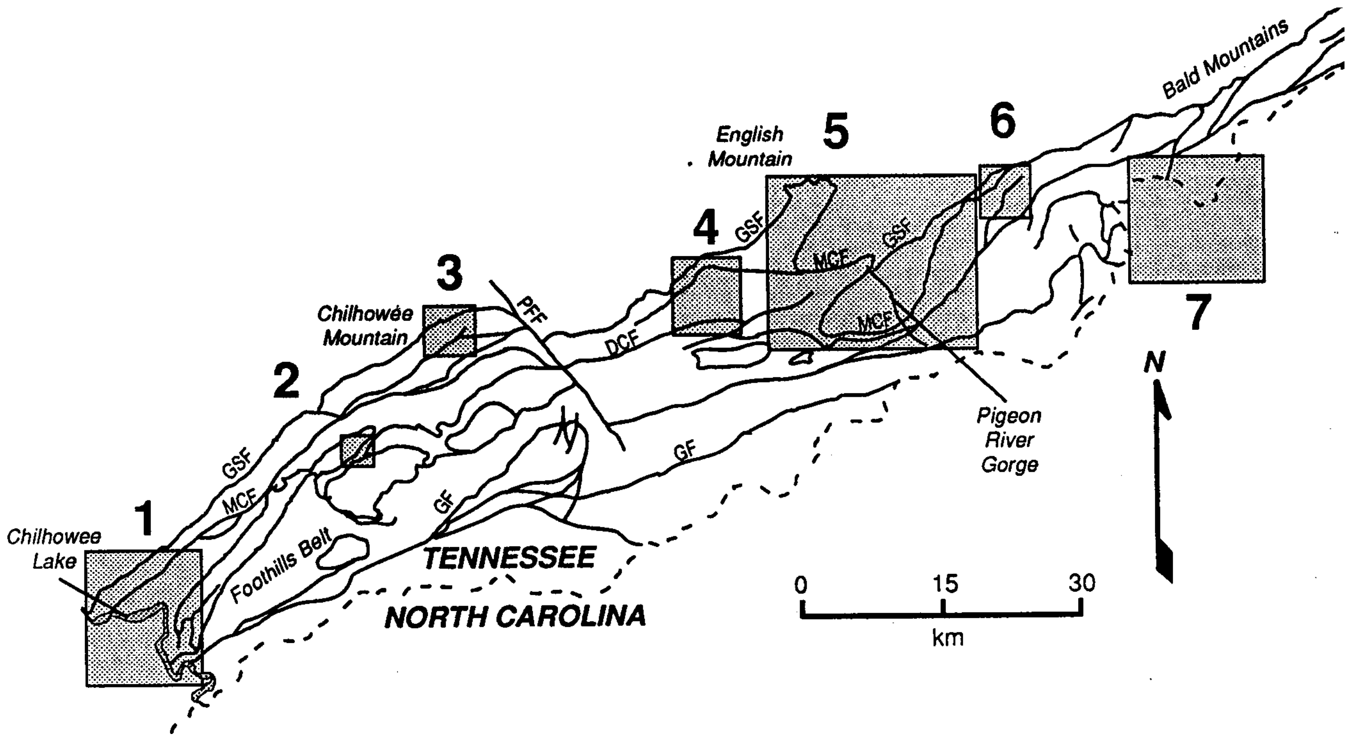


FIGURE 1. Location of areas referred to in text: Area 1 – Shingle Mountain; Area 2 – Kinzel Springs; Area 3 – Chilhowee Mountain; Area 4 – Dixon Mountain; Area 5 – Pigeon culmination; Area 6 – Del Rio District; and Area 7 – Hot Springs window and vicinity. Faults labeled as follows: GSF = Great Smoky fault; DCF = Dunn Creek fault; MCF = Miller Cove fault; and GF = Greenbrier fault. Map modified from Hardeman (1966), fault terminology adopted from Hatcher et al. (1989).

Smoky belt, in the hanging wall of the Great Smoky fault, occur several large blocks of the Chilhowee Group that have in places been mapped as resting on portions of the Walden Creek Group. The three belts (Fig. 1) are separated from each other by continuous faults in the Foothills area of the Great Smoky Mountains (King et al., 1958; Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965; Hardeman, 1966). Northeast of the Pigeon River the Walden Creek Group dies out in a structurally complex ground to the southeast of the Mountain City area, and it has not been identified as such in Virginia. Southwest of Tennessee, the Walden Creek Group thins and is cut off by the Cartersville fault, which is probably the equivalent of the Miller Cove fault (Hatcher et al., 1989). Its correlations in these areas are controversial, and there is insufficient, continuous map evidence as to the structure to the northeast of the Pigeon River Gorge.

In the central Great Smokies and the Foothills belt, King et al. (1958) divided the Walden Creek Group into four formations as follows (lowest to highest): 1) Licklog Formation, a sequence of siltstone and shale with minor interbedded sandstone and pebble conglomerate; 2) Shields Formation, a sequence of coarse-grained feldspathic sandstone and white quartz-pebble conglomerate that fines upward into sandy shale; 3) the Wilhite Formation, which consists of a lower sequence of sandy siltstone and shale (termed the Dixon Mountain Member) and an upper sequence of carbonate breccias and bedded limestone with minor intercalations of sandstone and conglomerate (termed the Yellow Breeches Member); and 4) the Sandsuck Formation, dominantly comprised of gray and green silty shale with interbedded conglomerate and sandstone. In the context of deciding the age of the Walden Creek Group, the Wilhite Formation is probably the most significant. Strata mapped as Wilhite Formation apparently contain olistostromes and olistoliths of carbonate rock (Rast and Kohles, 1986; Unrug and LePain, 1988; Unrug and Unrug, 1990). The aforementioned faunal assemblage was recovered matrix surrounding these carbonate bodies (Unrug and Unrug, 1990).

King et al. (1958) also pointed out that on Chilhowee and English Mountains the basal Chilhowee Cochran Formation lies on the Sandsuck, and they deduced that the Walden Creek as a whole overlies the Snowbird Group. Northeast of the Great Smoky Mountains, the Sandsuck rests stratigraphically on the Snowbird Formation in the Hot Springs area (Oriel, 1950, 1951). In the Del Rio area and the southern Bald Mountains (Fig. 1), Ferguson and Jewell (1951) and Bearce (1966) mapped all the lithologies that in the Great Smokies would have been assigned to the Wilhite and Shields formations as Sandsuck (Bearce, 1969). In all these

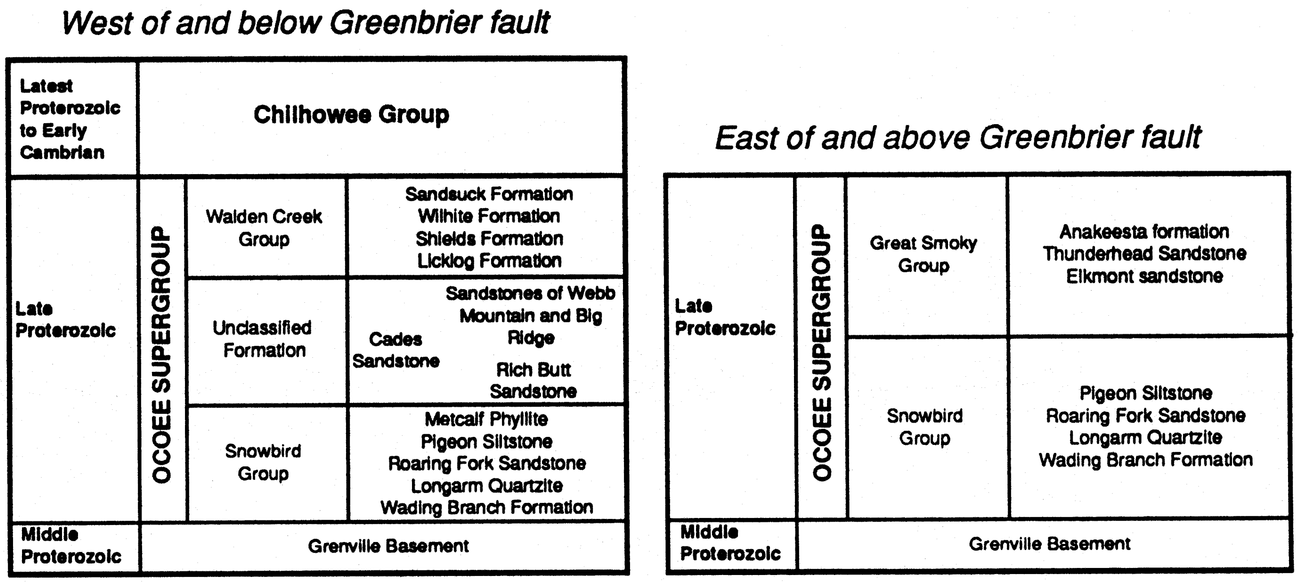


FIGURE 2. Stratigraphy of the Ocoee Supergroup in the Great Smoky Mountains (modified from King et al., 1958).

instances the contact between the Sandsuck *sensu lato* and the Snowbird, Walden Creek, and Chilhowee Groups in the Del Rio area.

In tracing the Walden Creek Group to the northeast, and especially northeast of the Pigeon River, the facies and the detailed lithologic sequence varies. The most constant features that unify the group are the sandy, bedded limestone and limestone breccias of the Yellow Breeches Member of the Wilhite Formation, and the abundant Shields-like conglomerates with diagnostic milky quartz pebbles and cobbles accompanied by occasional pebbles of granite, aplite, and rip-up clasts of dark slate. The conglomerates of the Shields Formation form a very thick sequence, occasionally with graded bedding and indications of massflow movement. Similar conglomerates occur locally as minor, thin-bedded units within the other formations of the Walden Creek Group.

To illustrate the relations of the Walden Creek Group to the underlying Snowbird Group and the apparently overlying Chilhowee Group, seven limited areas have been selected. These areas are geographically distributed from the foothills of the Smoky Mountain of Tennessee to the Bald Mountains of Tennessee and North Carolina (Fig. 1). The areas include: 1) Shingle Mountain; 2) Kinzel Springs; 3) Chilhowee Mountain; 4) Dixon Mountain; 5) Pigeon culmination; 6) Del Rio District; and 7) Hot Springs window. The geology of each area will be briefly reviewed based on the most recent, detailed mapping as well as pertinent sedimentologic and structural studies. Each locality will then constitute a test of a working hypothesis. Simply stated, that hypothesis is that the Walden Creek Group is post-Cambrian. Three corollaries of this hypothesis then exist: 1) the Walden Creek Group cannot lie stratigraphically beneath the Lower Cambrian Chilhowee Group; 2) any rocks that stratigraphically lie beneath the Chilhowee cannot be part of the Walden Creek Group; and 3) in any area where strata of the Chilhowee Group are in demonstrable contact with that of the Walden Creek Group, that contact must by definition be either structural or unconformable with the latter overlying the former. In each area, the plausibility of these corollaries will be examined in order to determine the validity of the hypothesis.

AREA 1 – SHINGLE MOUNTAIN

The area lies northeast of Chilhowee Lake (Fig. 1) and is bounded by the Miller Cove fault to the northwest and a succession of thrusts to the southeast (Neuman and Nelson, 1965; see also Woodward et al., this volume). In the Shingle Mountain area the Walden Creek Group is apparently represented by a Wilhite succession, and occupies a triangular area bounded by faults. It has been interpreted as Phanerozoic (Unrug and Unrug, 1990) on the basis of the aforementioned microfossil fauna. A disturbed cross section of Wilhite rocks is well exposed along US Highway 129 at Chilhowee Lake and appears as a dominantly clastic sequence broken by numerous faults, where the detailed order of stratigraphic succession is difficult to determine. The well-exposed thick succession of milky quartz-pebble conglomerate has been mapped as Wilhite (Neuman and Nelson, 1965), and appears to be very similar to conglomerate of the Shields Formation (Hamilton, 1961). At this locality the Chilhowee Group is separated from the Wilhite Formation by the Miller Cove fault; therefore, relationships between the two sequences are indeterminate.

Assuming that the Wilhite is younger than the Chil-


Miller Cove
Raven
Cliff
Ridge
Chestnut
Cove
Capshaw
Branch
Briar
Matthew
Mountain
Mark
FAULT
Kinzel Springs
Mile 27
Mile 28
Mile 29
Mile 30
Kinzel
CAPSHAW
LITTLE
TUCKALEECHEE
Creek
Short
Tipton
Branch
Ridge
Cemetery
Qal
Ob
pЄwc
pЄwd
pЄw
pЄwl
SEQUENCE BROKEN BY MILLER COVE FAULT
Wilhite Formation 1
pЄwd, dark siltstone
pЄw, light siltstone 1
pЄwc, conglomerate 1
N
0
1
km

howee (Unrug and Unrug, 1990), the Miller Cove fault places younger strata of the Wilhite over older strata of the Chilhowee. The younger over older geometry can most simply be explained as the result of fault movement along a preexisting unconformity at the base of the Walden Creek Group, as proposed by Tull and Groszos (1990). At Ocoee Gorge the sequence is overturned; however, Costello and Hatcher, (1986, this volume) interpret the Great Smoky Walden Creek Group contact as conformable (it should be noted that some controversy regarding the stratigraphy in this area does exist (e.g., Wiener and Merchat, 1978). This relationship then indicates that if the upper portion of the Walden Creek Group is only as young as Early Ordovician, the entire Walden Creek Group represents a stratigraphic equivalent of the Chilhowee Group, Rome Formation, Conasauga Group, and Knox Group. This relationship introduces an additional paradox as Walden Creek Group strata are again thrust over the Chilhowee Group along the Miller Cove fault at the western end of Ocoee Gorge (Hatcher and Milici, 1986). Thus, if the Miller Cove fault is interpreted as a slipped unconformity, resulting in this younger over older geometry, that unconformity must be beneath the strata of the Great Smoky Group in the vicinity of the Ocoee Gorge. These complex relationships only arise if the Walden Creek Group is indeed post-Chilhowee.

Area 2 – Kinzel Springs

In the Kinzel Springs area, rocks of the Walden Creek Group, ranging from the Shields Conglomerate to shales and sandstones of the Wilhite Formation, are situated immediately above the Miller Cove thrust in numerous exposures along Tennessee Highway 73 (Fig. 3). The Shields Formation forms a cliff overlooking Kinzel Springs, with conglomerate bands showing abundant sedimentary structures that indicate that the section is upright and dips to the north. South of the Shields outcrop the Shields-Wilhite succession is cut off by the Great Smoky thrust that frames the Tuckaleechee Cove window. The stratigraphy at Kinzel Springs clearly resembles that described from the Dixon Mountain area by Hamilton (1961). The Shields consists mainly of coarse-grained, milky quartz-pebble conglomerate. Similar, though thinner conglomerate bands occur locally in the Wilhite of the area as well. This section was previously mapped as part of the Wilhite Formation, but in view of the massiveness of the exposed sequence it is probably the Shields (Fig. 3). Overlying this conglomerate is a sequence of interbedded laminated shale and siltstone with minor sandstone. Extensive sections exposed along roadcuts indicate that the rocks are folded into recumbent isoclinal folds verging northwest. These recumbent folds are associated with thrusts and are refolded by smaller upright anticlines and synclines with a well-developed cleavage inclined steeply to the south and southeast. At the northern end of the well-exposed road section, the Miller Cove fault separates and thrusts these rocks over Lower and Middle Cambrian strata. Within the Wilhite section are large-scale faults, one of which is probably the continuation of the Dunn Creek fault. Two localities in this section (Fig. 3) have yielded the acritarch assemblage reported by Knoll and Keller (1979). Although originally thought to beVendian, additional work completed on similar faunal assemblages has prompted some qualification (A.H. Knoll, written communication, 19991):

> As we have learned more about the stratigraphic and paleoenvironmental distributions of Proterozoic microfossils, it has become apparent while some acritarch assemblages have significant biostratigraphic value, *Sphaerocongregus* (=*Bavlinella*) and leiosphaerid assemblages of the type found by Knoll and Keller (1979) in Ocoee shales are essentially facies biotas widely associated with basinal sediments of Neoproterozoic age (e.g., Vidal and Nystuen, 1990). The taxa found in these assemblages have long geological ranges that certainly extend into the Phanerozoic. In this, Dr. Unrug's summary of the paleontological information from AHK is essentially correct (Unrug and Unrug, 1990). This does not, however, necessarily imply that Phanerozoic turbidities contain similar acritarch assemblages. Indeed, Paleozoic turbidities tend to contain recognizably Paleozoic microfossils… Such fossils are absent from Ocoee acritarch assemblages studied to date.

It should be noted that the rocks sampled by Knoll and Keller (1979) occur above the Capshaw Branch fault, and thus are not in demonstrable stratigraphic contact with strata of the Walden Creek Group that have yielded the apparently post-Cambrian microfossil assemblage reported from Shingle Mountain (Unrug and Unrug, 1990). Their correlation with the strata of Shingle Mountain is based on the occurrence of the characteristic milky* quartz-pebble conglomerate.

Area 3 – Chilhowee Mountain

Here, along strike from the type locality of the Chilhowee Group, the Chilhowee Group is bounded to the northeast by a thin strip of Sandsuck strata, cut off by the Great Smoky fault, and exposed along both flanks of Chilhowee Mountain. Examination of sedimentary structures clearly indicates that the section is upright (Walker et al., 1988). The lowest formation of the Chilhowee Group, the Cochran Con-

FIGURE 3 – Geology of the Kinzel Springs area. Star indicates locality discussed in Knoll and Keller (1979). Modified from King (1964) as follows: 1 – occurrence of thick intervals of milky quartz-pebble conglomerate suggests units mapped as p€wd could belong to the Shields Formation as described by Hamilton (1961).

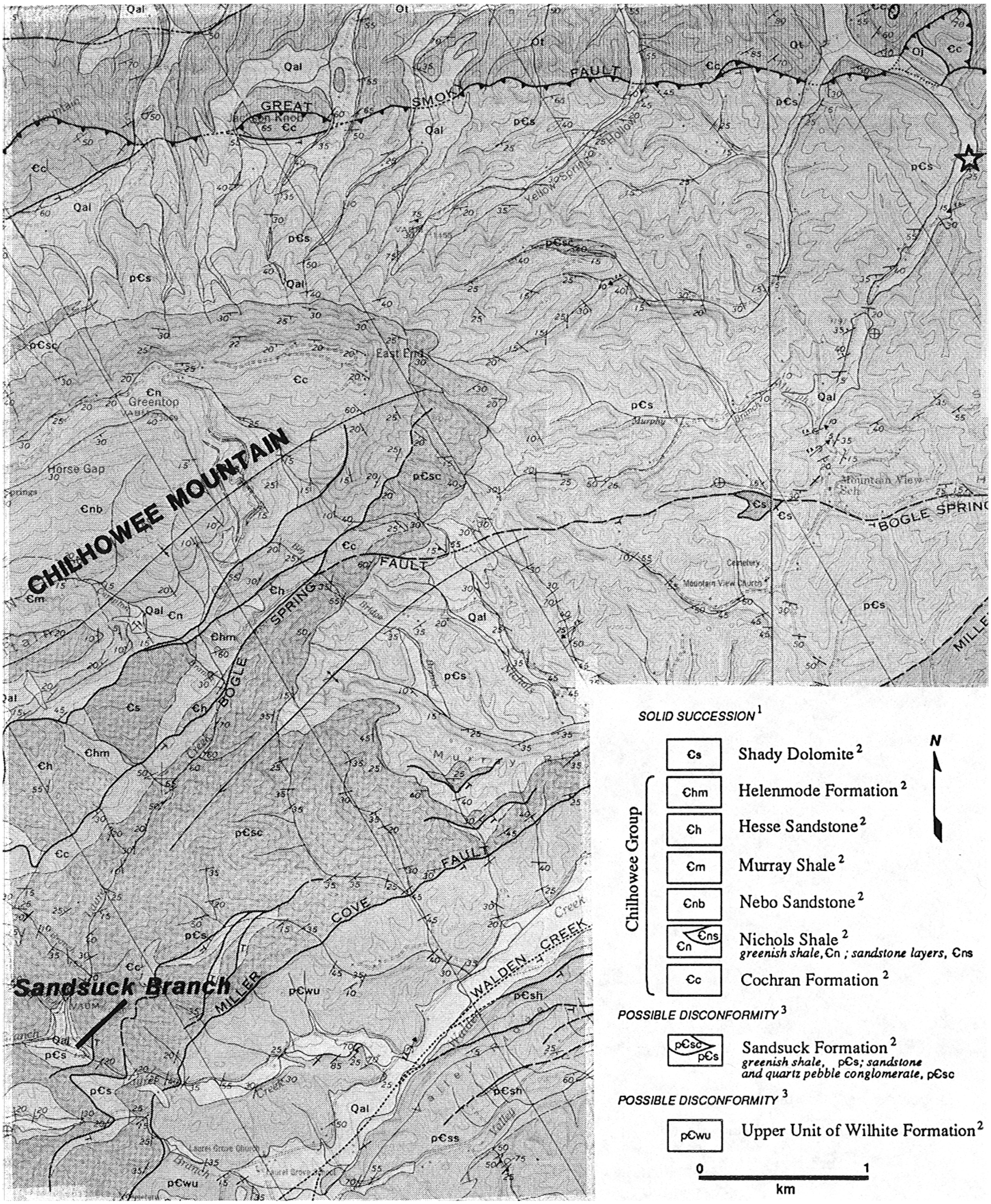


FIGURE 4. Geology of the Chilhowee Mountain area. Star indicates fossil localities discussed in Knoll and Keller (1979). Modified from King (1964) as follows: 1 – units younger than Shady Dolomite and occurring in the Valley and Ridge and are omitted from legend, 2 – units raised to formal status after publication, 3 – originally described as a "probably disconformity," 4 – originally described as conformable (see text for more discussion).

glomerate, is underlain by the Sandsuck Formation, which is comprised of fine-grained shale and siltstone (Fig. 4). Exposures of fine-grained Sandsuck rocks (Fig. 4) north of the Miller Cove fault along Wear Valley Road, yielded the acritarch assemblage reported by Knoll and Keller (1979; Knoll, written communication, 1990). The stratigraphic relationship would therefore preclude a post-Cambrian age for the Sandsuck Formation, and thus require its removal from the Walden Creek Group if the latter is indeed post-Chilhowee as proposed by Unrug and Unrug (1990). Furthermore, the apparent occurrence of the *Sphaerocongregus (=Bavlinella)* and leiosphaerid assemblage described by Knoll and Keller (1979) from both the Sandsuck of Chilhowee Mountain and the Shields Formation of Kinzel Springs requires that this acritarch assemblage be assigned a biostratigraphic range of Late Proterozoic to Siluro-Devonian, which seems somewhat questionable.

Area 4 – Dixon Mountain Area

This complex area of Walden Creek rocks, including the Sandsuck, is situated between the continuation of the Miller Cove thrust (English Mountain fault of Hamilton [1961]) in the vicinity of English Mountain and the Dunn Creek fault north of the Great Smoky Mountains. The thrust terminology in the area has been controversial; therefore, we have followed the nomenclature outlined by Hatcher et al., (1989).

This area (as well as areas 5, 6, and 7) is separated from both the strata of Shingle Mountain and the rocks of Chilhowee Mountain by the transverse Pigeon Forge fault (Fig,.1). Correlation with sequences exposed at Shingle and Chilhowee mountains again depends on the occurrence of the characteristic conglomerate previously described. The internal structure of the Walden Creek Group in this area is complex (Fig. 5). Hamilton (1961) divided the Wilhite Formation into two members, the upper Yellow Breeches carbonate-bearing member and the lower Dixon Mountain Member that consists mainly of siltstone, shale, and other siliciclastic rock. Dixon Mountain proper is underlain almost entirely by the siltstone member, but to the north the situation is more complex. The northern part of this area can be described as a syncline that preserves a core of Yellow Breeches Member flanked by Dixon

Mountain Member

Fine-grained strata of the Yellow Breeches Member north of Wilhite Creek (Fig. 5) yielded the acritarch assemblage reported by Knoll and Keller (1979). These strata are covered by a thick and has been divided into lower, middle, and upper members (Hamilton, 1961). The middle member contains the diagnostic, Shields-like, milky quartz-pebble conglomerate and the lower and upper members are both comprised of shale, siltstone, and sandstone lithologies.

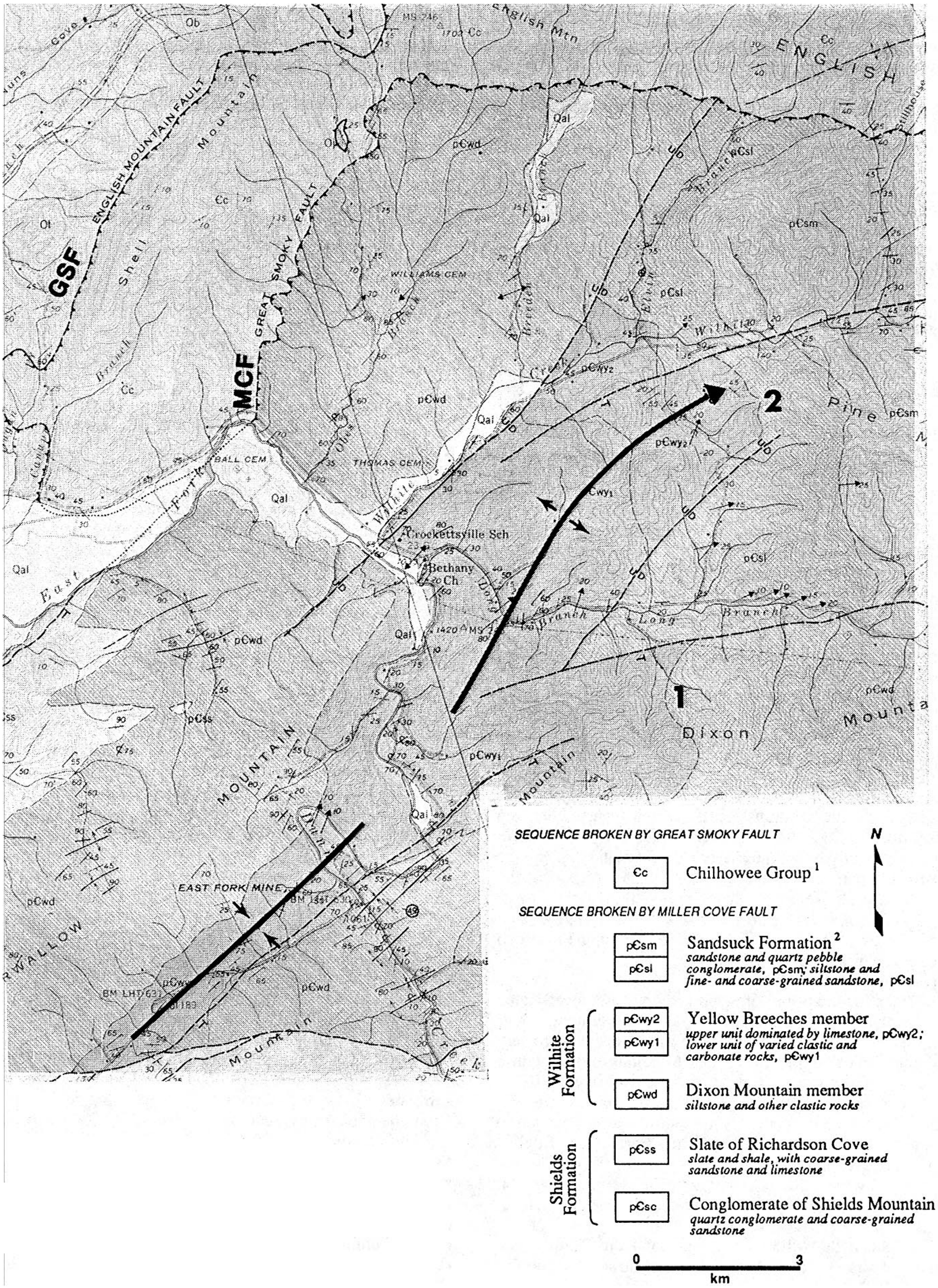
Based on the conclusions drawn from Chilhowee Mountain (that the Sandsuck is pre-Chilhowee), the relationships shown in Figure 5 must be, in part, incorrect if the Walden Creek Group is post-Chilhowee (Unrug and Unrug, 1990). Thus, either: 1) the shale and siltstone sequences north of the Yellow Breeches Member have been incorrectly correlated with the Sandsuck; 2) the contact between the Sandsuck and Yellow Breeches Member is thrust fault, placing younger Yellow Breeches Member over the Sandsuck; or 3) the contact between the Sandsuck and Yellow Breeches Member is, in fact, an overturned unconformity. The Sandsuck is mapped as being conformable with the Wilhite, although the map evidence is insufficient to preclude an alternative interpretation, because the junction between the two is mapped through poorly exposed ground and dips shown on the map are discordant to contacts. Moreover, on the Wilhite section does, however, appear to be continuous at the northwest end of Pine mountain (Hamilton, 1961). Interpreting the contact as an overturned unconformity, however, would appear to be inconsistent with observable facing data in the area. If the Wilhite Formation is indeed younger than the Chilhowee, the correlation of the units above the Wilhite in the Dixon Mountain area to the Sandsuck Formation of Chilhowee Mountain must be discontinued, despite the occurrence of the diagnostic quartz-pebble conglomerates in both Mountain (Fig. 4) indicate that rocks that lie stratigraphically beneath the Sandsuck Formation cannot be post-Cambrian in age, and therefore cannot be part of the Walden Creek Group, again assuming the latter is post-Chilhowee in age (Unrug and Unrug, 1990). The significance of this deduction bears heavily on the next two areas to be discussed.

Area 5 – Pigeon Culmination

The structure of this area has been recently investigated by Trimble (1985) and Robert (187), and although their maps show detailed differences, the salient features are very similar. The culmination (Green Mountain block) with a core of Cambrian rocks is surrounded and overthrust by folded rocks of the Walden Creek and Snowbird Groups. The core, therefore, occupies a window that is bounded to the north by the Great Smoky thrust (termed the English Mountain fault by Hamilton [1961]), and to the east, south, and west by the Miller Cove thrust (Fig. 1). As in area 4, we have followed the fault nomenclature outlined by Hatcher et al., (1989).

Between the Miller Cove fault and the Dunn Creek fault, a thin strip of Walden Creek strata structurally overlies the Cochran (basal Chilhowee) conglomerate. Of course, the Miller Cove fault again may be a slipped unconformity as discussed in area 4. The significance of area 5 is that is shows the continuation of the Wilhite sequence around the Cambrian core of the culmination.

Across the culmination there is also a change in the basal Chilhowee Group, as quartzose strata of the Cochran Formation changes into more pebbly arkosic conglomerate, siltstone, and shale of the unicoi Formation (Walker, 1990).l


GSF
MCF
ENGLISH MOUNTAIN FAULT
GREAT SMOKY FAULT
1
2
SEQUENCE BROKEN BY GREAT SMOKY FAULT
N
Cc
Chilhowee Group[1]
SEQUENCE BROKEN BY MILLER COVE FAULT
p€sm
p€sl
Sandsuck Formation[2]
sandstone and quartz pebble conglomerate, p€sm; siltstone and fine- and coarse-grained sandstone, p€sl
Wilhite Formation
p€wy2
p€wy1
Yellow Breeches member
upper unit dominated by limestone, p€wy2; lower unit of varied clastic and carbonate rocks, p€wy1
p€wd
Dixon Mountain member
siltstone and other clastic rocks
Shields Formation
p€ss
Slate of Richardson Cove
slate and shale, with coarse-grained sandstone and limestone
p€sc
Conglomerate of Shields Mountain
quartz conglomerate and coarse-grained sandstone
0
3
km

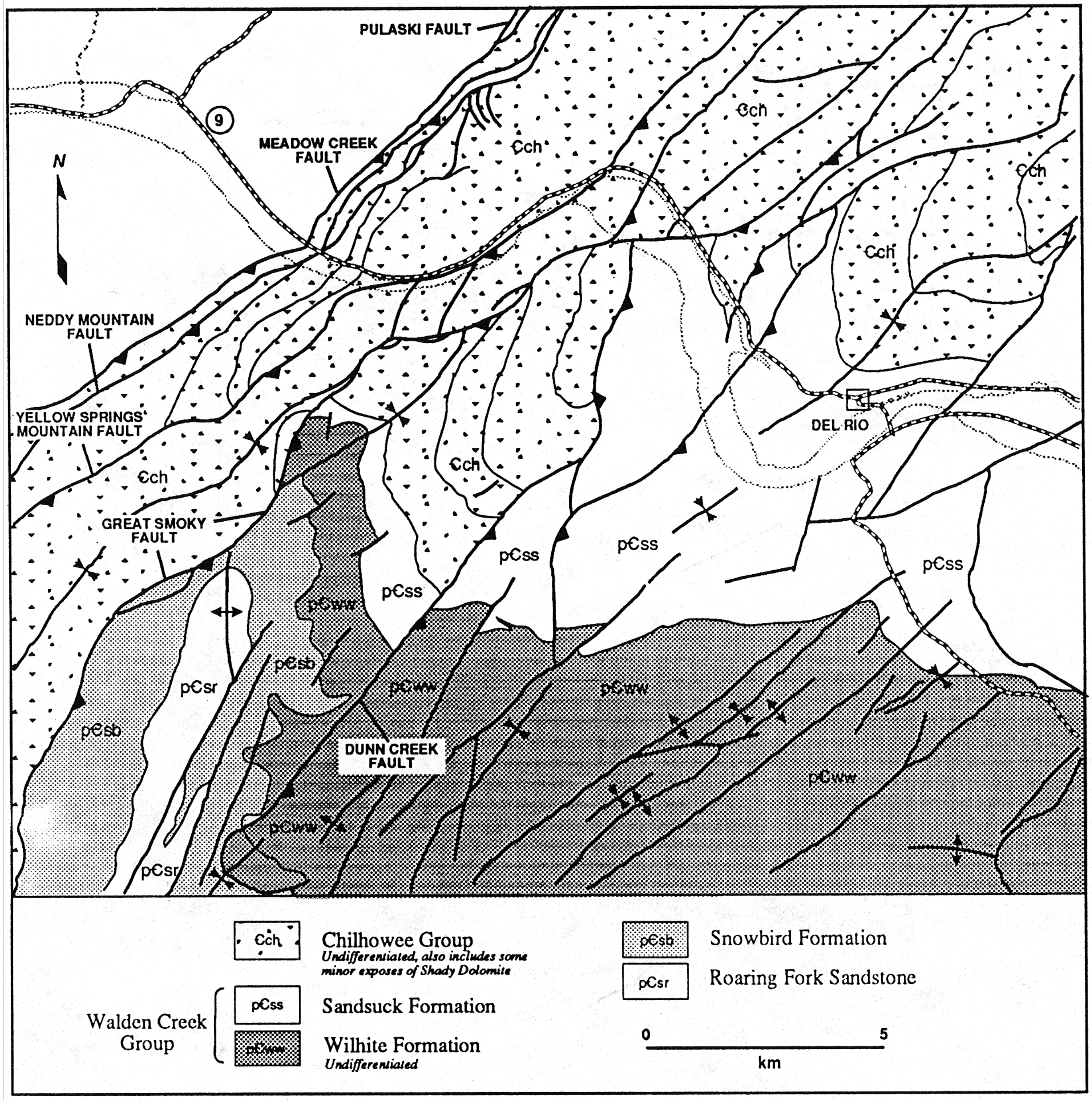


FIGURE 6 – Geology of a portion of the Del Rio District (modified from Keller, 1980).

the Unicoi may be the stratigraphic equivalent of both the Cochran and the Sandsuck formations at Chilhowee Mountain (see Rodgers, this volume).

Area 6 – Del Rio District

This area has been mapped by Ferguson and Jewell (1951), Keller (1980), and in part by Neavel (1985). Detailed mapping by Keller documented an apparently continuous succession of Snowbird (Pigeon Formation), Walden Creek (including the Sandsuck), and Chilhowee (Fig. 6) between the trace of the Great Smoky and Dunn Creek faults.

Again it might be possible to infer an unconformity or a tectonic break beneath the Sandsuck, which changes its mapped thickness from southeast to northwest from about 1,450 to 1,050 m, that consists of shale with interbedded milky quartz-pebble conglomerate. Since both the Walden

FIGURE 5. Geology of the Dixon Mountain area (from Hamilton, 1961). Star indicates fossil locality discussed in Knoll and Keller (1979). GSF = Great Smoky fault, MCF = Miller Cove fault (see text for explanation). Note apparent change in stratigraphic succession from locality 1 to locality 2.

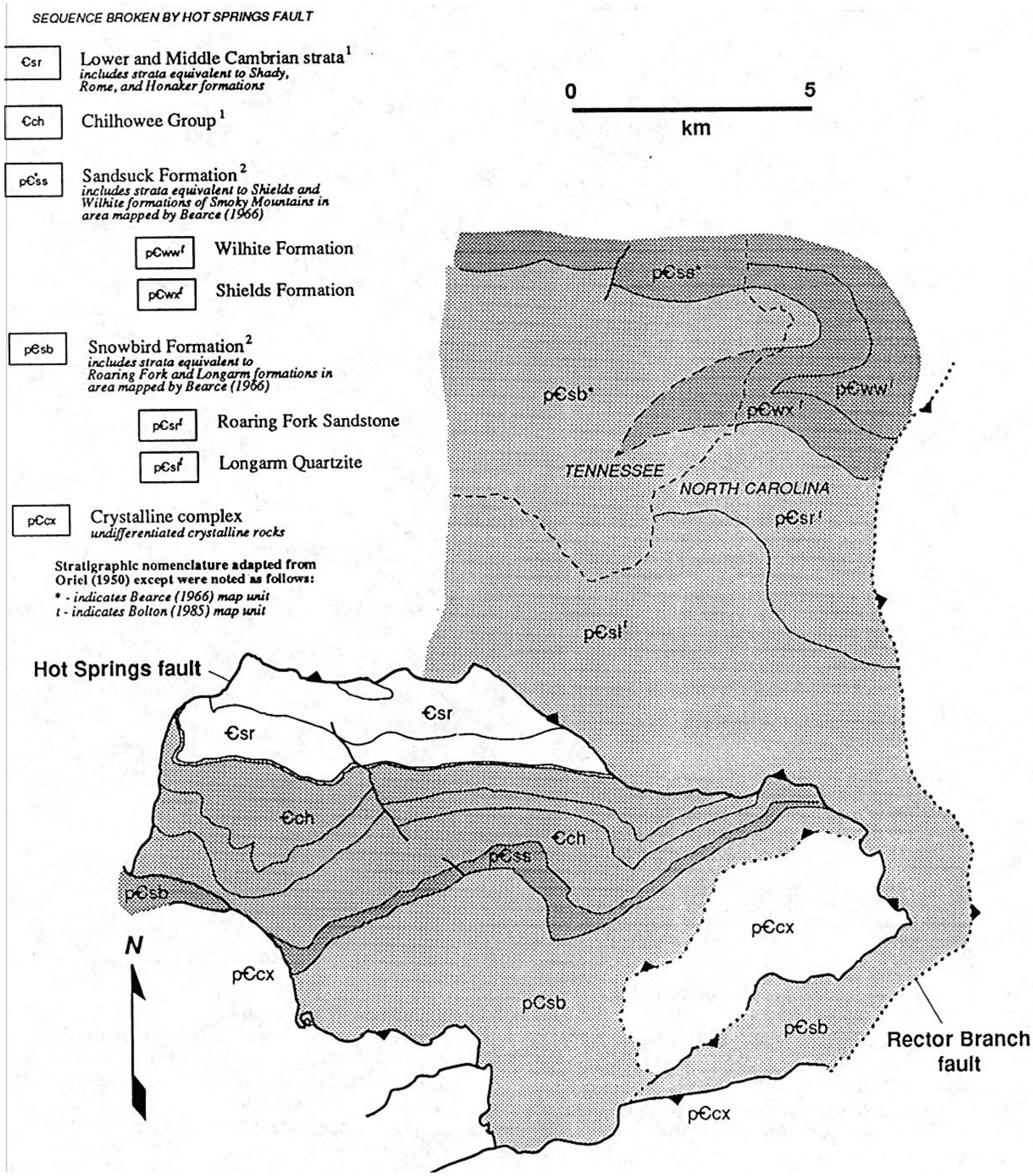


FIGURE 7 – Geology of the Hot Springs window and vicinity (compiled from Oriel, 1950; Bearce, 1966; Bolton, 1985).

Creek and the Wilhite sequences dip in the same direction to the northeast, a thrust would be more likely, although there is no obvious for it. The Wilhite succession does appear at least in places, to be disconformable on the Pigeon Siltstone of the Snowbird Group, because the latter shows greater variation in dip. The geology in area 6 therefore, suggest that the strata mapped as Walden Creek Group in this area cannot be younger than Early Cambrian. Clearly this area has to be further investigated for faults and sampled for any possible fossils. If the Walden Creek-Chilhowee stratigraphic relationships (after King et al., 1958) are to be disregarded, then the stratigraphic integrity of this section has to be overturned. If the succession remains correlated to some Upper Proterozoic-Lower Cambrian sequence such as the Kahatchee Mountain Group of the Alabama Talladega belt, which is mainly pelitic, but also has a minor carbonate member termed the Sawyer formation (Butts, 1926; Tull, 1982). The Sawyer Limestone is a bedded sandy limestone and dolomite with algal stromatolites (Butts, 1926) and lies beneath siliciclastic strata correlated with the Chilhowee Group by Smith (1888). The correlation was confirmed by the discovery of Lower Cambrian fossils in the immediately overlying Jumbo Dolomite (Tull et al., 1988).

Area 7 – Hot Springs Window

The area in and around the Hot Springs window has been mapped by Oriel (1950, 1951). The window is surrounded by several thrusts and has an inner window of Grenville gneisses overlain by feldspathic sandstone, shale, and other clastic rock of the Snowbird Group (Fig. 7). The Snowbird is topped by greenish argillaceous phyllite and siltstone of the Sandsuck Formation, that are overlain unconformably (?) by the Unicoi Formation, which has a conglomeratic unit at the base. This basal conglomerate contains unmistakable clasts of the underlying Sandsuck (Walker and Simpson, 1991). The section (clearly exposed along North Carolina Highway 209) again illustrates a continuity of succession from the Ocoee into the Chilhowee.

The absence of the Shields or Wilhite rocks from the sequence within the window indicates that much of the Walden Creek either was not deposited or that they are entirely younger than the Ocoee-Sandsuck-Chilhowee sequence. Outside the window, the Shields Formation rests directly and without an obvious discontinuity on Snowbird lithologies (Bolton, 1985). To the northwest of this area, Bearce (1966) mapped the Snowbird-Sandsuck-Chilhowee as a continuous sequence. It is clear from Bearce (1969) that he viewed the Sandsuck as an equivalent of the Walden Creek Group, and adopted the simpler threefold terminology to agree with previously established stratigraphics of adjacent areas (Ferguson and Jewell, 1951; Shekarchi, 1959). Outside the Hot Springs window, in the Buffalo Mountain thrust sheet, Bolton's (1985) mapping indicates unmistakable Shields and Wilhite conglomeratic rocks could probably be extended into Bearce's area (Fig. 7). Bolton (1985) reported over 1,300 m of the Shields Formation from the Rich Mountain area. Within the Hot Springs window, this coarse-grained deposit referred to as "Sandsuck" by Bearce (1969), Ferguson and Jewell (1951), and Shekarchi (1959) is absent. Stratigraphic relationships both inside and outside the Hot Springs window; therefore, preclude a post-Chilhowee age for the Sandsuck and probably all local equivalents of the Walden Creek Group.

DISCUSSION AND CONCLUSION

Examination of the limited number of areas discussed demonstrates the complexity of the Ocoee and Chilhowee relationships. Several salient points emerge: 1) the Sandsuck Formation lies stratigraphically beneath the Chilhowee Group at Chilhowee Mountain, English Mountain, the Del Rio District, and the Hot Springs areas;

3)the Snowbird, Sandsuck, and Chilhowee form a continuous stratigraphic sequence within the Hot Springs window; and 3) rocks that are very similar in lithology to the Shields, Wilhite, and Sandsuck of the type Walden Creek Group have been mapped by numerous workers as being stratigraphically beneath the Chilhowee Group in the area between the Foothills belt and the Mountain City window. These three points indicate that the Great Smoky and Snowbird Groups must be older than the Chilhowee. The occurrence of a Siluro-Devonian, or even post-Early Cambrian fauna in rocks of the Wilhite Formation at Shingle Mountain would require that the Walden Creek Group (sans Sandsuck Formation) not be a stratigraphic part of the Ocoee Supergroup and the Chilhowee Group by an unconformity. This is consistent with the position of Tull and Groszos (1990), but appears to be contradicted by relationships observed in Ocoee Gorge (see Costello and Hatcher, this volume).

Critical examination of the available data suggest one of four possible scenarios: 1) mapping by numerous workers in the area between the Foothills belt and Mountain City window is in error in that several important contacts separating parts of the Walden Creek Group from the Chilhowee Group should have been mapped as faults or unconformities (in which case the Sandsuck should be removed from the Walden Creek Group); 2) the mapping in the area northeast of the Foothills belt is essentially correct, but the units beneath the Chilhowee Group were incorrectly correlated with nearly identical strata of the Walden Creek Group, which would mean that two paleotectonic regimes separated in time by 200 to 300 m.y. (the former related to Proterozoic extension and the latter to Acadian orogenesis) resulted in the deposition of identical sedimentary sequences; 3) the mapping in the area northeast of the Foothills belt is essentially correct, but the units yielding the Paleozoic fossil assemblage have been incorrectly correlated with strata of the Walden Creek Group, again requiring that two paleotectonic regimes resulted in the deposition of nearly identical sedimentary; or 4) age assignments given by Unrug and Unrug (1990) to the Walden Creek Group are in error. To dismiss any three of these scenarios requires a greater confidence in one method than another (biostratigraphic vs. field mapping).

We strongly urge that the field relationships discussed here be further examined, that the similar strata of apparently different ages be studied systematically for fossil occurrences, and that further systematic work on the reported Wilhite fauna be conducted and examined in light of our increasing understanding of the biostratigraphic ranges of microfossils. It is our hope that his discussion will stimulate these studies. We feel that at the present time the weight of available evidence suggests that a post-Chilhowee age for the Walden Creek Group is not probable, and that the stratigraphic succession advanced by Safford (1856) and refined by King et al. (1958) should continue to be considered valid.

ACKNOWLEDGEMENTS

We wish to express thanks to colleagues J. Rodgers, J. Costello, R. D. Hatcher, Jr., and T. Hamilton – Smith for their many comments and constructive criticism. We also wish to express thanks to the Kentucky Geological Survey for providing essential photographic and editorial services.

REFERENCES

Bearce, D. N., 1966, Geology of the Chilhowee Group and the Ocoee Series in the southwestern Bald Mountains, Greene and Cocke counties, Tennessee [Ph.D. thesis]: Knoxville, University of Tennessee, 147 p.

Bearce, D. N., 1969, Geology of the southwestern Bald Mountains in the Blue Ridge province of Tennessee: Southeastern Geology, v. 11, p. 21 – 36.

Bolton, J. C., 1985, Structure and stratigraphy of the Rich Mountain area, North Carolina [M. S. thesis]: Lexington, University of Kentucky, 103 p.

Butts, Charles, 1926, The Paleozoic rocks, in Adams, G. I., Butts, C., Stephenson, L. W., and Cooke, W., eds., Geology of Alabama: Geological Survey of Alabama Special Report 14, p. 40 – 223.

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. 218.

Culver, S. J., Repetski, J. E., Pojeta, J., Jr., and Hunt, D., 1990, Early Cambrian foraminifera and Metazoan shelly fossils from West Africa: Geological Society of America Abstracts with Programs, V. 7, p. 221.

Ferguson, H. W., and Jewell, W. B., 1951, Geology and barite deposits of the Del Rio District, Cocke County, Tennessee: Tennessee Division of Geology, Bulletin 57, 235 p.

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, 118p.

Hamilton, W. B., 1961, Geology of the Richardson Cove and Jones Cove quadrangles, Tennessee: U. S. Geological Survey Professional Paper 349-A, 55 p.

Hardeman, W. D., 1966, Geologic map of Tennessee: Tennessee Division of Geology, four sheets, scale 1:250,000.

Hatcher, R. D., Jr., and Milici, R. C., 1986, Ocoee Gorge; Appalachian Valley and Ridge to Blue Ridge transition, in Neathery, T. L., ed., Geological Society of America Centennial Field Guide – Southeastern Section: Boulder, Colorado, Geological Society of America, P. 265 – 270.

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 Appalachians-Ouachita Orogen in the United States: Geological Society of America, The Geology of North America, v. F-2, p. 511 – 535.

Hatcher, R. D., Jr., Thomas, W. A., Geiser, P. A., Snoke, A. W., Mosher, S., and Wiltschko, D. V., 1989, The Alleghanian orogen, in Hatcher, R. D., Jr., Thomas, W. A., and Viele, G. W., eds., The Appalachian –Ouachita Orogen in the United States: Geological Society of America, The Geology of North America, v. F-2, p. 233 –318.

Keller, F. B., 1980, Late Precambrian stratigraphy, depositional history, and structural chronology of part of the Tennessee Blue Ridge [Ph.D,. thesis]: New Haven,Yale University, 353 p.

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., Hadley, J. B., Neuman, R. B., and Hamilton, W., 1958, Stratigraphy of the Ocoee Series, Great Smoky Mountains, Tennessee and North Carolina: Geological Society of America Bulletin, v. 69, p. 947 – 967.

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.

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-C4.

Neavel, K. E., 1985, Structural features and kinematic history of the Del Rio District, central-eastern Tennessee [M. S. thesis]: Lexington, University of Kentucky, 124 p.

Neuman, R. B., and Nelson, W. H., 1965, Geology of the western Great Smoky Mountains: U. S. Geological Survey Professional Paper 349 – D, 81 p.

Oriel, S. S., 1950, Geologic map of the Hot Springs area, Madison County, North Carolina: North Carolina: American Journal of Science, v. 249, p. 1 – 31.

Rast, Nicholas, 1989, The evolution of the Appalachian chain, in Bally, A. W., and Palmer, A. R., eds., The Geology of North America – An overview: Geological Society of America, The Geology of North America, v. A, p. 323 – 348.

Rast, Nicholas, and Kohles, K. M., 1986, The origin of the Ocoee Supergroup: American Journal of Science, v. 286, p. 593 – 616.

Resser, C. E., 1938, Cambrian System (restricted) of the southern Appalachians: Geological Society of America Special Paper 15, 140 p.

Robert, L. C., 1987, Structural geology and geometries of Hartford, Tennessee [M. S. thesis]: Knoxville, University of Tennessee, 147 p.

Safford, J. M., 1856, A geological reconnaissance of the State of Tennessee: First Biennial Report State Geologist, 164 p.

Shekarchi, E., 1959, The geology of the Flag Pond Quadrangle, Tennessee-North Carolina [M. S. thesis]: Knoxville, University of Tennessee, 140p.

Simpson, E. L., and Sundberg, F. A., 1987, Early Cambrian age for synrift deposit of the Chilhowee Group of southwestern Virginia: Geology, v. 15, p. 123 – 126.

Smith, E. A., 1888, Report of progress for the years 1884 – 1888: Alabama Geological Survey Report of Progress, 24 p.

Trimble, D. C., 1985, Styles of sedimentation and part of the Del Rio District [M. S. thesis]: Lexington, University of Kentucky, 136 p.

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, F. 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., Harris, A. G., Repetski, J. E., McKinney, F. K., Garret, C. B., and Bearce, D. N., 1988, New paleontologic evidence constraining the age and paleotectonic setting of the Talladega slate belt, southern Appalachians: Geological Society of America Abstracts with Programs, v. 21, p. 62 – 63.

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.

Vidal, G., and Nystuen, J. P., 1990, Micropaleontology, depositional environments, and biostratigraphy of the Upper Proterozoic Hedman Group, southern Norway: American Journal of Science, v. 290-A [Cloud Volume], p. 170 – 212.

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, 447p.

Walker, D., Skelly, R. L., Cudzil, M. R., and Driese, S. G., 1988, The Chilhowee Group of East Tennessee: Sedimentology of the Lower Cambrian fluvial to marine transition, in, Driese, S. G., and Walker, D., (eds.), History of Paleozoic Sequences: Southern Appalachians: Mid-continent Section of the Society of Economic Paleontologists and Mineralogists Field Type #6: Knoxville, University of Tennessee, Department of Geological Sciences Studies in Geology #10, p. 24 – 59.

Walker, 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 Simpson, E. L., 1991, Stratigraphy of Upper Proterozoic and Lower Cambrian siliciclastic rocks, southwestern Virginia and northeastem Tennessee, in Schultz, A., and Compton – Gooding, E., eds., Geologic evolution of the eastern United States, field trip Guidebook: Virginia Museum of Natural History Guidebook 2, p. 121 – 159.

Wiener, L. S., and Merschat, C. E., 1978, Structure of Boyd Gap, in Hatcher, R. D., Jr., Merschat, C. E., Milici, R. C., and Wiener, L. S., Field Trip 1-A in Milici, R. C., ed., Field trips in the southern Appalachians: Tennessee Division of Geology Report of Investigations 37, p. 39 – 40.

Wood G. D., and Clendening, J. A. 1982, Arcitarchs from the Lower Cambrian Murray Shale, Chilhowee Group, of Tennessee, U. S. A.: Palynology, v. 6, p. 255 – 265.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 55-67

TECTONIC EVOLUTION OF THE GREAT SMOKY MOUNTAINS

Nicholas B. Woodward[1], Jeffrey B. Connelly[2], Randall R. Walters[3], and Jonathan C. Lewis[4]

[1]Department of Geology, University of Maryland, College park, Maryland, 20742; [2]Department of Geological Sciences, University of Tennessee, Knoxville, Tennessee, 37996; [3]Exxon Company, U. S. A., Midland, Texas, 79703; [4]13690 Cedar Drive, Conifer, Colorado, 80433

ABSTRACT

The Great Smoky Mountains area preserves three thrust fault systems, the Greenbrier, Dunn Creek, and early Miller Cove, assembled during the Taconic orogeny. Although these fault zones have ductile fabrics, regional cleavage and metamorphism postdate emplacement of the Greenbrier and Dunn Creek systems. Internal deformation within these earliest two thrust sheets prior to the main cleavage event is therefore insignificant. In addition, both the Greenbrier and Dunn Creek thrust sheets preserve well formed ramp-related folds. We therefore reconstruct these earliest thrust systems based on foreland models of ramps and flats. The thrusts form a folded imbricate fan structure with lower hanging well ramp anticlines folding higher thrust sheets. The Taconian package of imbricated Ocoee strata was emplaced onto the Valley and Ridge during the Alleghanian orogeny by the late systems occupied various parts of the early ductile thrust zones, and almost certainly excised significant lower parts of the three early thrust sheets.

INTRODUCTION

The Great Smoky Mountains (GSM) area of Tennessee and North Carolina preserves several fault systems of different ages. Interactions between these various thrust fault systems and thrust related structures has complicated structural and stratigraphic relations in this area. To better understand these complexities, a significant change in thrust system interpretation in the GSM area is suggested here. In North America, emphasis in mapping is usually placed on fault-tracing and naming, usually from the perspective of the footwall strata. Thus, the Great Smoky fault is that fault that places old rocks, commonly Precambrian ones, over younger Valley and Ridge strata. In Alpine tectonics (e.g. Trumpy, 1969), however, the emphasis is placed on identifying and segregating the "nappes", or thrust sheets, with much less emphasis on the fault surfaces that bound them. We will use this approach for the GSM because there are multiple thrust and extensional fault systems within the western Blue Ridge. These late thrust and extension faults truncate early low-angle faults and commonly cover the basal thrust surfaces that underlie the older thrust blocks. Thus, the new structural reconstructions we suggest for the GSM region are based on restoration of thrust sheets whose interpretation rests on key areas where initial thrust relationships are preserved. Our emphasis lies in sequential restorations of the area based on structures such as transecting faults and cleavage. This is done by restoring the complex deformation history from youngest to oldest.

The GSM area occupies the best mapped large area in the western Blue Ridge province (Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; Neuman and Nelson, 1965; Fig 1). Recent work on kinematics of structural fabrics in parts of the area (Lewis, 1988; Walters, 1988; Connelly, in prep.) has added significantly to our understanding of the previously mapped structural geometries. Our contribution has been to build on this map framework by adding fault fabric data, strain data, and cleavage studies to understand the kinematic evolution of the GSM structural belt. Until other parts of the western Blue Ridge are equally well-mapped, the GSM area will remain as a principal index area for structural geometries and fabrics that may occur elsewhere in the western Blue Ridge.

REGIONAL GEOLOGY

Stratigraphy

The Ocoee Supergroup was divided into three groups by King et al. (1958) based largely on the lithologic successions exposed along the French Broad (Oriel, 1950; Ferguson and Jewell, 1951), Pigeon (Hadley and Goldsmith (1963), Little Pigeon (Hamilton, 1961), Little (King, 1964), and Little Tennessee Rivers (Neuman and Nelson, 1965) (Table 1). The successions are not entirely compatible. The Snowbird Group underlies both the Great Smoky Group (Pigeon River) and the Walden Creek Group (French Broad River). The Walden Creek Group also overlies the Great Smoky Group in Ocoee Gorge (Costello and Hatcher, 1986). There are no chronostratigraphic markers which can be used to correlate the lithostratigraphic successions. Based on superposition of stratigraphic units, it appears likely that the Snowbird Group may be chronostratigraphically equivalent to lower parts of the Great Smoky Group and the Walden Creek Group may be similarly equivalent to parts of the upper Great Smoky Group.

Because of uncertain stratigraphic relations, several "unclassified" lithostratigraphic units remained after the work of King et al. (1958). Our contribution to Ocoee stratigraphy is the assignation of most of these previously unclassified unites to the established formations based on structural criteria (Walters and Woodward, 1987; Connelly

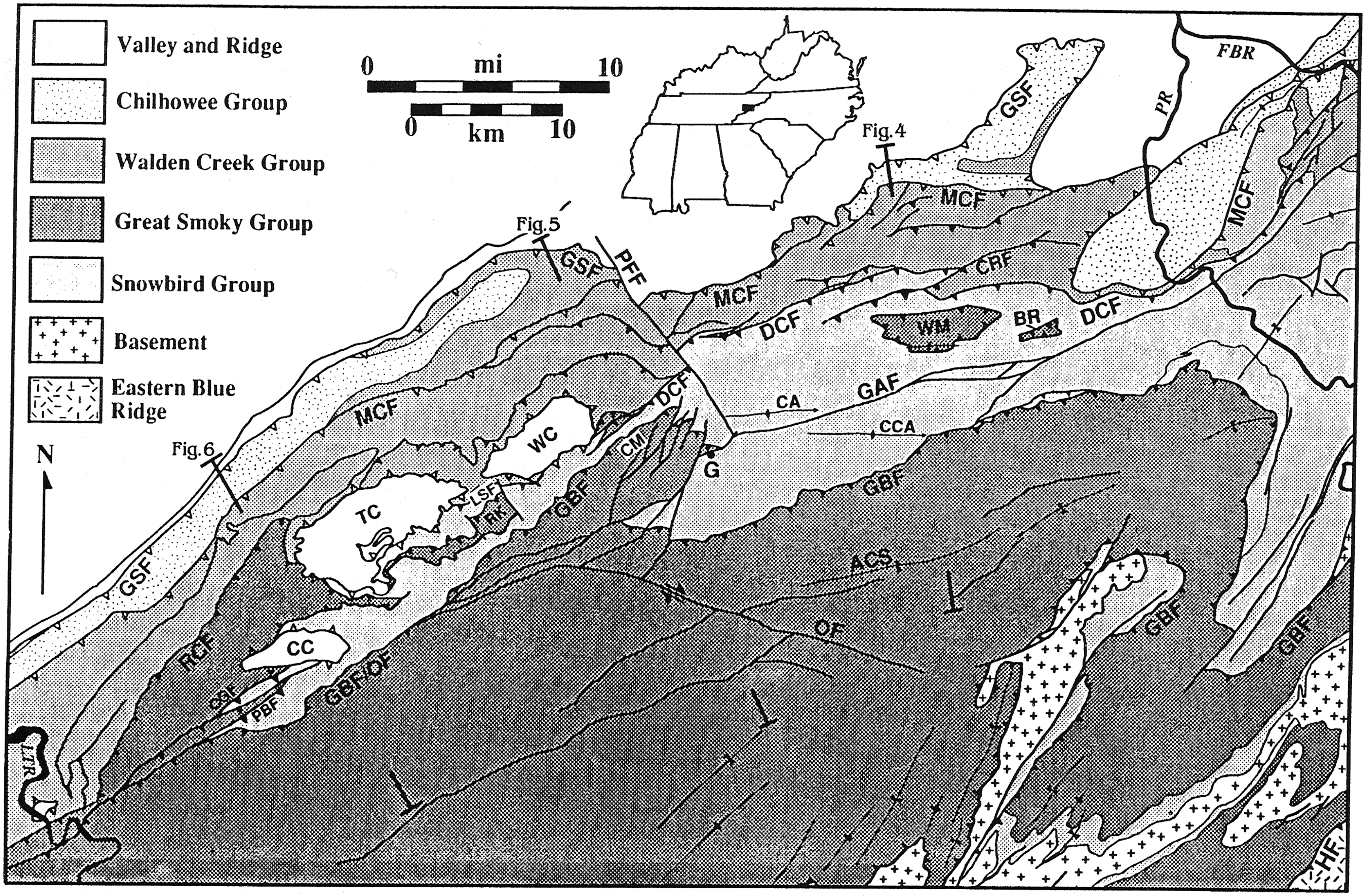


FIGURE 1. Regional map of the Great Smoky Mountains area (modified from King et al., 1968; Hadley and Neston, 1971, Walters, 1988, and Keller, 1980). ACS = Alum Cave syncline; BR = Big Ridge; CA = Cartertown anticline; CC = Cades Cove; CCA = Copeland Creek anticline; CGF = Colen Ground fault; CM = Cove Mountain; CRF = Chestnut Ridge fault; DCF = Dunn Creek fault; FBR = French Broad River; G = Gatlinburg; GAF = Gatlinburg fault; GBF = Greenbrier fault; GSF = Great Smoky fault; HF = Hayesville fault; LSF = Line Springs fault; LTR = Little Tennessee River; MCF = Miller Cove fault; OF = Oconaluftee fault; PBF = Parsons Branch fault; PFF = Pigeon Forge fault; PR = Pigeon River; RCF = Rabbit Creek fault; RK = Roundtop klippe; TC = Tuckaleechee Cove; WC = Wear Cove; WM = Webb Mountain. Thrust faults with open teeth late and with closed teeth early. Cross-section lines are shown for Figures 4, 5, and 6.

Table 1. Stratigraphic units of the Ocoee Supergroup (after King, 1964).

Age	North of and below Greenbrier fault				
Cambrian (?) and Cambrian	Chilhowee Group		Cochran Formation and higher units		
Later Precambrian	Ocoee Series	Walden Creek Group (PЄwc)	Sandsuck Formation Wilhite Formation Shields Formation Licklog Formation		
			Western GSM	Eastern GSM	
		Unclassified Formations	Cades Sandstone	Rocks of Webb Mt. and Big Ridge	Rich Butt Sandstone
		Snowbird Group	Metcalf Phyllite	Pigeon Siltstone (PЄp) Roaring Fork Sandstone (PЄr) Longarm Quartzite (PЄl) Wading Branch Formation (PЄw)	
			Base not exposed	Unconformity	
Earlier Precambrian				Basement complex	

Correlation between these sequences uncertian

Age	South of and above Greenbrier fault		
Cambrian (?) and Cambrian	Rocks of Murphy marble belt		Nantahala Slate and higher units (Early Paleozoic (?))
			Lithologic break, but probably conformable
Later Precambrian	Ocoee Series	Great Smoky Group (PЄgs)	Unnamed sandstone Anakeesta Formation (PЄa) Thunderhead Sandstone (PЄt) Elkmont Sandstone (PЄe)
		Snowbird Group	Roaring Fork Sandstone (PЄr) Longarm Quartzite (PЄl) Wading Branch Formation (PЄw)
			Unconformity
Earlier Precambrian			Basement complex

and Woodard, 1990). We assign most of the unclassified formations (Cades Sandstone, Rocks of Webb Mountain and Big Ridge) to the lithologically similar Great Smoky Group (Fig. 1). The Metcalf Phyllite is recognized as a highly tectonized part of the Snowbird Group, within which most sedimentary structures have been variably transposed.

Structural Geology

Thrust faults are the dominant geologic structures within the GSM area (Fig. 1). The older thrust faults in this area are interpreted to be Ordovician (Taconic) in age (e.g. Hadley and Goldsmith, 1963; King, 1964; Connelly and Dallmeyer, 1991). During the Carboniferous Alleghanian orogeny, this stack of Taconic thrust sheets was emplaced into its current position by the Great Smoky fault, and later folded (King, 1964; Neuman and Nelson, 1965) into a basin and dome (window) pattern by Alleghanian thrust structures of the Valley and Ridge (Boyer and Elliott, 1982; Woodward, 1985). In order to understand the geometry of the Taconian thrust sheets in the GSM area, we must first remove the effects of the younger deformation event.

The major fault systems in the GSM area are 1) the post-Great Smoky Gatlinburg fault system; 2) the Alleghanian Great Smoky fault system, including the Miller Cove fault. The Miller Cove fault separates cleaved rocks on the southeast from uncleaved rocks of the Chilhowee Mountain block, the English Mountain block, and the Valley and Ridge to the northwest; 3) the Taconian early Miller Cove fault system that bounds the cleaved and faulted rocks of the Miller Cove thrust sheet, but that is now occupies by the Alleghanian Miller Cove fault; 4) the Taconian Dunn Creek-Line Springs-Rabbit Creek fault system; and 5) The Taconian Greenbrier fault.

Cleavage

Hadley and Goldsmith (1963) and King (1964) recognized that metamorphic isograds cross the major structures within the GSM region, and are truncated by the Miller Cove and Great Smoky faults. Two additional elements of the rock fabric evolution of this area are key to interpreting the structural history. Hamilton (1961) recognized that throughout most of the eastern GSM, cleavage diverges from the axial planes of folds and therefore may have been superimposed on the folds. Connelly et al. (1989) established that his cleavage is axial planar to folds within the Miller Cove thrust sheet, but transects most other structures within the Dunn Creek and Greenbrier thrust sheets (Fig. 2). The structures within the overlying Dunn Creek and Greenbrier thrust sheets can therefore be placed in a hinterland to foreland sequence of deformation.

Connelly and Dallmeyer (1990, 1991) reported ^{40}Ar/^{39}Ar whole rock and muscovite results from a transect across the eastern GSM. Metamorphic cooling ages from the chlorite metamorphic zone, where cooling effects are minimal, range from 460 Ma to 420 Ma, suggesting a Taconian age of metamorphism. The GSM therefore preserve a rare record of Taconian low-grade thrust systems which have been only slightly overprinted by later deformation.

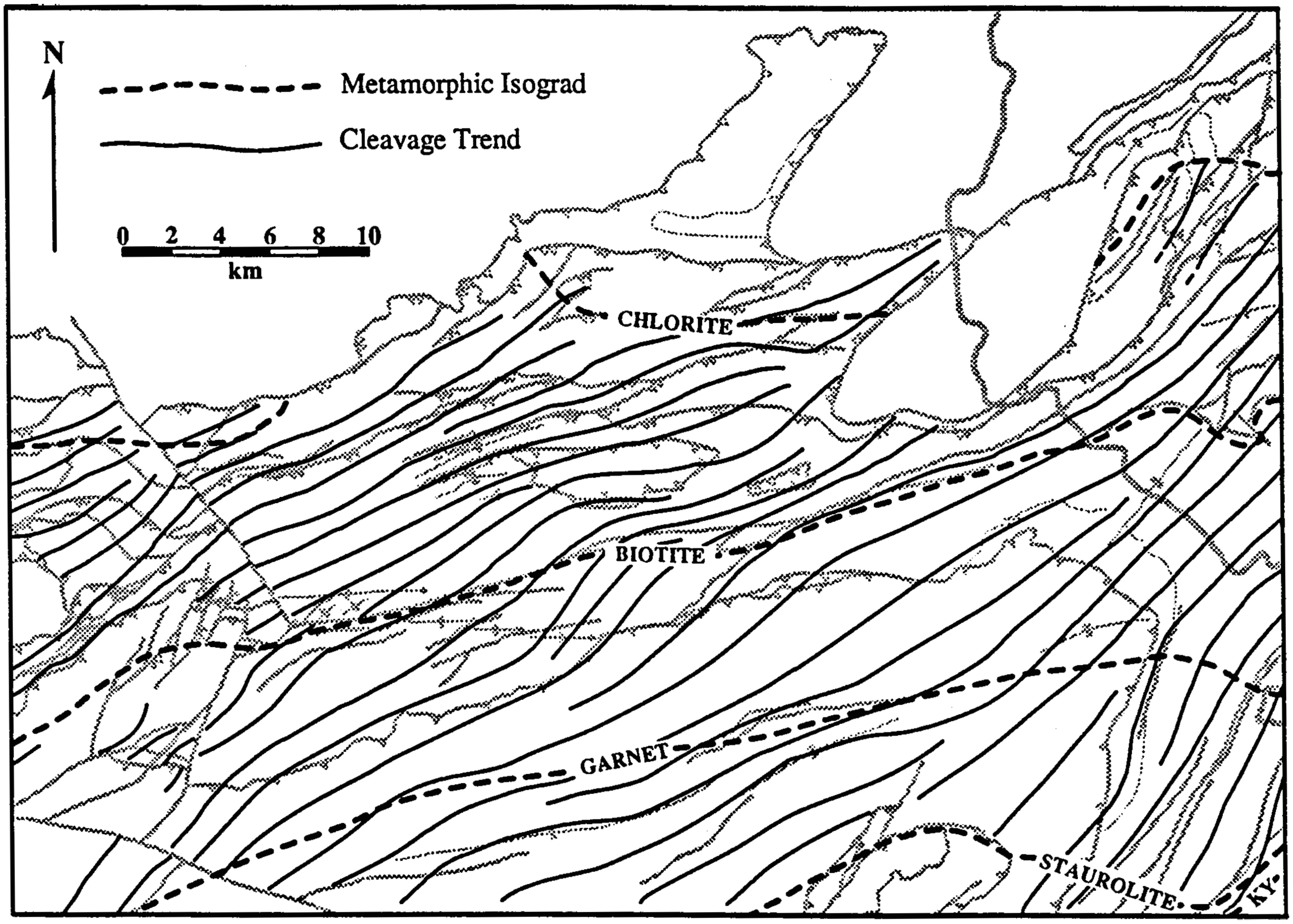


Figure 2. Cleavage from lines and metamorphic isograds from the eastern GSM (northeast corner of Fig. 1) Cleavage and isograds transect the major structures of the Greenbrier and Dunn Creek thrust sheets and are axial planar to folds in the Miller Cove thrust sheet (based on data from Hamilton, 1961; Hadley and Goldsmith, 1963; King, 1964; Keller, 1980; and Connelly, in pre.).

FAULT SYSTEMS

Gatlinburg Fault

The Gatlinburg fault system trends east-northeast and cuts across all of the earlier fold and thrust structures in the GSM (Fig. 1). King (1964) suggested that it is a late high-angle reverse fault system, but displacements are relatively minor (hundreds of meters) and no ramp-related folding, typical of thrusts, has been recognized. If high-angle reverse motion had consistently occurred on Gatlinburg –system faults, repetition of the low-angle fault structures, such as those of the Dunn Creek fault at the Pigeon River, would be expected, but his is not observed.

The Gatlinburg-system faults roughly parallel the major east-northeast late fold trends that dome the overlying Great Smoky thrust sheet even where they transect structures within it. Strata of different groups within the Ocoee are rarely juxtaposed by Gatlinburg-system faults; where units are juxtaposed, the offsets omit strata as commonly as they duplicate strata. The geographic distribution of faults that omit strata is one of symmetry along the domal trends of the folded Great Smoky thrust sheet, with the culmination-side block up thrown in almost all cases.

Fault zones along Gatlinburg system faults generally contain openwork breccias (King, 1964; Robert, 1987). These brittle fault fabrics contrast with the ductile fabrics observed within most other thrust zones in the GSM. These lines of evidence suggested to Woodward (1986) that the Gatlinburg faults are dominantly extensional in origin and related to post-emplacement extension of the crystalline Great Smoky thrust sheet as it was folded over subthrust duplex horses. In some areas these extensional motions reactivated earlier thrusts or partially truncated them, and in other areas all earlier thrusts and folds are truncated.

Other late high-angle faults that offsets al other structures include the Pigeon Forge fault and the Oconaluftee fault (Fig, 1). These faults diverge from the east-northeast trend of the main Gatlinburg system faults, but likely formed at approximately the same time and may be included in the Gatlinburg fault system.

Great Smoky Fault

The Great Smoky faults is part of the Blue Ridge Piedmont thrust sheet and emplaces rocks of the Blue Ridge province over the Valley and Ridge province. Paleozoic strata from the Cambrian Chilhowee Group up through the Cambro-Ordovician Knox Group are present in different places within the Blue Ridge thrust sheet. In the GSM region, only rocks as young as the Rome Formation are preserved in the Chilhowee Mountain and English Mountain fault blocks. In northeastern Tennessee, rocks as young as the Knox Group are exposed within the allochthonous Shady Valley synclinorium. Rocks this young within the Blue Ridge thrust sheet require that the footwall cutoffs of these units beneath the Blue Ridge must extend nearly to the Brevard zone or beyond (Harris et al., 1981) no matter how the subthrust structural details are drawn (Boyer and Elliott, 1982; Woodward, 1985; Hatcher et al., 1987; 1990).

Displacement along the Great Smoky fault has been estimated by Hatcher (1989) to be between 350 and 500 km. Final emplacement of the Great Smoky thrust sheet occurred during the Alleghanian orogeny, but the estimated magnitude of this displacement suggests that transport occurred over an extended period of time. At time-average foreland thrusting rates of 0.1 cm/yr (Royse et al., 1975), emplacement could have taken more than 350 Ma. As will be discussed in greater detail later, the Great Smoky fault observed today occupies earlier ductile deformation zones in a number of areas. Thus, the base of the Great Smoky sheet in a number of areas may truncate any of the earlier thrust sheets. Where well exposed, the basal Great Smoky thrust zone appears to be a mesoscopically faulted process zone (Hatcher and Milici, 1986) similar to that observed along Valley and Ridge faults (Harris and Milici, 1977; Wojtal, 1986). A major component of deformation in these mesoscopically faulted process zones is partitioned into extension of the fault zone during thrust motion (Wojtal, 1986; Woodward et al., 1988; Erickson and Wiltscho, 1991). It is not clear if the lowest parts of the Taconian thrust stack have been variably removed in different places by this mesoscopic faulting, or if the Great Smoky fault simply truncated the Taconian thrust stack at different levels in different places.

Miller Cove Fault

The most external major structural boundary preserved within the Blue Ridge is the Miller Cove fault, which juxtaposes cleaved Walden Creek Group strata on the south and southeast with uncleaved Chilhowee and Walden Creek Group strata on the north and northwest (King, 1964; Costello, 1984; Fig. 3A). Hamilton (1961) called the fault that juxtaposes these same rocks south of English Mountain the Great Smoky fault, and called the fault juxtaposing the Chilhowee strata and Valley and Ridge strata the English Mountain fault. We prefer to reserve the Great Smoky fault name for the northwesternmost Blue Ridge bounding fault (e.g. Hatcher et al., 1989). Because both the Miller Cove fault and Great Smoky fault of Hamilton (1961) south of English Mountain juxtapose the same stratigraphic sequences a short distance along strike form on another, we consider them to be (have been) continuous, with their branch line with the Great Smoky fault partially eroded where cleaved Ocoee strata are in direct contact with Valley and ridge rocks, such as east of the Pigeon Forge fault (Fig. 1). This Miller Cove fault (in the broad sense) must be post-Taconic because it separates rocks with Taconian cleavage from those without it. It most likely formed early in the motion of the Great Smoky thrust system, juxtaposing previously thrust faulted and deformed Ocoee strata against the undeformed footwall ramp of uncleaved Chilhowee and Sandsuck strata.

Early Miller Cove Fault

Cleavage within the Walden Creek Group strata of the Miller Cove thrust sheet is parallel to many small-displacement ductile thrust faults and is axial planar to folds associated with these faults. The ductile Chestnut Ridge fault (Figs. 1, 3A; Connelly, in prep.) is a well exposed example that truncates the overlying Dunn Creek fault north of Webb Mountain. Given the geometries of the cleavage is related to body deformation within a moving thrust sheet deformed under ductile conditions (see Mitra and Elliott [1980] for an example of similar cleavage-thrust relationships in the Virginia Blue Ridge). We infer, therefore, that the base of this Taconian "early Miller Cove" thrust sheet was either reactivated as, or truncated by, the brittle Miller Cove fault during the Alleghanian. It is unclear how much of the early ductile thrust zone may be preserved at the base of the early Miller Cove sheet given the relatively small preserved regional area of this thrust sheet.

Early Miller Cove thrust sheet deformation trends northeast across all earlier-formed structures in the GSM (Witherspoon, 1981; Fig. 2). The late folds refold the more east-west structures in the Dunn Creek and Greenbrier sheets steepening the plunge early fold hinges and causing small fold hinge offsets across related late minor faults.

Dunn Creek- Line Springs – Rabbit Creek Fault System

A broad belt of Pigeon Siltstone (Snowbird Group) within the Dunn Creek thrust sheet separates the Miller Cove thrust sheet from the Greenbrier thrust sheet in the eastern GSM (Figs. 1, 3B). Just west of Gatlinburg, however, the

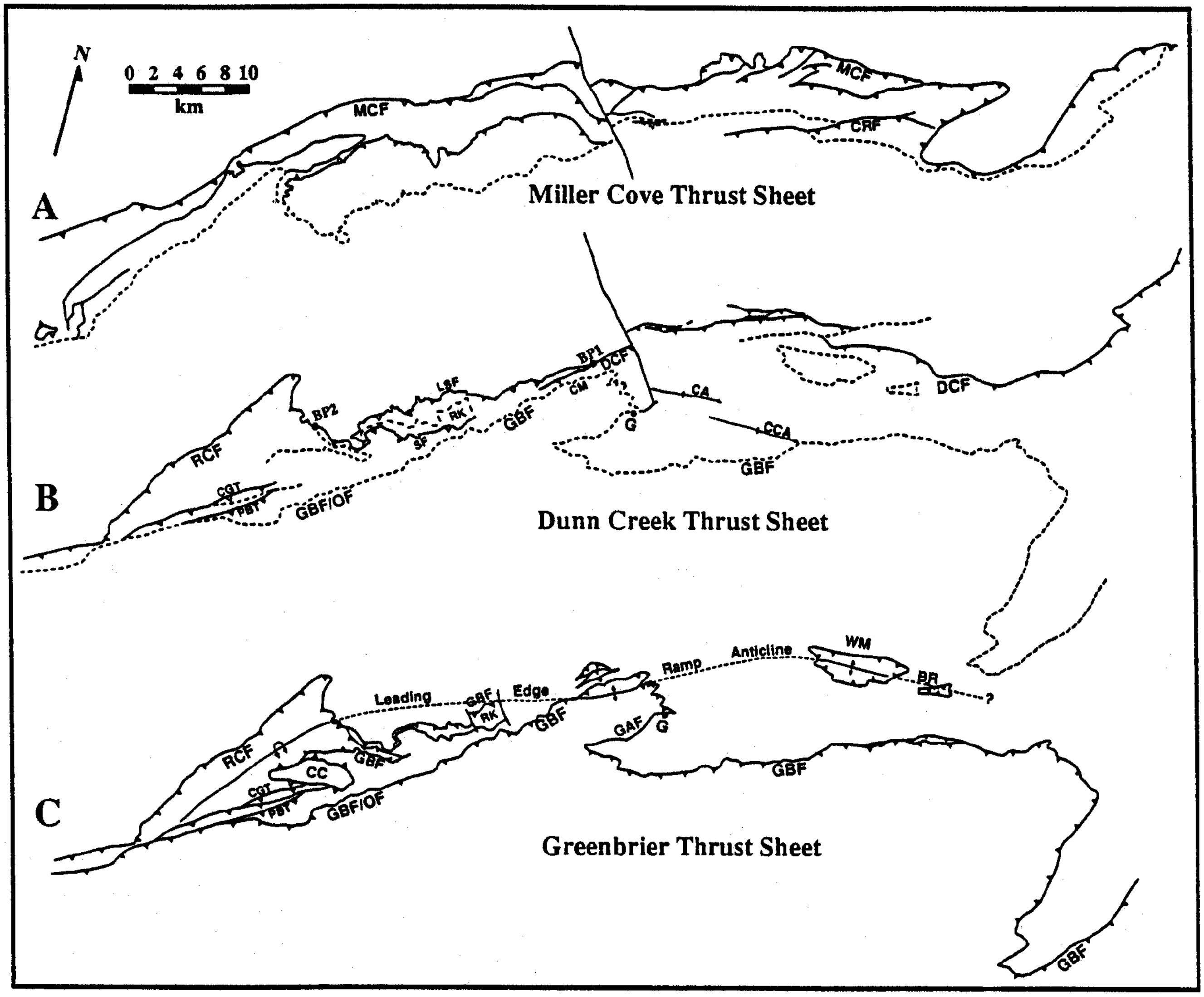


FIGURE 3. Outline maps of the Miller Cove, Dunn Creek, and Greenbrier thrust sheets. Abbreviations the same as those in Fig. 1. A: Outline map of the Miller Cove thrust sheet. Solid barbed lines indicate the Miller Cove thrust and its imbricates. Dashed lines show the trailing edges of the thrust sheet. B: Outline map of the Dunn Creek-Line Springs-Rabbit Creek thrust sheet. The Greenbrier leading edge branch line is exposed north of Cove Mountain (branch point BPI) and on the southwest edge of Tuckaleechee Cove (BP2). The Parsons Branch, Coalen Ground, and Sinks faults are ductile imbricates of the Dunn Creek-Line Springs-Rabbit Creek thrust zone because they all transect and repeat parts of Metcalf Phyllite ductile deformation zones and the overlying Greenbrier thrust sheet. C: Outline Map of the Greenbrier thrust sheet including the Cades Sandstone and the rocks of Webb Mountain and Big Ridge. There is a leading edge hanging wall ramp anticline exposed at Webb Mountain, Cove Mountain, and within the Rabbit Cove nappe. It has been folded by deformation in the Dunn Creek thrust sheet.

Greenbrier sheet extends northward around an eastwardly concave reentrant and directly overlies the Miller Cove thrust sheet on the north ridge of Cove Mountain. Although many of the present boundaries between the Greenbrier sheet and structurally lower thrust sheets are late Gatlinburg-system faults, the Dunn Creek sheet clearly thins northward and westward to become a horse block bounded by the Greenbrier and Dunn Creek-Line Springs thrust faults. Down-dip plunging folds within the Pigeon Siltstone become much more common from east to west as this reentrant is approached, and the overlap area coincides with the appearance of the highly tectonized Metcalf Phyllite of the Snowbird Group.

Southwest of Wear Cove, the Line Springs fault forms the base of the Metcalf Phyllite. Bedding within the Metcalf becomes less recognizable, and in many areas the tectonite fabric is characterized by shear bands (King, 1964; Witherspoon, 1981; Woodward et al., 1989). A zone of shear-banded Metcalf Phyllite between the Line Spring fault and the klippe of the Greenbrier thrust sheet at the Sinks (Roundtop klippe; Lewis, 1988) approaches half a kilometer in thickness. In this area, the Line Springs fault delineates the base of the Metcalf ductile deformation zone and the Greenbrier fault delineates the top. The Great Smoky fault occupies the position of the older Line Springs fault zone on the southeast side of Wear and Tuckaleechee Coves. The Rabbit Creek fault branches from the Line Springs fault zone on the west side of Tuckaleechee Cove and places Cades Sandstone over the Wilhite Formation (Walden Creek Group) of the Miller Cove sheet from there southwestward to beyond the Little Tennessee River at Chilhowee Lake.

The broad Dunn Creek thrust sheet east of Gatlinburg is relatively little affected by the folds, faults, and cleavage of underlying thrust sheets. The internal structural geometry of this sheet is therefore of great interest. The major fold structure of the Dunn Creek thrust sheet is the Cartertown-Copeland Creek anticline. Hinge regions of this fold have been modified by superimposed strains, which have also tightened interlimb angles. It is a major east-plunging box anticline that extends westward into the reentrant in the Greenbrier thrust sheet at Gatlinburg. Because the Dunn Creek sheet was emplaced prior to significant cleavage formation, it is attractive to treat it as a foreland-style thrust sheet in which major anticlines are interpreted to overlie the positions of major hanging-wall ramps (Dahlstrom, 1970). If this interpretation as applied to the Dunn Creek thrust sheet is correct, then the Cartertown-Copeland Creek anticline marks the ganging wall segment of the major ramp through the Snowbird Group (Connelly and Woodward, in press).

The reentrant in the Greenbrier thrust sheet, although dissected by later faults, roughly follows the shape of this anticline in the underlying thrust sheet, suggesting that the Greenbrier thrust sheet is simply folded over it. Similar styles of thrust sheet deformation were observed by Jones (1971) in the Alberta foothills.

Greenbrier Fault

The Greenbrier thrust sheet is comprised of Great Smoky Group strata of the Thunderhead, Elkmont and Anakeesta Formations throughout the GSM area (Figs. 1, 3C). The leading edge of the Greenbrier thrust sheet contains segments of the Greenbrier, Gatlinburg, and Oconaluftee fault systems. The Greenbrier fault as mapped (king, 1964) underlies several klippen in front of the main fault trace north of Cove Mountain and at the Sinks. We infer that it also underlies the Cades Sandstone north of Cades Coves and the rocks of Webb Mountain and Big Ridge (Walters and Woodward, 1987; Connelly and Woodward, 1990; Fig. 3C).

Connelly (in prep.) remapped the rocks of Webb Mountain and Big Ridge and documented that the coarse sandstones everywhere overlie a mylonitic (Greenbrier) fault zone that juxtaposes them with underlying Snowbird Group rocks. Bedding in sandstones at Webb Mountain and Big Ridge is at a high angle to the fault across the mylonitic zone on the south side of the mountains (hanging-wall flat on footwall flat). We interpret these structural geometries as the leading edge hanging wall ramp anticline of the Greenbrier thrust sheet that was later folded by underlying structures and is now mostly eroded (Connelly and Woodward, in press).

Great Smoky Group strata near the front of the main Greenbrier thrust sheet dip homoclinally southward in most areas. King (1964, cross section I' –I") shows that bedding in the Thunderhead Sandstone on Cove Mountain, however, dips steeply into the thrust forming a hanging wall ramp anticline inferred at Webb Mountain (Fig. 3C). Southwest of Cove Mountain, King (1964, cross section J" – J"") illustrates that bedding within the Greenbrier sheet is again approximately parallel to the thrust surface behind the ramp on Cove Mountain (Fig. 3C). This flat-on relationship has been folded and truncated by the later ductile Sinks fault, which we infer to be one of the Line Springs (Dunn Creek system) imbricates (Lewis, 1988).

Walters (1988) remapped the Cades Cove area and documented that the Cades Sandstone everywhere overlies the Metcalf Phyllite along a mylonitic fault zone. A recumbent fold (Rabbit Creek nappe) defined by the Cades Sandstone north of Cades Cove occupies the present leading edge of the Greenbrier thrust sheet. Mylonites in the Greenbrier fault zone on the north side of Cades Cove appear truncated by the fault that underlies the Rabbit Creek nappe. Thus, although we believe that the recumbent fold began as the leading edge ramp anticline of the Greenbrier thrust sheet, it has been significantly modified by subsequent motion on the Rabbit Creek fault (Dunn Creek system).

Superimposed Imbricate Faulting

Because the Rabbit Creek and Greenbrier thrust sheets are so thin at their leading edges in the western GSM, the senses of the various fault generations can be easily identified. The major fault contacts of the area are 1) the Greenbrier (Oconaluftee) system, which bounds the northern side of the Great Smoky Group outcrop belt; 2) the Rabbit Creek fault, which emplaces the overturned Cades Sandstone onto the Walden Creek Group of the Miller Cove thrust sheet; and 3) the Great Smoky fault, which underlies the Metcalf Phyllite and Cades Sandstone around the Cades Cove window.

In the western GSM, Neuman and Nelson (1965) observed that the Metcalf Phyllite appears to stratigraphically overlie the Cades Sandstone in some exposures and stratigraphically underlie it in others. Thus, they suggested that the two units may intertounge. Fault rocks and structures along the contacts, however, indicate that the lithologic contacts in the area are faults rather than stratigraphic contacts

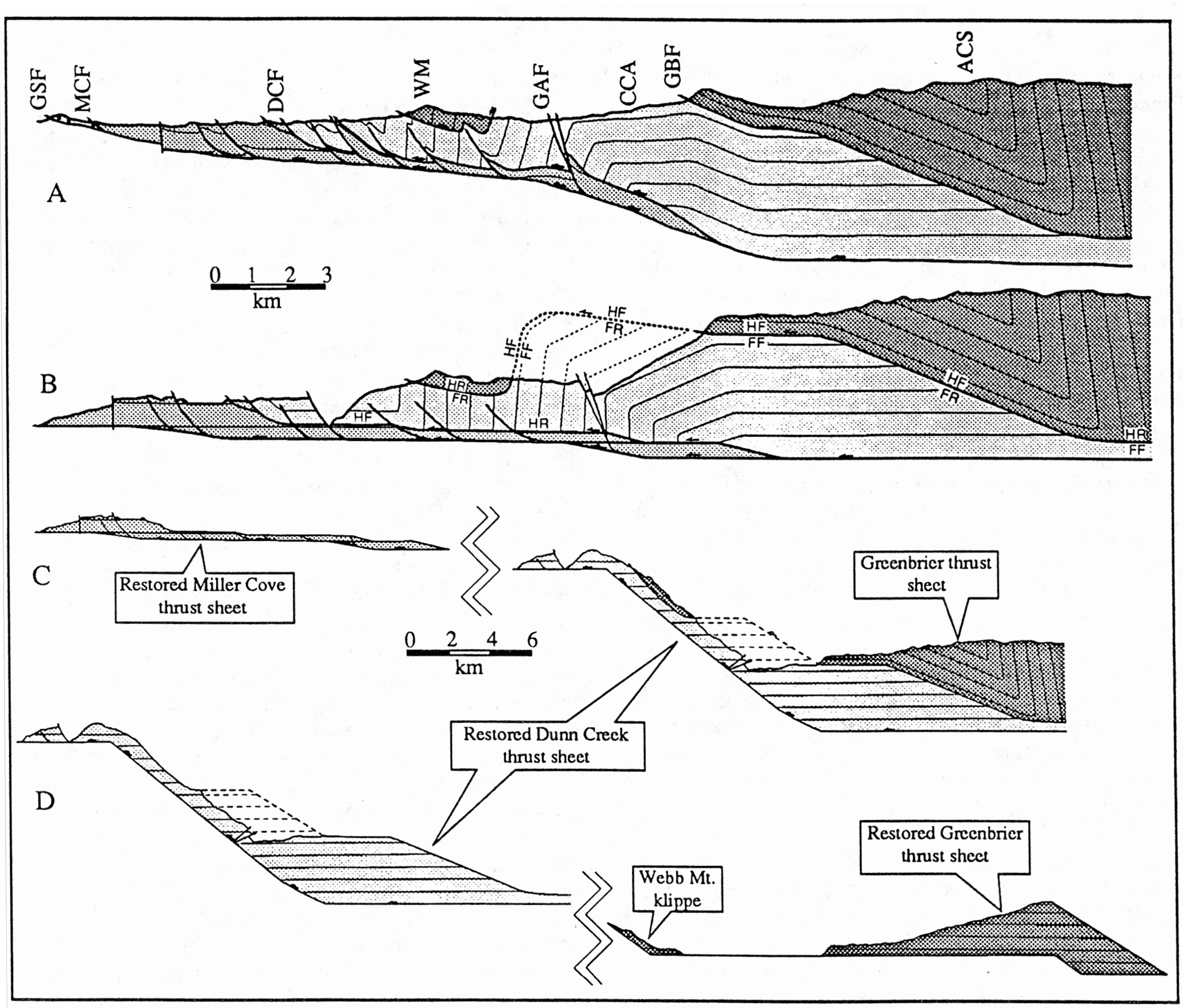


FIGURE 4. Cross section across the eastern GSM through Webb Mountain. A: Present day (deformed) cross section. B: Cross section restored to pre-early Miller Cove deformed section. C: Cross section restored to pre-Dunn Creek deformed section. D: Fully restored section. HR = hanging wall ramp; HF = handingwall flat; FR = footwall ramp; FF = footwall flat. Other abbreviations and patterns same as those in Fig. 1.

(Walters, 1988).

The Metcalf Phyllite overlies the Cades Sandstone in two outcrop belts on the southwest side of Cades Cove. The Metcalf along the southern contact shows well developed shear band structures with a reverse, northwest, sense of displacement. Walters (1988) called this the Parsons Branch fault (Figs. 1, 3C). The Cades Sandstone in the Coalen Ground thrust sheet beneath the Parsons Branch fault is upright and southeast dipping although relatively highly strained (2.7:1 X:Z axial ratio measured on conglomerate clasts). This unit in turn overlies shear-banded Metcalf Phyllite along a repeated segment of the Greenbrier fault. The Metcalf beneath this segment of the Greenbrier is again thrust above overturned Cades Sandstone along the Coalen Ground fault.

The most important contact relation in the western GSM that demonstrates the stratigraphic relationships of these unclassified units is on the north side of Cades Cove, where the Metcalf Phyllite dips to the northwest beneath the Cades Sandstone. This was shown as a stratigraphic contact by Neuman and Nelson (1965), but the contact has shear bands and ribbon quartz indicating that it is a north vergent ductile thrust fault. The Greenbrier fault in this area dips toward and is cut off by the Great Smoky/Rabbit Creek fault. Thus, the

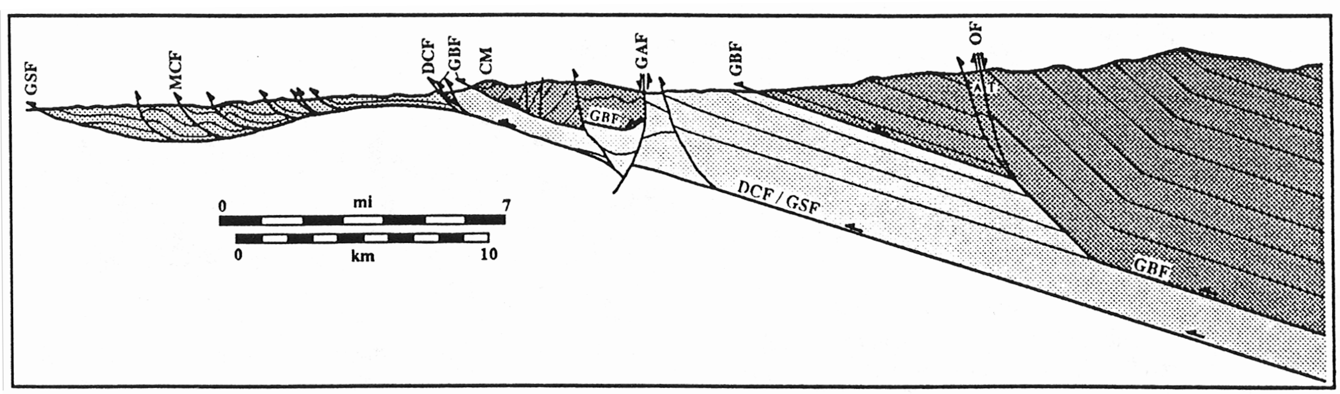


Figure 5. Cross section across Cove Mountain in the Central GSM (after King, 1964, section G-G'"). Abbreviations and patterns same as those in Fig. 1.

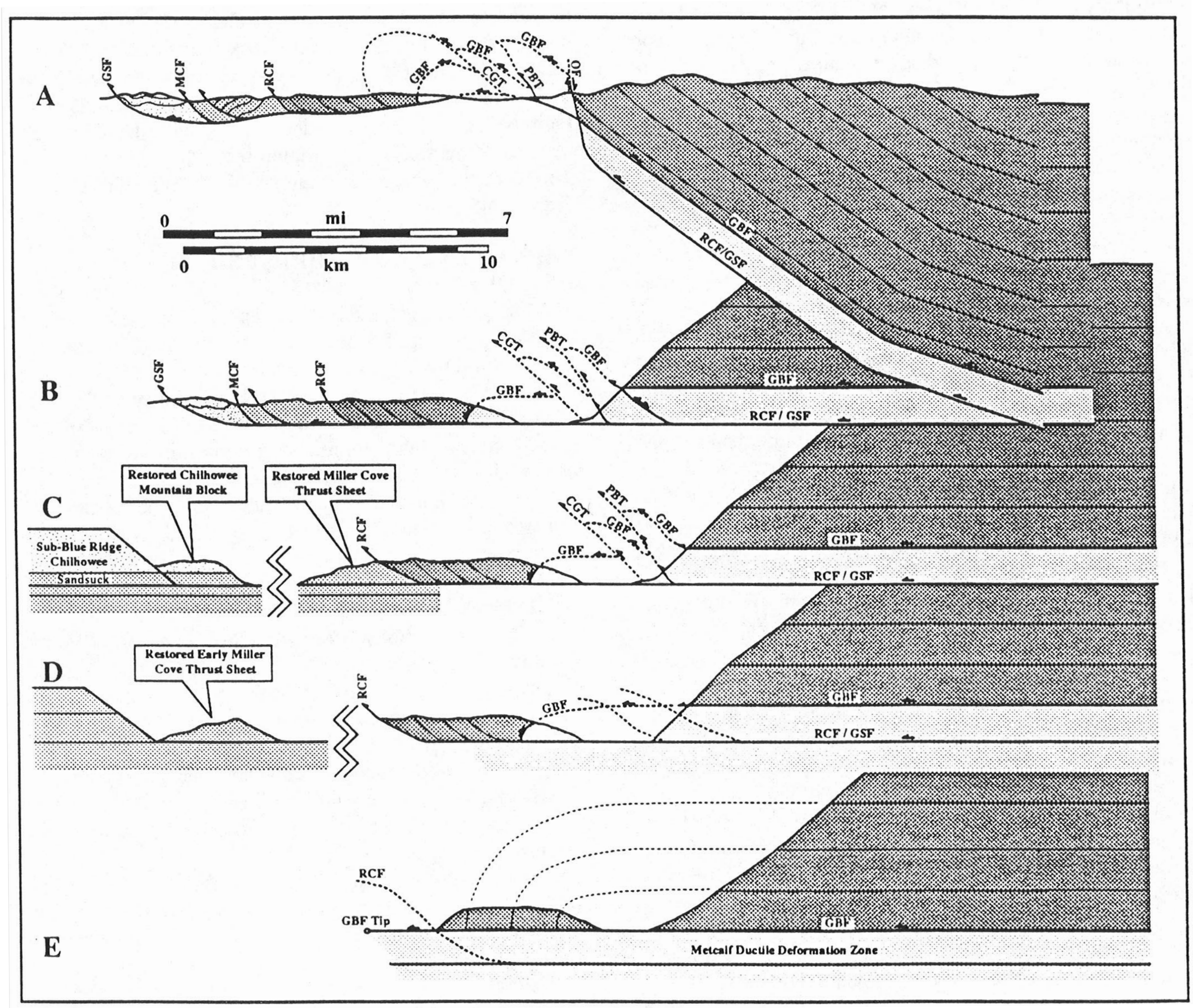


FIGURE 6. Cross section across Cades Cove in the western GSM (after Neuman and Nelson, 1965, section D-D'). A: Deformed section. B: Deformed section after removal of Alleghanian folding. C: Section restored to pre-Early Miller Cove deformed section. D: Section restored to pre-ductile imbrication. E: Section restored to pre-Rabbit Creek faulting. Abbreviations and patterns same as thosein Fig. 1.

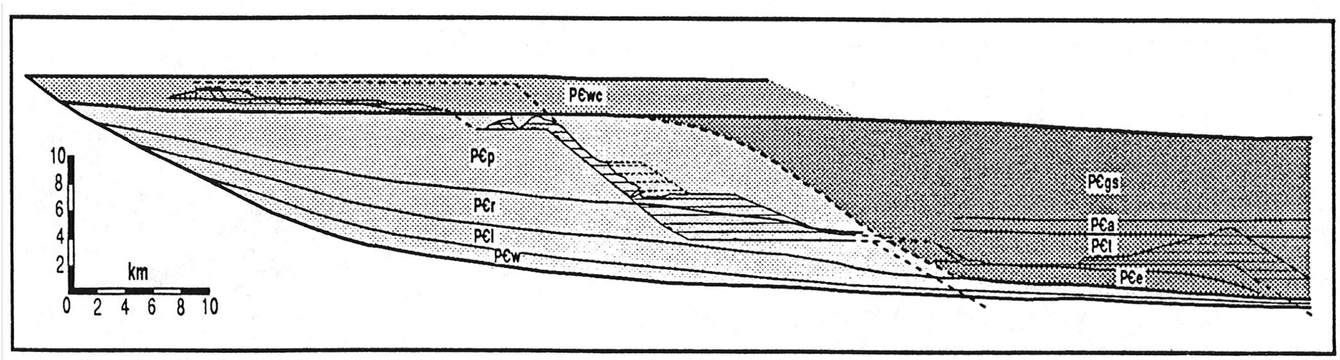


FIGURE 7. Schematic restored Ocoee basin prior to Ordovician deformation based on Figure 5. Positions of preserved thrust sheets and inferred fault trajectories shown. Abbreviations same as those in Table 1. Patterns same as those in Fig. 1.

Rabbit Creek fault as exposed, juxtaposes the overturned limb of the recumbent fold within the Rabbit Creek thrust sheet with the Miller Cove sheet, and therefore cannot simply be a continuation of the Greenbrier fault. The Greenbrier fault is cut by both the Parsons Branch and Coalen Ground faults south of Cades Cove and the Sinks fault farther east. We suggest that the Rabbit Creek fault also truncates the Greenbrier fault, but at a lower angle and with substantially greater displacement. We also suggest that many out of sequence ductile imbricate thrust faults in the GSM root in the Rabbit Creek Line Springs Dunn Creek fault zone regionally, but can only be uniquely be identified in a few areas.

Southwest of Cades Cove, tracing of any of the previously discussed faults continuously along strike for any distance is difficult if not impossible. Neuman and Nelson (1965) show the Oconaluftee fault trending more southward than the Rabbit Creek fault. Hardeman et al. (1966) showed the Oconaluftee Greenbrier fault cutting across the southern end of the Rabbit Creek fault, and Rodgers (1953) called the fault continuing across the Little Tennessee River the Gatlinburg fault.

The Oconaluftee and Gatlinburg faults are late brittle faults with variable displacement sense, and the Rabbit Creek system faults, whether in sequence or out of sequence, are ductile reverse faults. The late, ductile, high-angle reverse faults of the Parsons Branch Coalen Ground Sinks system truncate and repeat the leading edge of the Greenbrier sheet southwest of Cades Cove (Walters, 1988). Unrecognized members of this fault system are probably present within the Greenbrier thrust sheet and elsewhere, but they may be difficult to may unless they juxtapose different rock units. We suggest that there are multiple fault systems that truncate the leading edge of the Greenbrier thrust sheet, and that the trailing upright limb of the Rabbit Creek nappe may be emplaced entirely over the leading edge anticline south of the Little Tennessee River.

THRUST SEQUENCES

As noted previously, the regional salty cleavage of the GSM foothills belt transects (Fig. 2) and therefore postdates most of the major early fault and fold structures. Because the eastern GSM region preserves ramp anticlines in both the Dunn Creek and Greenbrier thrust sheets, a reconstruction of thrust patterns of this area is possible (Fig. 4). The reconstruction is presented in four steps from youngest to oldest. 4) The Great Smoky and Miller Cove thrust are restored, as are late brittle extension faults of the Gatlinburg fault system (Fig. 4A). 3) The early Miller Cove fault and ductile imbricate faults within the Miller Cove fault and Creek thrust sheets are restored (Fig. 4B). Within the eastern GSM foothills area, internal strains associated with the emplacement of the early Miller Cove thrust sheet are low (<30%) and are not accounted for in this restoration. 2) Dunn Creek thrust movement is restored returning the hanging wall flat leading edge and the hanging wall ramp beneath the Cartertown-Copeland Creek anticline to the top of the

Snowbird Group ramp (Fig. 4C). Unfolding of the Cartertown-Copeland Creek anticline also unfolds the Greenbrier thrust sheet as exposed at Webb Mountain and Big Ridge. Based on this restoration, minimum displacement of the Dunn Creek thrust sheet is ~22km.1) Webb Mountain, Big Ridge, and Cove Mountain all expose the leading-edge hanging-wall ramp anticline of the Great Smoky Group within the Greenbrier thrust sheet (Figs. 4,5). Restoration of the Greenbrier thrust sheet to its origin returns these klippen to the top of the Great Smoky Group ramp southeast of the Snowbird Group-Great Smoky Group facies change (Fig. 4D). A minimum displacement of ~23 km is estimated for the Greenbrier thrust sheet.

The Cades Cove area in the western GSM region can similarly be reconstructed in six stages (Fig. 6). 6) The Great Smoky thrust sheet is unfolded and late brittle faults (Gatlinburg-Oconoluftee) are restored. This requires removal of displacement on all Valley and Ridge faults beneath the Great Smoky fault (Fig, 6B). 5) Alleghanian Great Smoky and

Miller Cove thrusting is restored, returning the Chilhowee Mountain block to the Chilhowee-level footwall cutoff and returning the Miller Cove fault to its position of last probable Ordovician movement (probably on top of other Ocoee strata). This requires that ductile fault rocks once present at the base of the Miller Cove, Rabbit Creek and Greenbrier thrust sheets be restored to the base of the Alleghanian allochthon (Fig, 6C). 4) Displacement on the Taconian early Miller Cove fault is then removed, as well as the associated ductile faulting, folding, and cleavage formation within the Miller Cove and overlying thrust sheets. A steeply-dipping second cleavage within the Rabbit Creek nappe present near the Rabbit Creek fault north of Cades Cove is believed to be of this generation, although it has not been dated. This restores the Walden Creek Group of the Miller Cove thrust sheet to the Walden Creek upper footwall cutoff (Fig. 6D). 3) The Parsons Branch, Coalen Gound, Sinks, and other late ductile faults that splay up from the Rabbit Creek-Line Springs fault zone and truncate the trailing edges of the Rabbit Creek nappe and the Roundtop klippe are restored (Fig. 6D). 2) The ductile Rabbit Creek thrusting and overfolding that caused the high strains within the leading edge of the Greenbrier thrust sheet is restored. This restores the folded and truncated Greenbrier fault beneath the Cades Sandstone north of Cades Cove to its position of last movement. The leading edge of the Greenbrier thrust sheet is present at depth at the Rabbit Creek footwall cutoff of the Rabbit Creek faults (Fig. 6E). 1) By analogy with the eastern GSM restoration, 23 km of displacement on the Greenbrier fault is restored, returning the leading-edge hanging-wall ramp anticline to a footwall ramp through the Elkmont and Thunderhead Sandstone southeast of the Snowbird Group-Great Smoky Group facies change.

IMPLICATIONS FOR THRUST SHEET RESTORATION

The structural patterns that can now be documented significantly simplify the stratigraphic patterns within the GSM region and suggest a minimum restoration of this part of the Ocoee basin based on restorable cross sections (Fig. 7). This schematic restoration requires that the Great Smoky Group and Snowbird Group are in part chronostratigraphically equivalent. This reconstruction is similar to the model of Neuman and Nelson (1965), although the restored cross sections have allowed dimensions to be placed on the present reconstruction.

SUMMARY

The Great Smoky Mountains area is a paradigm for Taconian foreland-style deformation in the southern Appalachians, as well as an interesting case study of a cleaved and metamorphosed imbricate thrust stack. It is comprised of three stacked thrust sheets which have been collectively transported and folded together during Alleghanian emplacement of the Great Smoky thrust system.

Many of the thrust sheet boundaries in the GSM area re not thrust faults, but the distribution of the lithologies and an understanding of the kinematics of the truncating faults does allow the original thrust systems to be reconstructed accurately. Our emphasis on the positions of the thrust sheets and that simply tracing individual faults to other areas of the western Blue Ridge probably will not improve our understanding of the regional geology without simultaneous kinematic studies.

ACKNOWLEDGEMENTS

Woodward received financial support from NSF Grant EAR 83-12872, which supported the early stages of this research. Connelly, Walters, and Lewis received support from the Great Smoky Mountain Conservation Association and of the Department of Geological Sciences, University of Tennessee. Reviews by John Costello and Greg Guthrie significantly improved the manuscript.

REFERENCES CITED

Boyer, S. E., and Elliott, D., 1982, Thrust systems American Association of Petroleum Geologists Bulletin, v. 66, p. 1196-1230.

Connelly, J. B., in preparation, Structural development, strain history and timing of deformation in the Great Smoky Mountain Foothills, Tennessee [Ph. D. thesis]: Knoxville, University of Tennessee.

Connelly, J. B., and Dallmeyer, R. D., 1990, Ordovician or Silurian metamorphism in the western Blue Ridge, Tennessee?: Evidence from $^{40}Ar/^{39}Ar$ 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}Ar / ^{39} Ar ages: Geological Society of America Abstract with Programs, v. 23, p. 18.

Connelly, J. B., Woodward, N. B., and Walters, R. R., 1989, Polyphase early Paleozoic tectonism preserved in the western Blue Ridge; example from the Great Smoky Mountains National Park: Geological Society of America Abstract with Programs v. 21, p. 65.

Connelly, J. B., and Woodward, N. B., 1990, Sequential restoration of early Paleozoic deformation; Great Smoky Mountains foothills, Tennessee: Geological Society of America Abstracts with Programs v. 22, p. 8.

Connelly, J. B., and Woodward, N. B., 1991, Tectonic evolution of the Blue Ridge in east-central Tennessee: Geological Society of America Abstracts with Programs, v. 23, p. 18.

Connelly, J. B., and Woodward, N. B., in press, Taconian foreland-style thrust system in the Great Smoky Mountains, Tennessee: Geology.

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., 1984, Relationships between the Cartersville fault and Great Smoky fault in the southern Appalachians: a reinterpretation [M. S. thesis]: Columbia, University of South Carolina, 75 p.

Costello, J. O., and Hatcher, R. D., Jr., 1986, Contact relations 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.

Dahlstrom, C. D. A., 1970, Structural geology in the eastern margin of the Canadian Rockies: Bulletin of Canadian Petroleum Geology, v. 18, p. 332-406.

Erickson, S. G., and Wiltscho, D. V., 1991, Spatially heterogeneous strength in thrust fault zones: Journal of Geophysical Research, v. 96, p. 842 7 – 8439.

Ferguson, H. W., and Jewell, W. B., 1951, Geology and barite deposits of the Del Rio district, Cocke County, Tennessee: Tennessee Division of Geology Bulletin 57, 235 p.

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.

Hadley, J. B., and Nelson, A. E., 1971, Geologic map of the Knoxville quadrangle, North Carolina, Tennessee, and South Carolina: U. S. Geological Survey Miscellaneous Investigations Map I-654, 1:250,000.

Hamilton, W. B., 1961, Geology of the Richardson Cove and Jones Cove quadrangles, Tennessee: U. S. Geological Survey Professional Paper 349-A, 55 p.

Hardeman, W. D., 1966, Geologic Map of Tennessee: four sheets, Tennessee Division of Geology, 1:250,000.

Harris, L. D., and Milici, R. C., 1977, Characteristics of thin-skinned deformation style in the southern Appalachians and potential hydrocarbon traps: U. S. Geological Survey Professional Paper 1018, 40 p.

Harris, L. D., Harris, A. G., DeWitt, W., Jr., and Boyer, K. C., 1981, Evaluation of southern eastern overthrust belt beneath the Blue Ridge Piedmont thrust: American Association of Petroleum Geologists Bulletin, v. 65, p. 2497 – 2505.

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, Colorado, Geological Society of America, The Geology of North America, v. F-2, p. 511 – 535.

Hatcher, R. D., Jr., and Milici, R. C., 1986, Ocoee Gorge; Appalachian Valley and Ridge to Blue Ridge transition: Geological Society of America Centennial Field Guide, Southeastern Section, p. 265 – 270.

Hatcher, R. D., Jr., Williams, R. T., Costain, J. D., Coruh, C., Thomas, W. A., 1987, Palinspastic reconstruction of the southern Appalachians: Geological Society of America Abstracts with Programs, v. 19, p. 696.

Hatcher, R. D., Jr., Thomas, W. A., Geiser, P. A., Snoke, A. W., Mosher, S., and Wiltscho, D. V., 1989, Alleghanian orogen, 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.

Hatcher, R. D., Jr., Osberg, P. H., Drake, A. A., Jr., Robinson, P., and Thomas, W. A., 1990, Tectonic map of the U. S. Appalachians, in Hatcher, R. D., Jr., Thomas, W. A. and Viele, G. W., eds., 1989, The Appalachian-Ouachita orogen in the United States: Boulder, Colorado, Geological Society of America, The Geology of North America, v. F-2, Plate 1.

Jones, P. B., 1971, Folded faults and sequence of thrusting in the Alberta Foothills: American Association of Petroleum Geologists Bulletin, v. 55, p. 292 – 306.

Keller, F. B., 1980, Late Precambrian stratigraphy, depositional history, and structural chronology of part of the Tennessee history, and structural chronology of part of the Tennessee Blue Ridge [Ph. D. thesis]: New Haven, Connecticut, Yale University, 353 p.

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., Neuman, R. B. and Hadley, J. B., 1968, Geology of the Great Smoky Mountains National Park, Tennessee and North Carolina: U. S. Geological Survey Professional Paper 587, 23 p.

Lewis, J. C., 1988, Structural geology and finite strain analysis of the Precambrian Thunderhead Sandstone along the Greenbrier fault and Roundtop klippe: Great Smoky Mountains, Tennessee [M.S. Thesis]: Knoxville, University of Tennessee, 186 p.

Mitra, G., and Elliott, D., 1980, Deformation of basement in the Blue Ridge and the development of the South Mountain cleavage, in Wones, D. R., ed., The Caledonides in the U. S. A.: Blacksburg, Virginia, Virginia Polytechnic Institute and State University Memoir 2, p. 307 – 311.

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.

Oriel, S. S., 1950, Geology and mineral resources of the Hot Springs window, Madison County, North Carolina: North Carolina Division of Mineral Resources Bulletin 60, 70 p.

Rast, N., and Kohles, K. M., 1986, The origin of the Ocoee Supergroup: American Journal of Science, v. 286, p. 593 – 616.

Robert, L., 1987, Structural geology and geometries of the Denton duplex along the frontal Blue Ridge, near Hartford, Tennessee [M. S. thesis]: Knoxville, University of Tennessee, 147 p.

Rodgers, J., 1953, Geologic map of East Tennessee with explanatory text: Tennessee Division of Geology Bulletin 58, part II, 168 p.

Royse, F., Warner, M. A., and Reese, D. L., 1975, Thrust belt structural geometry and related stratigraphic problems Wyoming-Idaho-northern Utah: Rocky Mountain Association of Geology, Symposium on deep drilling frontiers in the central Rocky Mountains, p. 44 – 54.

Trumpy, R., 1969, The Helvetic nappes of eastern Switzerland: Ecolgae Geological Helvetiae, v. 62, p. 105 – 142.

Walters, R. R., 1988, Structural Geometries, fabrics and stratigraphic relationships in the Cades Cove region, Great Smoky Mountains National Park, Tennessee [M. S. thesis]: Knoxville, University of Tennessee, 145 p.

Walters, R. R., and Woodward, N. B., 1987, Structural relationships in the Cades Cove area, Great smoky Mountains National Park, Tennessee: Geological Society of America Abstracts with Programs, v. 19, p. 880.

Witherspoon, W. D., 1981, Structure of the Blue Ridge thrust front, Tennessee, southern Appalachians [Ph. D. thesis]: Knoxville, University of Tennessee, 165 p.

Wojtal, S., 1986, Deformation within foreland thrust sheets by populations of minor faults: Journal of Structural Geology, v. 8, p. 341 – 360.

Woodward, N. B., ed., 1985, Valley and Ridge thrust belt: Balanced structural sections, Pennsylvanian to Alabama: Appalachian Basin Industrial Associates, University of Tennessee Department of Geological Sciences Studies in Geology no. 12, 64 p.

Woodward, N. B., 1986, Fault geometries and tectonic reconstructions of the Tennessee Blue Ridge: Geological Society of America Abstracts with Programs, v. 18 p. 273.

Woodward, N. B., Wojtal, S. F., Mitra, G., Dunne, W., Simpson, C., Evans, M., and Costello, J., 1989, Geometry and deformation fabrics in the central and southern Appalachian Valley and Ridge and Blue Ridge: IGC field trip T 357, American Geophysical Union, 105 p.

Woodward, N. B., Wojtal, S., Paul., J. B., and Zadins, Z., 1988, Partitioning of deformation within several external thrust zones of the Appalachian orogen: Journal of Geology, v. 96, p. 351 – 361.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 69-77

POTASSIUM-ARGON DATING IN THE WESTERN BLUE RIDGE OF NORTH CAROLINA AND TENNESSEE

Stephen A. Kish
Department of Geology, Florida State University, Tallahassee, FL 32306

INTRODUCTION

Geological studies of metamorphic terranes are often hampered by the lack of well preserved fossil material that can be used to establish the stratigraphic age, and thus indirectly the ages of deformational and metamorphic events. Radiometric dating offers a means of establishing the ages of certain types of geologic events within a metamorphosed terrane; however, as in the case of paleontological studies applied to stratigraphy, the most accurate age estimates can only be established using several different approaches to extract satisfactory answers.

This paper presents the results of K-Ar dating in the Blue Ridge of Tennessee and North Carolina. It discusses the implications of this dating with respect to the age of Paleozoic sedimentation and metamorphism within this portion of the Blue Ridge.

GEOLOGICAL SETTING

The western Blue Ridge of southwestern North Carolina and adjacent Tennessee is basically an allochthonous anticlinorium, with a core of Grenville-age gneisses flanked by a cover sequence of late Precambrian and lower Paleozoic metasedimentary rocks of the Ocoee Supergroup and Chilhowee Group. The Ocoee Supergroup is one of the most extensive clastic sedimentary units in the southern Appalachian Blue Ridge (Hadley, 1970). In the Murphy belt of North Carolina and Georgia (Fig. 1) there is a sequence of metasandstones and marble that may be correlative with the Chilhowee Group and Shady Dolomite exposed on the western edge of the Blue Ridge (Hadley 1970). A sequence of clastic rocks overlying the marble has been proposed to be as old as Cambrian (Kish and other, 1975) or as young as Devonian (Tull and Groszos, 1990).

The age of a portion of the Ocoee Supergroup (the Walden Creek Group) has recently been proposed to be as young as middle Paleozoic on the basis of microfossils (Unrug and Unrug, 1990). Because rocks of the Walden Creek Group appear to have undergone the same metamorphic history as other units of the Ocoee Supergroup and the Blue Ridge as a whole, such an age assignment would have important implications with regard to the Paleozoic tectonic history of this region.

PREVIOUS GEOCHRONOLOGICAL STUDIES

Long and others (1959) and Kulp and Eckelmann (1961) conducted the first extensive K-Ar radiometric dating studies in the southern Appalachians. Their results indicated that K-Ar ages of metamorphic micas from the Blue Ridge were approximately 350 Ma; they interpreted these ages to be the approximate time of Paleozoic metamorphism. However, even during these initial studies it was recognized that argon might diffuse out of mica at temperatures significantly lower than those associated with the formation of the mica.

Hadley (1964) noted that the distribution of K-Ar and Rb-Sr radiometric dates of micas from crystalline rocks of the Appalachians had a high degree of correlation with the age of deposition of thick clastic wedges in the Appalachian Valley and Ridge. Hadley (1964) and Armstrong (1966) suggested that temperatures within the higher grade portions of a metamorphic belt would be maintained at sufficiently elevated levels following metamorphism to allow the continuous loss of ^{40}Ar for millions of years following the peak temperature conditions of regional metamorphism. Cooling would be largely controlled by erosion of the metamorphic terrane.

The transition from complete loss to complete retention of radiogenic argon (^{40}Ar) takes place over a narrow temperature range. This critical temperature is usually referred to as a “closure” or “blocking” temperature (Dodson, 1973). The most recent information concerning argon retention temperatures of various micaeous minerals indicated that diffusion of ^{40}Ar can occur at temperatures equivalent to, or lower than, lower greenschist facies metamorphism. The blocking temperature for argon diffusion in biotite is approximately 300^{O} $\pm$ 40^{O}C for muscovite (Dodson, 1973; Dodson and McCelland-Brown, 1985). Hornblende appears to retain ^{40}Ar at higher temperatures (500^{O} – 550^{O}c). Understanding the relationship between the radiometric age of minerals and their thermal (cooling) histories led to several different approaches to constrain the timing of Paleozoic metamorphism in the Blue Ridge.

Butler (1972) noted that the oldest K-Ar biotite ages in the Blue Ridge, mostly from lower amphibolite facies rocks, range from 380 to 440 Ma (Fig. 1). He proposed that these ages represent a minimum age of Paleozoic metamorphism. Kish (1974) obtained conventional D-Ar dates from slates (reported in this paper) of greenschist facies rocks and hornblende from upper amphibolite facies rocks (Kish, 1989). The ages of both types of materials have a significant range; however, in both slates and hornblendes there is a grouping of maximum ages around 480 Ma. Dallmeyer (1975, 1988b), using ^{40}Ar – ^{39}Ar dating of hornblende from the western Blue Ridge, obtained several release spectra of approxi-

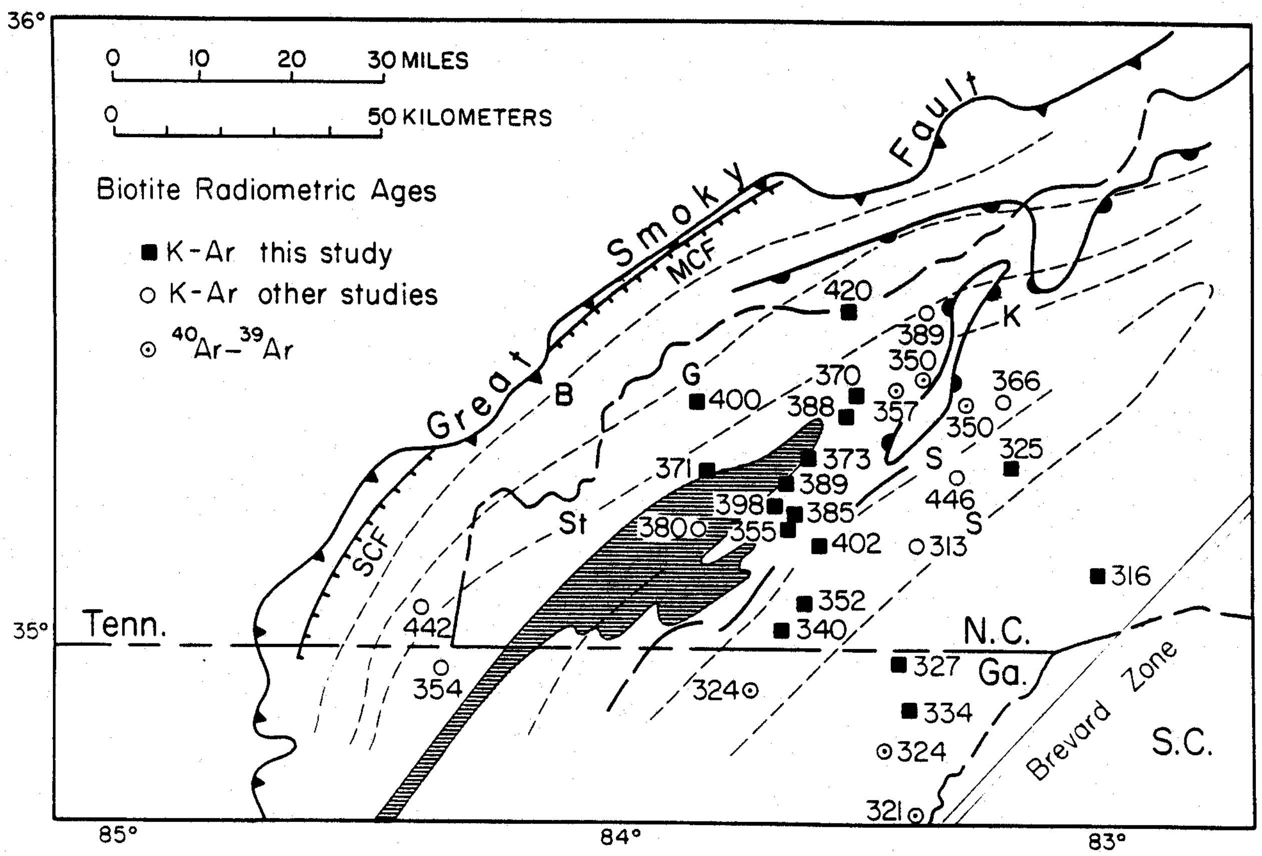


FIGURE 1. K-Ar and ^{40}Ar – ^{39}Ar biotite ages – Blue Ridge of southwestern North Carolina and adjacent Georgia and Tennessee. Ruled pattern represents rocks of the Murphy belt. Metamorphic isograds from Carpenter (1970): B = biotite: G = garnet: St = staurolite; K = kyanite; S = sillimanite. Faults: SCF = Sylco Creek fault; MCF = Miller Cove fault; heavy line with semicircles – Greenbrier fault; unlabeled heavy line = Hayesville fault. Sources of published data are give inTable 3.

mately 420 – 430 Ma for samples from both granitic basement rocks and calc-silicate layers in metasedimentary rocks of the Murphy belt (Fig. 4).

POSSIBLE PROBLEMS WITH K-AR AGES

A underlying assumption with a "cooling model" for K-Ar mineral ages is that the maximum observed mineral ages in a metamorphic terrane may only approximate a minimum age of metamorphism.

The usefulness of hornblende for studying the timing of metamorphic events is offset by its tendency to incorporate possibly significant amounts of "extraneous" ^{40}Ar during crystallization. This can produce K-Ar dates that in some cases greatly exceed the actual age of metamorphism (Roddick and Farrar, 1971; Wilson, 1972). It has also been demonstrated that biotite can also incorporate extraneous ^{40}Ar during crystallization (Brewer, 1969, Wilson 1972). An appropriate question to ask is whether the "old" mineral ages observed in the western Blue Ridge may be associated with the presence of excess ^{40}Ar in biotite and hornblende.

There are several ways to determine if a biotite or hornblende age is anomalously old. Because there are small differences in ^{40}Ar closure or blocking temperatures between muscovite and biotite, coexisting micas extracted from the same rocks yield K-Ar ages that are normally muscovite ≥ biotite (Cliff, 1985). A plot of K-Ar biotite versus Rb-Sr biotite for samples from both the eastern and western Blue Ridge (Fig. 3) demonstrates that the ~420 – 440 MA biotite ages are highly discordant, and have a reverse age relationship versus muscovite. These K-Ar biotite ages are suspect and are probably the result of "excess" ^{40}Ar.

The ^{40}Ar – ^{39}Ar spectra technique offers a means of detecting excess ^{40}Ar exhibit a "saddle-shaped" release spectra upon incremental heating (Cliff, 1985). Unfortunately, the process of in vacuo heating produces dehydration reactions that may be a important factor in the rate of argon release (Lee and other, 1991), and examples of apparently flat ^{40}Ar – ^{39}Ar spectra with anomalously old ages may exist (Maboko, 1991). An example of where excess ^{40}Ar can be demonstrated to be present in hornblende from the Blue Ridge are samples collected near ore-zone rocks at Ducktown, Tennessee (Fullagar and Bottino, 1970; Fullagar and others, 1980). Hornblende ^{40}Ar – ^{39}Ar ages in other parts of the western Blue Ridge (~420 Ma) are more problematical. Hornblende from calc-silicate zones in metasedimentary rocks of the Brasstown Formation (Dallmeyer, 1988b) have a moderately complex release spectra; hornblende from basement granitic rocks exhibits relatively flat release spectra (Dallmeyer, 1975a); both types of hornblende yield plateau ages of approximately 420 Ma. Kish (1989) noted that the ~480 Ma K-Ar hornblende ages from high grade amphibolites might be anomalously old, but observed that there was little variation in age despite a significant variation in potassium content. Samples with low potassium content would tend to have higher K-Ar ages versus samples with high potassium contents, if the samples incorporated roughly the same amount of excess ^{40}Ar.

Dating of muscovite from very low grade rocks can eliminate the effects of a prolonged cooling history; however, due to the very-fine grain size in slates and phyllites, K-Ar dating must be done by analyzing the whole rock sample was first proposed by Harper (1964) and applied with varying success in several orogenic regions. This method was first proposed by Harper (1964) and applied with varying success in several orogenic regions. The major advantages of this technique are: 1) the primary potassium phase in truly pelitic slates is a well-ordered white mica (muscovite or phengite); and 2) greenschist-facies metamorphism is associated with the higher structural levels of an orogen. Uplift and erosion rapidly cool rocks below the Ar blocking temperature for muscovite and phengite. Hence K-Ar whole rock slate ages will more closely approximate the age of regional metamorphism than K-Ar metamorphic rocks that remained at elevated temperatures long after the formation of metamorphic minerals.

Several problems are associated with the K-Ar dating of slates (Cliff, 1985, Sutter and others, 1985). Anomalously old ages can result when detrital muscovite is present in samples. This problem can be counterbalance by using sedimentologic techniques on crushed samples to obtain the very fine-gained (<2um) material, which is almost exclusively neomineralic. These problems can also be minimized by careful sample selection utilizing petrographic and X-ray diffraction studies to screen the samples. In areas where slates have been dated by both conventional K-Ar and ^{40}Ar / ^{39}Ar stepwise heating techniques, similar, but not always identical, ages have been obtained (Reynolds and Muecke, 1978).

PRESENT STUDY

Analytical Techniques

Samples were crushed and sieved to a –40/+80 mesh size. The sieved samples were washed with deionized water and air dried.

Table 1. K-Ar Analytical Data for Samples from the Blue Ridge of Southwestern North Carolina and Adjacent Tennessee

Sample Number	Type	K(Wt.%)	$^{40}Ar^*$	RAD%	Age (Ma)
1	M	4.99	6.029	72	287
1	B	7.09	9.497	96	316
2	M	6.91	8.169	98	281
2	B	6.59	9.103	98	325
3	M	5.28	6.380	93	287
4	M	5.77	8.006	76	326
5	B	6.02	10.12	98	388
6	M	6.34	10.07	97	369
6	B	4.88	7.782	97	370
7	M	5.82	8.828	50	354
7	B	4.89	8.984	96	420
8	WR	2.78	4.205	88	353
9	WR	5.11	9.373	27	420
10	WR	3.03	5.586	96	421
11	B	6.61	11.57	98	402
12	M	5.50	8.099	95	344
12	B	4.03	6.146	97	355
13	M	6.38	9.881	95	360
13	B	6.91	11.52	97	385
14	M	7.71	11.70	98	354
15	B	4.46	7.719	97	398
16	B	3.32	5.336	41	373
17	M	6.95	10.33	98	347
17	B	5.32	8.954	94	388
18	WR	3.33	5.903	97	407
19	M	2.75	4.173	90	354
19	B	4.68	7.494	97	371
20	B	5.90	10.27	98	400
21	WR	4.35	7.116	98	379
22	WR	3.58	6.763	98	431
23	WR	2.56	5.605	97	491
24	WR	2.79	5.374	97	438
25	WR	2.59	4.413	96	393
26	WR	2.67	5.712	98	481
27	WR	3.47	5.496	96	368
28	WR	2.48	5.337	94	483
29	M	5.82	8.147	93	329
29	B	6.43	9.708	96	352
30	B	6.61	9.645	97	341
31	M	2.99	3.365	94	269
32	M	3.03	3.494	90	275
33	WR	5.04	7.581	98	351
34	WR	2.64	4.251	95	373
35	WR	2.97	5.066	97	393
36	WR	4.24	7.121	97	388
37	WR	2.16	3.913	94	415
38	WR	3.38	7.566	98	500
39	B	5.70	8.124	97	334
40	B	7.70	10.71	98	327
41	WR	3.17	5.680	97	411
42	WR	2.77	5.015	96	415
43	H	0.96	1.824	94	433
44	H	0.52	0.8485	94	378

45	A	0.14	0.329	84	522
46	H	0.73	1.274	94	401
47	H	0.68	1.487	95	490
48	H	0.47	0.9775	90	469
49	H	0.24	0.5084	84	477
50	H	0.18	0.3678	41	462

40Ar* Radiogenic 40Ar – (10-5 scc/gm)
RAD% Radiogenic 40Ar percent
B – Biotite: M – Muscovite; WR – Whole Rock
H – Hornblende: A – Actinolite

Mineral separates were purified using a combination Frantz Isodynamic magnetic separator, shaker table, and heavy liquids.

Potassium measurements were obtained using a Instrumentation Laboratories Model 143 flame photometer, which utilizes an internal lithium standard to correct for variations in machine response. All potassium values are based on triplicate analyses.

Argon analyses were obtained by conventional isotope dilution methods using a ^{38}Ar spike and a AEI MS-10 mass spectrometer operating in static mode. Normally most samples had yields of at least 90 percent radiogenic ^{40}Ar.

Analytical results are reported in Table 1. Sample locations are reported by latitude and longitude in Table 2 in the Appendix; the sample locations are also shown in Figure 4. The overall analytical uncertainty of K-Ar ages is ±2 percent at one standard deviation. All ages have be calculated using constants of Steiger and Jager (1977).

K-Ar Muscovite and Biotite Ages

Nearly concordant biotite versus muscovite K-Ar ages in the eastern and western Blue Ridge (Figs. 1-3) range from approximately 300 Ma for middle to upper amphibolite facies rocks of the eastern Blue Ridge to approximately 350 Ma from middle amphibolite facies rocks of the western Blue Ridge. One group of biotite ages, from samples collected east of the northern portion of the Murphy belt (Fig. 1), yield consistently older K-Ar ages compared to muscovite from the same samples.

Biotite samples collected from garnet-grade schist of the Great Smoky Group on the North Carolina Tennessee state line (sample 9) and northeast of Robbinsville, N. C., have ages of approximately 400 Ma. These ages are similar to biotite ages obtained from a sample collected 9 km southeast

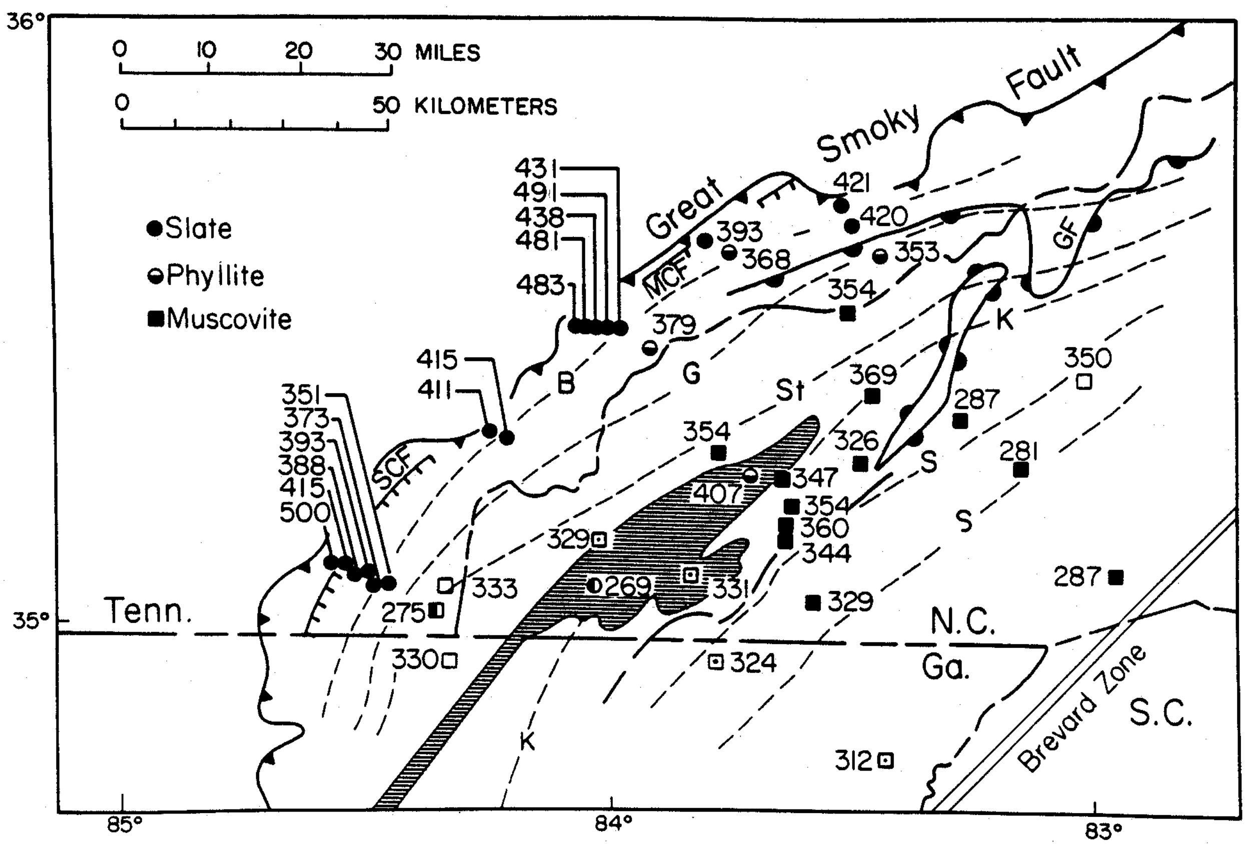


Figure 2. K-Ar and ^{40}Ar – ^{39}Ar ages for muscovite and whole rock slates and phyllites – Blue Ridge of southwestern North Carolina and adjacent Georgia and Tennessee. Vertical, half-filled symbols indicate possibly retrograded samples. Abbreviations are the s ame as Figure 1. Sources of published data listed inTable 3.

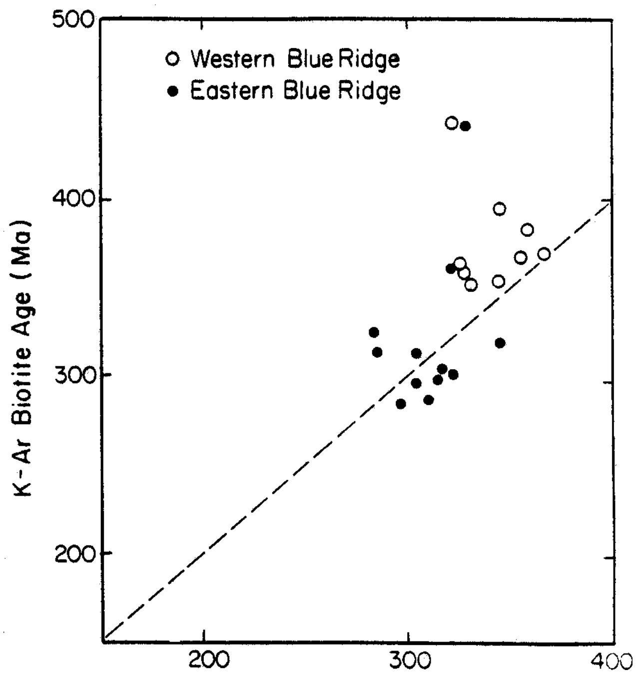


Figure 3. K-Ar biotite versus K-Ar muscovite or Rb-Sr biotite for the same sample, rocks of the Blue Ridge of southwestern North Carolina and adjacent Georgia and Tennessee. From Kish (1989).

of Newfound Gap (389 Ma) reported by Kulp and Eckelman (1961) and samples (400 – 440 Ma) from ore-zone rocks at Ducktown, Tennessee (Kulp and Eckelman, 1961; Dallmeyer, 1975b; Fullagar and others, 1980). Sample 9, collected from schist in the Anakeesta Formation, has the oldest biotite K-Ar age obtained in this study (420 Ma). A coexisting K-Ar muscovite age from this sample, however, is distinctly younger (354 Ma); similar differences exist for biotite and muscovite K-Ar ages in the Ducktown region. This relationship suggests that these older biotite dates should not be accepted as simple cooling ages until more analyses are available for biotite from these upper greenschist facies rocks

A sample of retrogressively metamorphosed schist collected near the Burra mine at Ducktown, Tennessee, (exposure described by Granath, 1978) has a very young K-Ar muscovite age (275 Ma); a similar young age (269 Ma) was obtained from a chlorite-bearing phyllite of the Mineral Bluff Formation, just south of Murphy, North Carolina (Fig. 2). The significance of these young ages with regard to regional metamorphic history is still uncertain

K-Ar Hornblende Ages

Hornblende, obtained from upper amphibolite facies and lower granulite facies amphibolites located just east of the Hayesville fault (Fig. 4), yield K-Ar ages of approximately 460 – 490 Ma. Samples collected to the east, near Franklin, North Carolina, have younger ages (378 – 433 Ma). A low potassium actionlite (sample 45) has a very old age (522 Ma), probably due to significant amounts of excess ^{40}Ar. A more detailed discussion of these data is presented in Kish (1989)

K-Ar Whole Rock Ages of Slates and Phyllites

Slate samples were collected from units of the Snowbird, Great Smoky, and Walden Creek Groups in the Blue Ridge of eastern Tennessee (Figs. 2 and 5). Samples were collected from exposures near the Ocoee, Tellico, Little Tennessee, Little, and Pigeon Forge Rivers. Descriptions of the geology of the sample localities were published by Hurst and Schlee (1962), Neuman and Nelson (1965), and King (1965).

With the exception of sample 38. All samples consisted of very fine-grained (<30um) pelitic rocks that have a well-developed slaty cleavage. Sample 38, collected at the location of field trip stop 7 of Hurst and Schlee (1962), was a silty shale without a district slaty cleavage. X-ray diffraction studies of the slates indicate a high degree of crystallinity for the 10A mica peak (height to half peak width ratio of approximately 10).

Slates collected within the Ocoee Gorge (southernmost group in Figure 2) yield progressively older ages (351 to 415 Ma) to the west, in a direction of decreasing metamorphic grade. Sample 38m, a siltstone, located west of the Syclo Greek fault (Hurst and Schlee, 1962), has a much older K-Ar age (500 Ma), possibly due to the presence of detrital mica that has not undergone complete recrystallization. The two slate samples collected in the gorge of the Tellico River have D-Ar ages (411 and 415 Ma) similar to the maximum ages observed for slates in the Ocoee Gorge. Samples collected along the Little River and Pigeon River yield ages that range from 368 to 421 Ma.

Given the analytical uncertainties of these ages, they are compatible with an Acadian metamorphic event. However, the most critical group of ages was obtained from rocks of the Wilhite Formation exposed on U. S. Highway 129 east of Tallassee, Tennessee. Of the five samples collected at this location, three have ages of approximately 480 Ma and two have ages of 430 Ma. Unlike sample 38 from the Ocoee Gorge, these samples exhibit sharp 10A x-ray diffraction peaks, indicating a high degree of crystallinity. Connelly and Dallmeyer (1991) have reported ^{40}Ar – ^{39}Ar plateau ages for whole rock slate samples that are very similar to the results of this study.

Unrug and Unrug (1990) reported the presence of middle Paleozoic microfossils from the Wilhite Formation that are from the same location as the ~420 – 480 Ma K-Ar ages. This location is an important site for testing hypotheses

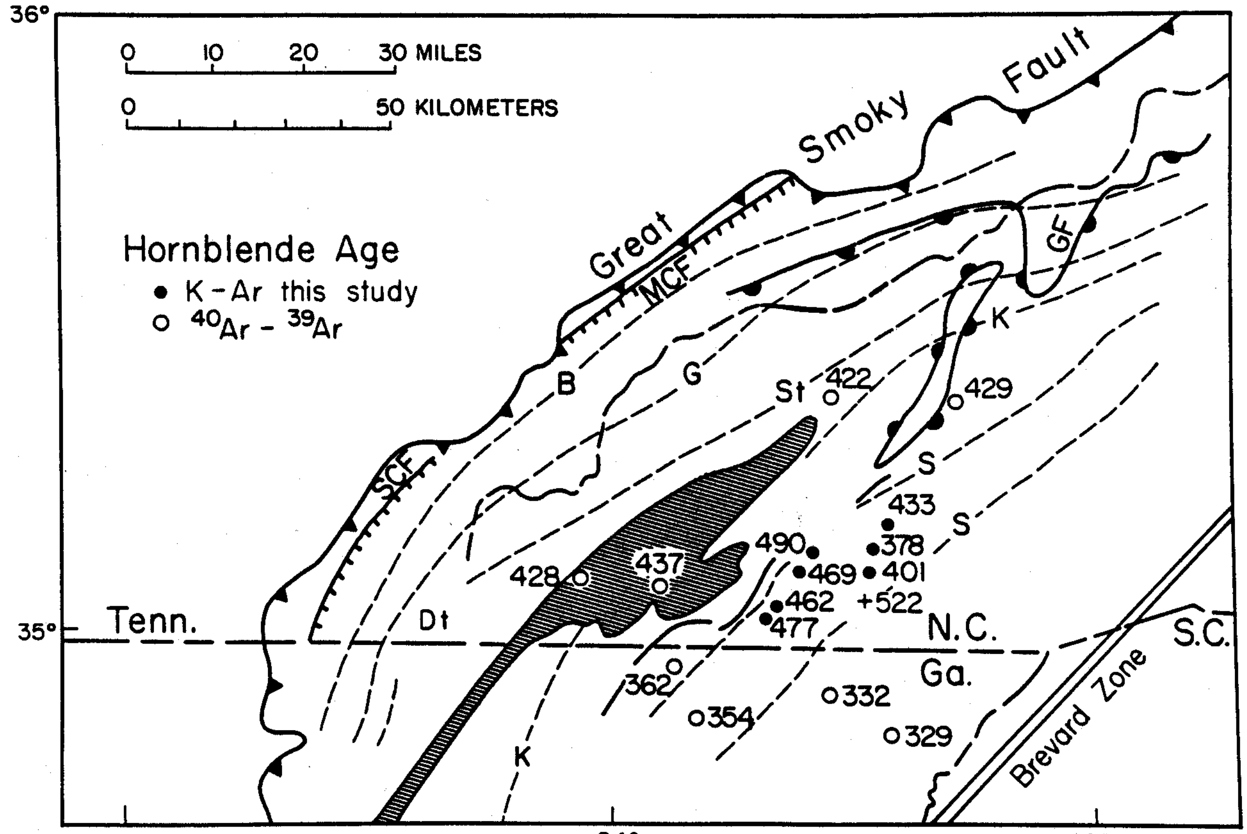


Figure 4. K-Ar and ^{40}Ar – ^{39}Ar hornblende ages – Blue Ridge of southwestern North Carolina and adjacent Georgia and Tennessee. Cross represents an actinolite sample. Abbreviations given in Figure 1. Sources of published data are listed in Table 3.

regarding the stratigraphic age and the timing of metamorphism that affected these rocks.

DISCUSSION

Available evidence from radiometric dating studies suggests that by the beginning of the Mississippian (360 Ma, Harland and others, 1982) amphibolite facies rock with the western Blue Ridge had cooled below temperatures associated with greenschist facies metamorphism. Clastic rocks of the early Mississippian Granger Formation in the Valley and Ridge contain detrital heavy minerals that indicate erosion of a high grade metamorphic source, presumably the Blue Ridge. By this time rocks of middle amphibolite faces had already been exposed and undergone erosion (Wiener, 1979).

The actual time of metamorphism and its implications regarding the minimum age of stratigraphic units within the Blue Ridge is less certain. Pegmatites in the western Blue Ridge near Bryson City, North Carolina, intrude units of the Great Smoky Group that are in tectonic contact with Grenville basement (Cameron, 1951). One of these pegmatites, the Cox Number 1, has a Rb-Sr whole rock age of 435±28 Ma (2 uncertainty; Kish and others, 1975; Kish, 1983). Pegmatites in adjacent portions of the eastern Blue Ridge and units of the Whiteside plutonic group have ages in the range of 380 – 400 Ma (Kish, 1983, 1989). Some of the Whiteside plutons (undated) have a well developed foliation. The $^{87}Sr/^{86}Sr$ initial ratios of many pegmatites is high (>0.715), suggesting that they may have formed by anatetic melting of crystal rocks. These data indicate that elevated temperatures existed in the Blue Ridge crust at this time. Goldberg and others (1989) recently obtained uranium-lead ages of ~390 Ma from zircons that may have formed during high grade metamorphism in the Blue Ridge of northwestern North Carolina. These lines of evidence are compatible with a middle Paleozoic (~390 Ma) metamorphic event. Metamorphism of this age has been documented in the Talladega belt of Alabama by combined paleontologic (Tull and others, 1988) and radiometric dating studies (kish, 1990).

A critical question is whether the Blue Ridge of North Carolina and Tennessee has the simple metamorphic history observed to the south in Alabama, or has a more complex history. Some lines of stratigraphic evidence for a Ordovician orogenic event include the presence of a thick middle Ordovician clastic sequence in eastern Tennessee (Rodgers, 1971) and conglomerates derived from an extensive section of underlying strata (Kellberg and Grant, 1956). Radiometric dates of hornblendes from amphibolite facies rocks and K-Ar ages of slates determined in this study provide the most direct evidence of a metamorphic event in the range 440 – 480 Ma.

Several major unanswered questions are posed by recent investigations regarding the Paleozoic history of the Blue Ridge. What are the youngest sedimentary units preserved within the Blue Ridge? Was the principal metamorphic event "Taconic" or Acadian?" Did portions of the Blue Ridge undergo two Paleozoic metamorphic events? Additional work, both in the field and laboratory, will hopefully answers to some of these questions.

APPENDICES

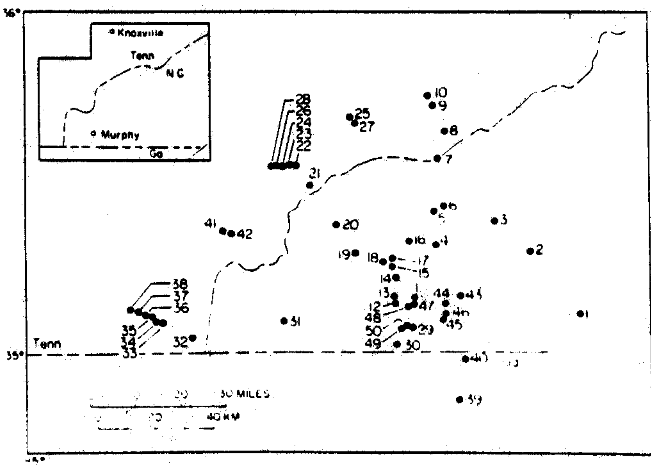


Figure 5. Location of samples reported in Table 1.

Table 3. Location of Samples

Sample	Latitude	Longitude
1	35° 06.8'	82° 59.0'
2	35° 22.6'	83° 08.1'
3	35° 22.4'	83 15.7'
4	35° 18.6'	83 30.2'
5	35° 25.1'	83 30.8'
6	35° 25.6'	83 29.1'
7	35° 34.9'	83 28.3'
8	35° 39.2'	83 26.6'
9	35° 43.2'	83 30.6'
10	35° 44.9'	83 31.2'
11	35° 09.0'	83 34.4'
12	35° 09.9'	83 31.8'
13	35° 10.3'	83 38.8'
14	35° 13.7'	83 37.8'
15	35° 16.0'	83 40.0'
16	35° 16.8'	83 38.5'
17	35° 19.8'	83 35.7'
18	35° 16.2'	83 41.5'
19	35° 18.2'	83 47.8'
20	35° 22.9'	83 51.6'
21	35° 30.2"	83° 50.0'
22	35° 31.5'	83 59.6'
23	26° 27.0'	83 43.2'
24	35° 33.3'	83 59.8'
25	35° 39.6'	83 42.5'
26	35° 33.7'	84° 07.4'
27	35° 41.8'	83 48.8'
28	35° 32.9'	84° 02.9'
29	35° 04.5'	83 35.0'
30	35° 02.2'	83 37.1'
31	35° 04.8'	84 02.2'
32	35° 02.1'	84 22.9'
33	35° 02.7'	84 26.8'
34	35° 04.5'	84 30.1'
35	35° 04.9'	84 31.3'
36	35°05.7'	84 32.6'
37	35° 06.7'	84 33.8'
38	35° 05.8'	84 36.8'
39	34° 49.2'	83 25.8'
40	34° 58.5'	83 23.2'
41	35° 21.8'	84 15.5'
42	35° 20.8'	84 11.7'
43	35° 10.1'	83 30.9'
44	35° 08.5'	83 34.8'
45	35° 06.2'	83 36.3'
46	35° 06.1'	83 36.0'
47	35° 09.1'	83 34.4'
48	35° 09.1'	83 34.6'
49	35° 04.5'	83 36.5'
50	35° 04.5'	83 35.2'

Table 3. Sources of Published Data used in Figures 1-4.

Article	B	M	W	H
Dallmeyer (1975a)	□			□
Dallmeyer (1975b)	□			
Dallmeyer (1988a)	□	□		□
Dallmeyer (1988b)				□
Dallmeyer (1989)		□		□
Fullagar et al (1980)	■			□
Kish (1974)	●	●	●	●
Kish (1989)				●
Kulp and Eckelmann (1961)	●	●		
Long et al (1959)	●	●		

B - Biotite
M - Muscovite
W - Whole Rock
H - Hornblende

● K-Ar

□ ^{40}Ar-^{39}Ar

ACKNOWLEDGMENTS

Potassium-argon analyses were performed at Florida State University. Winston Russell helped with isotope dilution analyses. Rosemarie Raymond and Grabrille Lee helped with the preparation of figures. Paul C. Ragland and Roy Odom provided helpful reviews of this paper.

REFERENCE CITED

Armstrong, R.K., 1966, K-Ar dating of plutonic and volcanic rocks in orogenic belts: in Potassium-argon dating: New York, Springer-Verlag, p. 117-133.

Brewer, M. S., 1969, Excess radiogenic argon in metamorphic micas from the eastern Alps, Austria: Earth and Planetary Science Letters, v. 6, p. 321 – 331.

Butler, J. R., 1972, Age of Paleozoic regional metamorphism in the Carolinas, Georgia and Tennessee southern Appalachians: American Journal of Science, v. 272, p. 319 – 333.

Carpenter, R. H., 1970, Metamorphic history of the Blue Ridge province of Tennessee and North Carolina: Geological Society of America Bulletin, v. 81, p. 749 – 762.

Cliff, R. A., 1985, Isotopic dating in metamorphic belts: Geological Society of London Journal, v. 142, p. 97 – 110.

Connelly, J. B., and Dallmeyer, R. D., 1991, Polymetamorphic evolution of the western Blue Ridge, Tennessee and North Carolina: evidence from ^{40}Ar – ^{39}Ar ages: Geological Society of America Abstracts with Programs, v. 23, p. 18.

Dallmeyer, R. D., 1975a, ^{40}Ar – ^{39}Ar and K-Ar ages of biotite and hornblende from retrograded basement gneisses of the southeastern Great Smoky Mountains: their bearing on the age of Paleozoic metamorphism: American Journal of Science, v. 275, p.444 –460.

Dallmeyer, R. D., 1975b, Incremental $^{40}Ar/^{39}Ar$ release ages of biotite from the Cherokee ore body, Ducktown, Tennessee: their bearing on the age of sulfide mineralization: Economic Geology, v. 70, p. 341 – 345.

Dallmeyer, R. D., 1988a, Late Paleozoic tectonothermal evolution of the western Piedmont and eastern Blue Ridge, Georgia: Controls on the chronology of terrane accretion and transport in the southern Appalachian orogen: Geological Society of America Bulletin, v. 100, p. 702 – 713.

Dallmeyer, R. D., 1988b, Polymetamorphic evolution of the western Blue Ridge allochthon: evidence from ^{40}Ar – ^{39}Ar mineral ages, in Fritz, W. J., and LaTour, E. L., Geology of the Murphy Belt and related rocks – Georgia and North Carolina: Georgia Geological Society Guidebook, v. 8, p. 95 – 101.

Dallmeyer, R. D., 1989, $^{40}Ar/^{39}Ar$ geochronology within the eastern Blue Ridge in Dallmeyer, R. D. (ed.) Tectonostratigraphic expression of terrane accretion in the southern Appalachian orogen: a geotraverse excursion: I.G.C.P. Project 233 Guidebook Series, v. 4, p. (7:10) – (7:21).

Dodson, M. H., 1973, Closure temperatures in cooling geochronological and petrological systems: Contributions to Mineralogy and Petrology, v. 40, p. 259 – 274.

Dodson, M. H., and McCelland-Brown, E., 1985, Isotopic and palaeomangetic evidence for rates of cooling, uplift and erosion, in Snelling, N. J., ed., The chronology of the geologic record: Geological Society of London, Memoir 10, p. 315-325.

Fullagar, P. D., and Bottiono, M. L., 1970, Sulfide mineralization and rubidium-strontium geochronology at Ore Knob, North Carolina and Ducktown, Tennessee: Economic Geology, v. 65, p. 541-550.

Fullagar, P. D., Odom, A. L., Dallmeyer, R. D., and Bottino, M. L., 1980, Possible excess ^{40}Ar in hornblende and biotite from the Appalachian massive sulfide deposits at Ore Knob, North Carolina and Ducktown, Tennessee: Economic Geology, v. 75, p. 329-339.

Goldberg, S. A., Rainey, L., and Butler, J. R., 1989, Geochronology and conditions of regional metamorphism within a Blue Ridge thrust sheet, North Carolina: Geological Society of America Abstracts with Programs, v. 21, p. 17.

Hadley, J. B., 1964, Correlation of isotopic ages, crystal heating and sedimentation in the Appalachian region: in Lowry, W. D., ed., Tectonics of the Southern Appalachians: Virginia Polytechnical Institute, Department of Geological Sciences Memoir 1, p.33-34.

Hadley, J. F., 1970, The Ocoee Series and its possible correlatives, in Fisher, G. W., Pettijohn, F. J., Reed, J. C., Jr., and Weaver, K. N., eds., Studies in Appalachian geology: central and southern: New York, Wiley-Interscience, p. 247-259.

Harland, W. B., Cox, A. V., Liewellyn, P. G., Pickton, C. A. G., Smith, A G., and Walters, R., 1982, A geologic time scale: Cambridge, Cambridge University Press, 131 p.

Harper, C. T., 1964, Potassium-argon ages of slates and their geological significance: Nature, v. 212, p. 1339 – 1341.

Hurst, V. J., and Schlee, J. S., 1962, Ocoee, metasediments, north central Georgia and southeast Tennessee: Georgia Department of Mining and Geology, Guidebook number 3, 28 p.

Kellberg, J. M., and Grant, L. F., 1954, Coarse conglomerates of the Middle Ordovician in the southern Appalachian Valley: Geological Society of America Bulletin, v. 67, p.697-716.

King, P. B., 1964, Geology of the central Great Smoky Mountains, Tennessee: U. S. Geological Survey Professional Paper 349-C, 148 p.

Kish, S. A., 1974, The structural and metamorphic history of the northern terminus of the Murphy belt [M. S. thesis]: Florida State University, Tallahassee, 131 p.

Kish, S. A., Merschat, C. E., Mohr, D. W., and Wiener, L. S., 1975, Guide to the geology of the Blue Ridge south of the Great Smoky mountains, North Carolina: Carolina Geological Society Field Trip Guidebook, 49 p.

Kish, S. A., 1983, A geochronological study of deformation and metamorphism in the Blue Ridge and Piedmont of the Carolinas [Ph. D. thesis]: Chapel Hill, University of North Carolina, 220 p.

Kish, S. A., 1989, Igneous and metanorphic history of the Eastern Blue Ridge, southwestern North Carolina: K-Ar and Rb-Sr studies, in Fritz, W., 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. 41-55.

Kish, S. A., 1990, The timing of Mid-Paleozoic (Acadian) metamorphism in the southern Appalachians: K-Ar studies in the Talladega slate belt, Alabama: Geology, v. 18, p. 650-653.

Kulp, J. L., and Eckelmann, F. D., 1961, Potassium-argon isotopic ages on micas from the southern Appalachians: Annals New

York Academy of Science, v. 91, p. 408-416.
Lee, J. K. W., Onstott, T. C., Cashman, K. V., Cumbest, R. J., and Johnson, D., 1991, Incremental heating of hornblende in vacuo: Implications for $^{40}Ar - ^{39}Ar$ geochronology and the interpretation of thermal histories: Geology, v. 19, p. 872-876.
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.
Maboko, M. A. H., McDougall, L., Zeitler, P. K., and FitzGerald, J. D., 1991, Discordant ^{40}Ar-^{39}Ar ages from the Musgrave Ranges, central Australia: Implications for the significance of hornblende ^{40}Ar ^{39}Ar ages from the Musgrave Ranges, central Australia: Implications for the significance of hornblende $^{40}Ar/^{39}Ar$ spectra: Chemical Geology (Isotope Geoscience Section), v. 86, p. 139-160.
Neuman, R. B., and Nelson, W. H., 1964, Geology of the western Great Smoky Mountains, Tennessee: U. S. Geological Survey Professional Paper 349-D, 81 p.
Roddick, J. C., and Farrar, E., 1971, High initial argon ratios in hornblendes: Earth and Planetary Science Letters, v. 12, p. 208-214.
Rodgers, John, 1971, The Taconic orogeny: Geological Society of America Bulletin, v. 82, p. 1141-1178.
Reynolds, P. H., and Muecke, G. K., 1978m Age studies on slates: applicability of the ^{40}Ar ^{39}Ar stepwise outgassing method: Earth and Planetary Science Letters, v. 40, p. 111-118.
Steiger, R. H., and Jager, E., Subcomission of geochronology: convention on the use of decay constants in geo-and cosmochemistry: Earth and Planetary Science Letters, v. 36, p. 359-362.
Sutter, J. F., Ratcliffe, N. M., and Mukasa, S B., 1985, $^{40}Ar/^{39}Ar$ and K-Ar data bearing on the metamorphic and tectonic history of western New England: Geological Society of America Bulletin, v. 96, p. 123-136.
Tull, J. F., Harris, A. G., Repetski, J. E., McKinney, F. K., Garrett, C. B., and Bearce, D. N., 1988, New paleontologic evidence constraining the age and paleotectonic setting of the Talladega slate belt, southern Appalachians: Geological Society of America, v. 100, p. 1291-1299.
Tull, J. F., and Groszos, M. S., 1990, Nested Paleozoic "successor" basins in the southern Appalachian Blue Ridge: Geology, v. 18, 1046-1049.
Unrug, Raphael, and Unrug, Sophia, 1990. Paleontologic evidence of Paleozoic age for the Walden Creek Group, Ocoee Supergroup, Tennessee: Geology, v. 18, p. 1041-1045
Wiener, L. S., 1979, Rate of mid-Paleozoic orogenic uplift in the southeastern Appalachians: Southeastern Geology, v. 21, p. 91-102.
Wilson, M. R., 1972, Excess radiogenic argon in metamorphic amphiboles and biotites from the Sulitjelma region, central Norwegian Caledonides: Earth and Planetary Science Letters, v. 14, p. 403-412.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 79-87

MURPHY BELT LITHOSTRATIGRAPHIC NOMENCLATURE

James F. Tull, Troy W. Thompson, Mark S. Groszos, Joseph G. Aylor, Jr., and Stephen A. Kish
Department of Geology B-160, Florida State University, Tallahassee, Florida 32306

INTRODUCTION

Classification and naming of lithostratigraphic units in the Murphy belt of the southern Appalachian Blue Ridge in North Carolina and Georgia (Fig. 1) have in general followed the North America Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983), but in many cases the applications have been loose because of the metamorphosed and polydeformed nature of the unites and because of uncertainties and mistakes in correlation. Also, some commonly used terms like "Murphy group" violate the North American Stratigraphic Code and should be replaced. Because of detailed mapping within the region during the last decade or so (see articles in this guidebook and references cited), we feel that the time is right to update and refine the stratigraphic nomenclature of the region (Fig. 2).

Our purpose here is: A) to review the relevant lithostratigraphic nomenclature for the Murphy belt, B) to refine the nomenclature to conform more strictly to the 1983 North American Stratigraphic Code and to reflect the results of recent work in the region by proposing new stratigraphic units where appropriate, C) to designate principal reference sections to supplement (but not supplant) the stratotype of many named units, and D) to designate type sections of newly named units (details provided in accompanying manuscripts in this guidebook).

The region under discussion has historically been called the Murphy belt (Hurst, 1955) or Murphy Marble belt (Van Horn, 1948). The term Murphy belt seems to be in most general use for this region today (i.e. 1985 Geologic Map Of North Carolina) and is the term we have chosen to use for that area of the western Blue Ridge in North Carolina and Georgia underlain by stratigraphic units previously referred to informally by such names as the Murphy group (Hatcher, 1972). In this paper we are redefining and renaming these units as the Hiwassee River and Mineral Bluff Groups (see below). These units lie stratigraphically above the Great Smoky Group and generally occupy a longitudinal valley, locally containing central and flanking ridges, stretching 175 k, from near Almond, North Carolina to Canton, Georgia (Fig. 1).

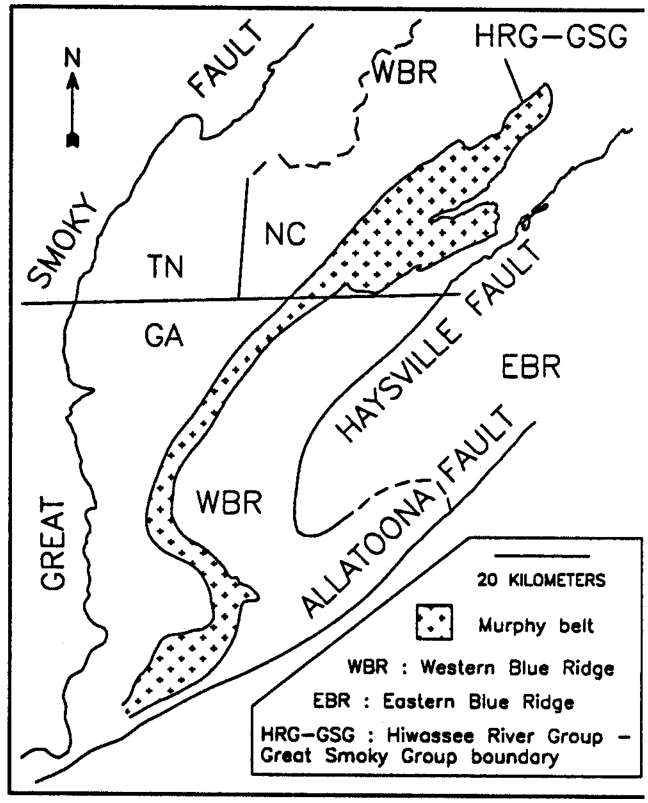


Figure 1. Location map of Murphy belt.

CHANGE IN GROUP TERMINOLOGY

The Murphy Marble is the most distinctive and economically important unit in the Murphy belt and was first formally named by Keith (1907) and effectively given formation status. The Stratigraphic Code does not permit use of the same geographic name for more than one lithostratigraphic unit, or use of the same geographic name for different hierarchical levels in the same sequence, such as formation and group.

Therefore Keith's (1907) original use of the term Murphy Marble takes precedence over the use of any group level term containing the word "Murphy". This unfortunately means that Hatcher's (1972) and subsequent workers' use of the term Murphy Group violates the Code and should not be continued. Other terms that have been applied to the stratigraphic sequence in the Murphy belt include "Murphy series" (Furcron, 1953), "Murphy sequence" (Forrest, 1969), "Murphy belt group" (Mohr, 1973) and "Murphy syncline group" (Nesbitt and Essene, 1982). These terms also should be abandoned. Most of the rocks of the Murphy belt, were included in the "Talladega series" of Crickmay (1936). Correlations between the type Talladega Group of Smith (1888) (redefined by Tull, 1982) and rocks of the Georgia, North Carolina, and Tennessee Blue Ridge have been made by several geologists, but use of the term "Talladega series" for

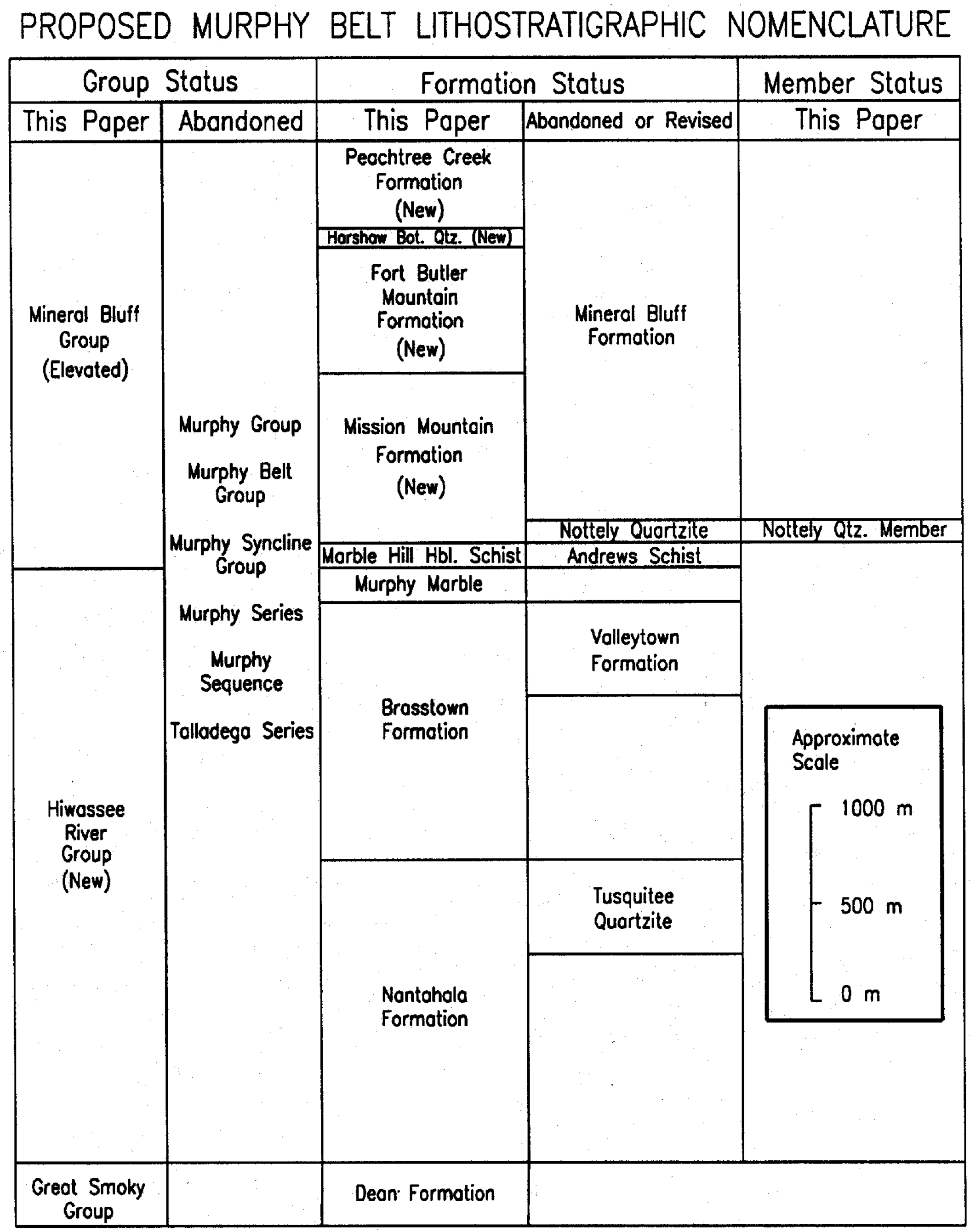


Figure 2. Proposed Murphy belt lithostratigraphic nomenclature.

rocks in the western Blue Ridge north of Cartersville, Georgia has been abandoned.

Our recent work has made us aware of an additional problem with the application of terms like "Murphy Group" to the entire sequence in the Murphy belt. A distinctive sequence of dominantly metaclastic rocks occurs stratigraphically above the Murphy Marble (see below) in the core of the Murphy syncline, and represents the youngest rocks in the Murphy belt. These rocks were given formation status as the Andrews Schist and Nottely Quartzite (Keith, 1907) and Mineral Bluff Formation (Hurst, 1955). Subsequently Forrest (1969) and Tull and Groszos (1988) recommended redefinition of the Nottely Quartzite as a member of the Mineral Bluff Formation. The Mineral Bluff is up to 2 km thick and is divisible into several mappable units (see Thompson and Tull, this volume), each of which can now be given formation status. Additionally, Tull and Guthrie (1985) and Tull and Groszos (1988) have proposed that a significant unconformity separates the Murphy Marble from overlying units. For these reasons we feel that it is appropriate to elevate the Mineral Bluff to group status and give the Nottely member status (see Thompson and Tull, this volume) and separate them from the underlying units in the Murphy belt.

Because of the problems mentioned above with the use of the term "Murphy ", a new group name should be applied to units below the Mineral Bluff Group. We are proposing that the term Hiwassee River Group to be used to incorporate those formations between the Great Smoky and Mineral Bluff Groups. Keith (1904) applied the term Hiwassee slate to rocks in Hiwassee Gorge, Polk County, Tennessee, which modern workers call Walden Creek Group. King and others (1958, p. 961) state "…no description was published, and the name was used so confusingly elsewhere that it is properly abandoned". Subsequent workers have not used the term Hiwasse slate. The North American Stratigraphic Code, Article 20b Abandoned Names states:" A name for a lithostratigraphic or lithodemic unit, once applied and then abandoned, is available for some other unit only if the name was introduced casually, or if it has been published only once in the last several decades and is not in current usage, and if its reintroduction will cause no confusion (North American Commission on Stratigraphic Nomenclature, 1983)." To avoid any confusion we are adding the term "River" to the name. We have chosen this name because the Hiwassee River near Murphy, North Carolina cuts through this group on both limbs of the Murphy syncline exposing excellent reference sections of all the formations in the group. Thus, the type area for this group is essentially the same type area as that for the previously used names, which incorporated the term "Murphy" in reference to this group.

The following is a summary of the stratigraphic nomenclature applied to the two newly named lithostratigraphic groups.

HIWASSEE RIVER GROUP (NEW)

Nantahala Formation

The Nantahala Formation was named for exposures in the Nantahala Gorge, North Carolina by Keith (1904; 1907). The base of the Nantahala Formation is recognized by most workers as a conformable and gradational contact with the underlying Dean Formation of the Great Smoky Group (Keith, 1907; Nuttall, 1951; Hurst, 1955). Keith (1907, p. 4) assigned the Dean Formation and the Nantahala Formation to the Nantahala Formation, though he said, "Most of the schists are near the base of the [Nantahala] formation and strongly resemble the slate and schist beds in the Great Smoky conglomerate." Hurst (1955) and subsequent workers included these schists within the upper part of the Dean Formation. We concur with this interpretation and place the contact above the previously described garnet-staurolite schist and below the graphitic slates.

The Nantahala Formation includes all black slate (Laminted metasiltstone), schist, and arkosic quartzite above the stratigraphically highest schist in the Dean Formation and below the Brasstown Formation. Bedding is typically thin to laminated and is defined by graphite-rich pelitic layers interbedded with lighter colored metasiltstone and metasandstone. In the present interpretation the Nantahala Formation is conformably overlain by the Brasstown Formation. Early workers recognized the Tusquitee Quartzite Brasstown Formation (Keith, 1907, Hurst 1955), but the Tusquitee is not recognized throughout much of the Murphy belt of Georgia. In the past, workers have found it difficult to distinguish the two formations (Keith, 1907; Hurst 1955; Fariley, 1965; Kish, 1974; Costello and others, 1982; Tull and Groszos, 1988; Aylor, this volume). Where the quartzite sequence is absent between the Nantahala and Brasstown, we refer to the sequence as Nantahala-Brasstown undifferentiated. Thin beds of meta-subarkose are common throughout the Nantahala-Brasstown section but can be differentiated from the thicker, prominent meta-subarkoses that are used to define the contact between the Nantahala Formation and the Brasstown Formation (Aylor, this volume). We proposed abandoning the Tusquitee Quartzite as a formal name (as explained below) and assigning these rocks to the Nantahala Formation. Excellent exposures on both banks of the Hiwassee River west of Murphy, North Carolina are proposed here as part of a composite reference section, 1550 meters thick (see Aylor, this volume).

Tusquitee Quartzite (Abandoned)

Keith (1907) first introduced the term Tusquitee for exposures in the Tusquitee Mountains, Clay County, North Carolina. We propose that the term Tusquitee Quartzite be abandoned, as suggested by Hadley (1970, p. 255) who said, "The two rock types [slates and quartzites], however, are interbedded throughout much of the Nantahala and are more feasibly considered as a single formation". The term Tusquitee Member as suggested by Mohr (1973) is also abandoned because of the interbedded nature of the metasandstone layers. Mohr (1973, p. 61) said, "Mappable units dominated by white metaquartzite are separated as the Tusquitee Member of the Nantahala Formation". We do not endorse Mohr's interpretation because many quartzites may be present as layers within slates of the Nantahala (Aylor, this volume; Kish and others, 1975). Conflict with the North American Stratigraphic Code (1983, Article 30 (I)) is avoided by formally abandoning the name Tusquitee Quartzite as either a separate formation or as a member of the Nantahala Formation.

Brasstown Formation

Keith (1907) named the Brasstown Formation for exposures along Brasstown Creek, Clay County, North Carolina. The base of the Brasstown Formation, as explained above, is defined as being above the uppermost meta-subarkose unit of the Nantahala Formation. The Brasstown Formation is composed of slates, schists, and thin meta-subarkose; most exposures show laminations or thin beds defined by alternating pelitic (commonly graphite bearing) and quartz-rich metasandstone and minor metasiltstone layers. The upper Brasstown Formation of current usage was originally separated out by Keith (1907) as Valleytown Formation (see below). The upper contact can be observed in the marble quarry near the Nantahala Talc and Limestone Quarry near Hewitt, North Carolina and at the County Quarry on Long Swamp Creek east of Jasper, Georgia (Tull and Groszos, 1988). The Brasstown and Murphy Marble are commonly interbedded for 2 to 3 m across a gradational contact. Excellent exposures are found along both sides of the Hiwassee River west of Murphy, here designated a reference section 1320 meters (see Aylor, this volume).

Valleytown Formation (Abandoned)

Keith (1970) named the Valleytown Formation for rocks exposed near the town of Valleytown in Cherokee County, North Carolina. Subsequent workers continued this usage until Hurst (1955, p. 49) suggested that this term be abandoned because, "As originally defined, the Valleytown Formation is without a definite lower boundary and is lithologically indistinguishable from underlying beds. The original definition has not been improved by subsequent usage. The name is therefore not retained." Rocks mapped as Valleytown Formation by earlier workers (Keith, 1907; LaForge and Phalen, 1913; Bayley, 1928; Hadley and Nelson, 1971) are mapped by more recent workers as Nantahala Formation, or Mineral Bluff Formation (Hurst, 1955; Fariley, 1965; Kish, 1974; Forrest, 1975; Costello and others, 1982; Tull and Groszos, 1988). We propose that the Valleytown Formation be officially abandoned and the rocks of this interval be placed in the Brasstown Formation.

Murphy Marble

Although much thinner (generally less than 150 m) than most units in the Murphy belt and laterally discontinuous, occupying only 50 percent of the strike on both limbs of the Murphy syncline (Tull and Groszos, 1988), the Murphy Marble is the most distinctive and readily identifiable unit in this belt. It is also economically important because of the long historical production of building and statuary stone, talc, and associated local concentrations of iron ore. Its low resistance to chemical weathering has helped to produce the low topographic expression of the Murphy belt within the core of the Blue Ridge Mountains. Keith (1907) effectively gave this unit formation status when he formally named it for exposures near Murphy, North Carolina and this designation has remained unchanged by subsequent workers. Excellent exposures of this unit are found in scores of active and abandoned marble quarries scattered throughout the length of the belt in North Carolina and Georgia, but upper and lower contacts are rarely exposed.

Individual marble lithologies have been named to designate type of building or statuary stone (for example Regal Blue, Cherokee, Etowah, etc.), but an internal stratigraphy is difficult to correlate from locality to locality and the Murphy Marble has never been formally differentiated into members. Generalized stratigraphic sections of the marble have been published from drill core data (Van Horn, 1948; Power and Forrest, 1971; Power, 1978).

MINERAL BLUFF GROUP (ELEVATED)

Arthur Keith (1907) was also the first to describe rock units associated with the synclinal core of the North Carolina Murphy belt. The bulk of his Murphy belt units that have retained their formational status comprise the Hiwassee River Group (see above). As stated above, Keith originally defined the Valleytown Formation as grading upward into the Murphy Marble, and because of incorrect stratigraphic interpretations, he correlated part of this unit with rocks in the core of the Murphy syncline. Keith (1907) also named the Nottely Quartzite, which he considered the youngest unit of the Murphy belt, for exposures along the Nottely River. Thus, other than the Nottely, Keith recognized no other rocks within the Mineral Bluff Group as used here.

Hurst (1955) completed an extensive study of the Mineral Bluff quadrangle that covered the western limb and core of the Murphy syncline in North Georgia. He applied Keith's descriptions of lithostratigraphy except for the Valleytown Formation, which he redefined as part of the Brasstown Formation. He subsequently defined the Mineral Bluff Formation as the youngest sequence of metasediments in the Murphy belt, occupying the trough of the Murphy syncline, and existing conformably above the Nottely Quartzite on both limbs of the syncline. Because the synclinal core is narrow within the Mineral Bluff Quadrangle, only the basal part of the Mineral Bluff sequence was included within Hurst's study. Based on field relationships, Forrest (1969) and Tull and Groszos (1988), have redefined the Nottely Quartzite as a member of the Mineral Bluff Formation were further described by Tull and Groszos (1988) by order of decreasing volumetric abundance: pelitic rhythmites, graphitic pelite, metasandstone, metaconglomerate, calcareous rocks, iron-rich deposits.

A low angle, regional unconformity, predating metamorphism and deformation, has been proposed to exist at the base of the Mineral Bluff Formation (Tull and Guthrie, 10983, 1985; Groszos, 1986; Tull and others, 1986; Groszos and Tull, 1987, 1988). Detailed field mapping has also shown that the Mineral Bluff Formation contains a distinctive and conformable internal stratigraphy (Thompson and Tull, 1991a and this volume). For these reasons we are proposing the following: 1) elevation of the mineral Bluff Formation to group status and 2) subdividing the Mineral Bluff Group into the following new formations: a) Mission Mountain Formation (including the Nottely Quartzite Member), b) Fort Butler Mountain Formation, c) Harshaw Bottom Quartzite, and d) Peachtree Creek Formation. See Thompson and Tull (this volume) for more detailed descriptions and definitions pertaining to the Mineral Bluff Group stratigraphy.

Andrews Schist (Abandoned)

The Andrews Schist of Keith (1907) has perhaps the most complex and controversial history relative to its definition and mapped distribution of any unit in the Murphy belt. The terminology and extent of this unit has been disputed by many workers since Keith (1907), and the debate seems far from over (see Fairley, 1988). Keith (1907) considered the Andrews Schist to lie stratigraphically between the Nottely Quartzite and the Murphy Marble, but near Murphy, North Carolina he mapped the Andrews on both sides of the Nottely, interpreting the Nottely as occurring in the core of a tight syncline. Several decades later, Hurst (1955) expanded Keith's definition and placed an extensive section subsequently Fariley (1965) enlarged the Andrews even further to include all the stratigraphy in the Tate, Georgia area above the Murphy Marble and immediately overlying Marble Hill Hornblende Schist. Since the 1960's however, geologist have attempted to return to Keith's more restrictive original definition. Power and Forrest (1971) reinterpreted Hurst's eastern belt of Andrews to be Mineral Bluff Formation and they, along with McConnell and Costello (1980) placed Fairley's Andrews in the Mineral Bluff Formation.

A close look at Keith's (1907) original definition and description is insightful. Keith described three conspicuous features of the Andrews: A) it is a calc-schist with a "fine matrix of carbonate of calcium, of about the same character as the underlying Murphy Marble", B) "one of its most conspicuous features is the large number of crystals of ottrelite" (chloritoid), and C) it contains characteristic deposits of brown hematite. Forrest (1975) also mentions the iron oxide layers and concretions as the most characteristic feature of weathered Andrews Schist.

Petrographic descriptions of the Andrews are rare but two things stand out. First, calc-schist is found in the lower part of Keith's Andrews where it is interlayered with impure marble, but calcium-bearing minerals and/or free carbonate appear to be rare or absent in the upper part. It is clear therefore that much of the "type" Andrews is not a calc-schist, and thus the unit cannot be defined on this basis. Secondly, Keith's (1907) report of abundant and characteristic "ottrelite" (also referred to as chloritoid) porphyroblasts in this unit has not been confirmed by recent work, in spite of the fact that Van Horn (1948) referred to the Andrews as the "Ottrelite Schist" unit. Petrographic work by Forrest (1975), as well as our own, suggests that characteristic "cross-biotite" porphyroblasts were misidentified by Keith and Van Horn as chloritoid. Units containing abundant "cross biotite" are present within the Brasstown Formation and the schist overlying the Nottely Quartzite Member of the Mission Mountain Formation (see below). Thus, Keith's second distinguishing characteristic of type Andrews can no longer be considered useful in defining or recognizing this unit.

The "type" Andrews contains abundant pyrite. Weathering of the unit has produced secondary hematite deposits that are both discordant and concordant to bedding, as well as occurring within overlying residuum. Hematite occurrences are also associated with overlying and underlying formations in the Murphy belt and extensive deposits of "brown iron ore" are concentrated at the stratigraphic top of the Murphy Marble in Georgia (Haseltine, 1924; Tull and Groszos, 1988). These occurrences are secondary, post-metamorphic deposits. Whether or not some of them may have stratigraphic significance is debatable (Tull and Groszos, 1988). At any rate, it does not appear to be prudent to involve these secondary deposits in the definition of the Andrews Schist.

Tull and Groszos (1988) maintain that in Georgia, schists above the Murphy Marble and below quartzites that they correlate with the Nottely are indistinguishable from schists of the Mineral Bluff in the section immediately above the Nottely. Forrest (1975) noted the difficulty of differentiating Mineral Bluff schists from the non-calcareous Andrews where the Nottely was absent. Even Keith (1907) mapped schists on both sides of the Nottely as Andrews. As we have examined in detail the units of the Mineral Bluff Group in North Carolina overlying the Nottely, we have recognized that they are locally similar lithologically to the Andrews. The lower, "calcareous" Andrews only occurs in a few surface exposures but is known from core drilling, where Van Horn (1948) referred to it as a 25 foot thick "transition zone". It contains layers of impure marble up to several centimeters thick, interbedded with cross-biotite schist. Impure marble interbedded with schist and metasandstone has also been recognized at several localities within the Mission Mountain Formation (La Tour and Fritz, 1988; Thompson and Tull, this volume). The Murphy Marble directly below the "transition zone" however, appears to be much more pure than the "transition zone" marble. Tull and Groszos (1988) cited evidence for a regional unconformity at the base of the Mineral Bluff Group, suggesting that the unconformity was at the base of the Nottely Quartzite Member of the Mission Mountain Formation. Because of the presence of the "transition zone" at the base of the Andrews, they interpreted the Andrews to be deposited gradationally above the Murphy Marble. It is now clear that a more detailed study of the "transition zone" is needed to determine its true relationship to the Murphy Marble.

The above discussion shows that Keith's (1907) description is of little use in defining, recognizing, or mapping the Andrews Schist. The discussion also clearly shows the great difficulty other geologists have had in the definition and recognition of this unit. Thus, it seems clear that abandonment of the term Andrews Schist has become necessary. We propose that the Andrews should now be included in Mission Mountain Formation of the Mineral Bluff Group (see below).

Marble Hill Hornblende Schist

The Marble Hill Hornblende Schist was defined by Fairley (1965) as a calc-schist and biotite hornblende schist occurring in the Tate, Georgia area. It ranges in thickness from a few tens of meters, up to approximately 100 meters. Throughout much of its outcrop trace it lies directly above the Murphy Marble, but locally, where the marble is absent, it lies directly upon the Brasstown Formation. It is overlain by mica schists of the Mineral Bluff Group. Most of the Marble Hill Hornblende Schist is actually an amphibolite, only locally schistose and calcareous. Based on geochemical studies, Kish and others (1991) indicated that the Marble Hill is of igneous parentage, and Fairley (1988) and Tull and Groszos (1991) have suggested that it is of volcanic origin because of its chemistry, tabular sheet-like occurrence directly at the base of the Mineral Bluff Group, and large areal extent (>150 km^2). Work by Kish and others (1991) and Tull and Groszos (1991) also indicates that two outlying "metagabbro" bodies of Fairley (1965) are parts of the Marble Hill, isolated within fold hinges. These bodies lie at the same stratigraphic level as the Marble Hill and are chemically similar to the Marble Hill.

We agree with Fairley's (1965) definition and recognition of the Marble Hill in the Mineral Bluff Group for several reasons. Thompson (unpublished data) has mapped amphibolitic units within the Mission Mountain Formation near the base of the Mineral Bluff Group near Murphy, North Carolina that are chemically and petrographically similar to the Marble Hill. In the Tate, Georgia area, the Marble Hill occurs at the very base of the Mineral Bluff Group, below which Tull and Groszos (1988) have postulated a regional low angle unconformity. The thickness of the Murphy Marble ranges from approximately 180 meters down to zero in this region. The Marble Hill lies continuously across the variable thickness of Murphy Marble, and where the marble is absent, the Marble Hill is in direct contact with the Brasstown Formation. The Marble Hill is an easily identifiable unit that marks a distinctive break between the Hiwassee River and Mineral Bluff Groups in the southwestern segment of the Murphy belt. Recent work (Fairley, 1988; Kish and others, 1991; Tull and Groszos 1991) indicates that, in spite of similar stratigraphic position above the Murphy Marble, the Andrews and Marble Hill Hornblende Schists are not correlative units as suggested by Power and Forrest (1971). The two units also do not occur in the same geographic area. Good natural exposures of Marble Hill Hornblende Schist can be found along the east-west hillside south of Marble Hill, in cliffs above the marble quarries.

Mission Mountain Formation (New)

This unit represents the thickest (~1 km) and the lowest formation in the Mineral Bluff Group (where the Marble Hill Hornblende Schist is missing, see above) and is named for exposures found on the northern slope of Mission Mountain near Peachtree, North Carolina. We concur with Tull and Groszos (1988) that a regional low angle unconformity separates the Hiwassee River and Mineral Bluff Groups, placing the Mission Mountain Formation unconformably above units of the Hiwassee River Group. Interlayered near the base of the Mission Mountain Formation is the Nottely Quartzite Member (see below). The Mission Mountain Formation is a turbidite-dominated sequence that is best characterized as a rhythmically layered and thinly laminated (1-10 cm) grayish-green metagraywacke. The unit is composed of fine-grained quartz, chlorite, biotite, plagioclase, muscovite, and calcium-bearing silicates (epidote, sphene). Carbonate-rich, calc-silicate layers and lenses are common, and siliceous marbles are locally present (see Thompson and Tull, SUNDAY Stop 2). A conspicuous zone of interlayered metagraywacke and mafic metaigneous rocks occurs approximately 150 meters up section from the Nottely Quartzite in at least one location on the west limb in North Carolina (see Thompson and Tull, SUNDAY Supplemental stop 1). In Georgia, mafic metaigneous rocks occur directly below the Mission Mountain Formation as the Marble Hill Hornblende Schist (see above). The proposed stratotype section is found along the Hiwassee River just west of Brasstown, North Carolina. See Thompson and Tull (this volume) for more detailed information about this unit.

Nottely Quartzite Member

As stated above, Keith (1907) defined the Nottely Quartzite for exposures along the Nottely River near Culberson, North Carolina. The Nottely is a fine to medium grained feldspathic quartzite that occurs locally at, but mostly near, the base of the Mineral Bluff Group. Forrest (1969) and Tull and Groszos (1988) suggested that the Nottely was a member of the Mineral Bluff Formation. We recommend retention of the Nottely at the member level, but place it as a member of the basal formation of the newly elevated Mineral

Bluff Group, the Mission Mountain Formation. For further insight, see above discussion of the Andrews Schist and Thompson and Tull (this volume). In Georgia, the Nottely is locally found on both limbs of the Murphy Syncline, whereas in North Carolina it is only rarely identified on the east limb. Near the Valley and Hiwassee River confluence, the Nottely Quartzite is made up of two metasandstone sections separated by mica schist, with the upper (southeastern) section approximately 20 meters thick and the lower (northwestern) section approximately 18 meters. The total thickness for both metasandstone sections and the intervening schist is approximately 55 meters. Another section of Nottely was measured northeast of Murphy, along U. S. Highway 19/129 (see Thompson and Tull, SUNDAY stop 3), with approximate thicknesses of 28, 15, and 80 meters of the upper and lower metasandstones, and total Nottely Quartzite Member thickness respectively. Well exposed reference sections can be found at the following locations: A) intersection of U. S. Highway 64 and Nottely River, B) just east of the Valley and Hiwassee River confluence, and C) along U. S. Highway 19/129 approximately 5 km north of Murphy, North Carolina.

Fort Butler Mountain Formation (New)

The Mission Mountain Formation grades upward into the Fort Butler Mountain Formation, which comprises the second thickest unit (~650 m) in the Mineral Bluff Group. The Fort Butler Mountain Formation is named for exposures that hold up the numerous mountains, one being Fort Butler Mountain, and ridge tops that lie east of the and parallel to U. S. Highways 64 and 19/129, between Ranger and Andrews, North Carolina. This sequence is also a turbidite-dominated package of metasediments. The dominant lithology is a thinly laminated to massive graphite-bearing sericitic metapelite that is locally sandy. Interlayered with the phyllites are thick-bedded (up to 2 m thick) metasandstone/metaconglomerate layers that range from monomictic to polmictic along strike. Coarse clastic zones approach 30 to 75 meters in thickness, with thinner zones being discontinuous. Excellent exposures are found on Bell, Fort Butler, Wildcat, and Will Scott Mountains, as well as along U. S. Highway 64 (see Thompson and Tull, stop 4) east of Murphy, North Carolina. For more detailed information on this unit see Thompson and Tull (this volume).

Harshaw Bottom Quartzite (New)

Grading up from the Fort Butler Mountain Formation is the Harshaw Bottom Quartzite, which is the most distinctive unit in the Mineral Bluff Group. This unit is named for exposures north of Harshaw Bottom, near the intersection of U. S. Highway 64 and Peachtree Creek, North Carolina (see Thompson and Tull, SUNDARY – Stop 5). It is dominantly a very fine-grained monomictic white quartzite and is locally epidote-rich. Primary blue quartz grains are rarely seen. The Harshaw Bottom type section is located on the ridge top northwest of the U. S. Highway 64 and Peachtree Creek intersection, where the maximum thickness approaches 100 meters. See Thompson and Tull, SUNDAY Stop 5, and Thompson and Tull (this volume) for more detailed information on this unit.

Peachtree Creek Formation (New)

The Peachtree Creek Formation represents the highest stratigraphic unit in the Mineral Bluff Group, and therefore possibly, the western Blue Ridge. It is interlayered with the upper part of the Harshaw Bottom Quartzite and is named after Peachtree Creek, which flows through part of this highest preserved unit. The Peachtree Creek Formation consists of very thinly laminated and very fine-grained interlayered metapelites and metagraywackes, and has a maximum thickness of 450 meters. The geochemistry of the metagraywacke suggest either a mixed sedimentary and igneous component or an unusual detrital assemblage, relative to other Mineral Bluff Group metasediments (see Thompson and Tull, this volume). Good exposures are rare but can best be seen along the Hiwassee River, south of the Murphy Medical Center, 7 km east of Murphy, North Carolina.

ACKNOWLEDGEMENTS

Very helpful reviews of this manuscript were provided by Randall Orndorff and Leonard Wiener. Their help in improving the manuscript is appreciated. Discussions with John Rodgers concerning the stratigraphic nomenclature were instrumental in the decision to write this paper. Some of our work in the Murphy belt has been supported by the National Science Foundation (ERA-8313740 to J. F. T.). This support is greatly acknowledged.

REFERENCES CITED

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 Paleozoic Stratigraphy in the western Blue Ridge: Carolina Geological Society Field Trip Guidebook.

Bayley, W. S., 1928, Geology of the Tate Quadrangle: Georgia Geological Survey Bulletin 43, 167 p.

Costello, J. O., McConnell, K. I., and Power, W. R., eds. 1982, Geology of Late Precambrian and Early Paleozoic rocks in and near the Cartersville district, Georgia: Georgia Geological Society, 17th Annual Field Trip, Guidebook, 40 p.

Crickmay, G. W., 1936, Status of the Talladega series in southern Appalachian stratigraphy: Geological Society of America Bulletin, v. 47, p. 1371 – 1392.

Fariley, W. M., 1965, The Murphy Syncline in the Tate Quadrangle,

Georgia: Georgia Geological Survey Bulletin 75, 71 p.
_____, W. M., 1988, The Andrews Schist in the Murphy Syncline, in Fritz, W. J., and LaTour, T. E., eds., Geology of the Murphy Belt and related rocks Georgia and North Carolina: Georgia Geological Society Guidebook, v. 8, no. 1, p. 95-101.
Forrest, T. J., 1969, Stratigraphy and structure of the Murphy belt in the Murphy, N. C. 7.5' Quadrangle: Geological Society of America Abstracts with Programs, Part 4, p. 23 – 24.
_____, 1975, Geologic evolution of a portion of the Murphy Marble belt in southwestern North Carolina [Ph. D. Dissertation]: Rice University, Houston, Texas, 76 p.
Furcron, S., 1953, Comments on the geology of the Ellijay Quadrangle, Georgia North Carolina, Tennessee: Geological Survey of Georgia Bulletin 60, p. 32- 40.
Groszos, M. S., 1986, The stratigraphy of the Murphy Group in the Murphy Syncline of northern Georgia: Geological Society of America Abstracts with Programs, v. 18,p. 224.
Groszos, M. S., and Tull, J. F., 1987, Lithologic sequences in the Murphy belt: Contrasting tectonic histories and of America Abstracts with Programs, v. 19, p. 87.
_____, 1988, Paleozoic stratigraphy of the southern Blue Ridge: Implications for Appalachian tectonic evolution: Geological Society of America Abstracts with Programs, v. 20, no. 7, p. A217.
Hadley, J. B., 1970, The Ocoee Series and its possible correlatives in Fisher, G.S., and others, eds., Studies in Appalachian Geology: Central and Southern: New York, Wiley Interscience, p. 247-259.
Hadley, J. B., and Nelson, A. E., 1971, Geologic map of the Knoxville quadrangle, North Carolina, Tennessee, and South Carolina: U. S. Geological Survey Miscellaneous Geological Investigation Map I-654.
Haseltine, R. H., 1924, Iron ore deposits of Georgia: Georgia Geological Society Bulletin 41, 222 p.
Hatcher, R. D., Jr., 1972, Developmental model for the southern Appalachians: Geological Society of America Bulletin, v 83, p. 2735-2760.
Hurst, V. J., 1955, Stratigraphy, structure, and mineral resources of the Mineral Bluff quadrangle, Georgia: Georgia Geological Survey Bulletin 63, 137 p.
Keith, A. 1904, Asheville Folio: U. S. Geological Survey Geologic Atlas, Folio no. 116, 10 p.
_____, 1907, Description of the Nantahala quadrangle, North Carolina and Tennessee: U. S. Geological Survey Geologic Atlas, Folio o. 116, 10 p.
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]: Florida State University, Tallahassee, Florida 131 p.
Kish, S. A., Campbell, S.K., Groszos, M. S., and Tull, J. F., 1991, Geochemistry and petrology of metaigneous rocks in the Murphy syncline, Tate, Georgia: Geological Society of America Abstracts with Programs, v. 23, no. 1, p. 53.
Kish, S. A., Merschat, C. F., Mohr, D. W.,and Wiener, L. S., 1975, Guide to the geology of the Blue Ridge south of the Great Smoky Mountains, North Carolina: Carolina Geological Society, Annual Field Trip Guidebook, 49 p.
LaForge, L., and Phalen, W. C., 1913, Description of the Ellijay quadrangle, Georgia, North Carolina and Tennessee: U. S. Geological Survey Geologic Atlas, Folio no. 187, 17
LaTour, T. E., and Fritz, W. J., 1988, Volcanogenic character of parts of the Mineral Bluff Formation: Evidence from field and geochemical studies, in Fritz, W. J., and LaTour, T. E., eds., Geology of the Murphy belt and related rocks Georgia and North Carolina: Georgia Geological Society Guidebook, v. 8, no. 1, p. 75 – 93.
McConnell, K. I., and Abrams, C. E., 1984, Geology of the greater Atlanta region: Georgia Geological Survey Bulletin 96, 127 p.
McConnell, K. I., and Costello, J. O., 1980, Geologic guide to the geology along a traverse through the Blue Ridge and Piedmont of north Georgia: in Frey, R.W., ed., Excursions in southeastern geology: American Geological Institute, v. 1, p. 241 – 258.
Mohr, D. W., 1973, Stratigraphy and structure of the Great Smoky and Murphy belt Groups, western North Carolina: American Journal of Science, v. 273-A, p. 41 – 71.
Nesbitt, B. E., and Essence, E. J., 1982, Metamorphic thermometry and barometry of a portion of the southern Blue Ridge Province: American Journal of Science, v. 282, p. 701-729.
North American Commission on Stratigraphic Nomenclature, 1983, North American Stratigraphic Code: American Association of Petroleum Geologists, v. 67, no. 5, p. 841-875.
Nuttall, B. D., 1951, The Nantahala-Ocoee contact in north Georgia: [M. S. Thesis, University of Cincinnati, 32 p.
Power, W. R., 1978, Economic geology of the Georgia Marble District: in 12th forum on the geology of industrial minerals, Georgia Geological Survey, Information Circular 49, p. 59 – 67.
Smith, E. A., 1888, Report of progress for 1884-1888: Geological Survey of Alabama, 24
Thompson, T. W., and Tull, J. F., 1991a, Mineral Bluff Formation: Internal stratigraphy of the Murphy syncline in the western Blue Ridge of North Carolina: Geological Society of America Abstracts with Programs, v. 23, no. 1, p. 138.
Thompson, T. W., and Tull, J. F., 1991b, Stratigraphy and of the Mineral Bluff Group, southwestern North Carolina, in Kish, S. A., ed., Studies of Precambrian Paleozoic Stratigraphy in the western Blue Ridge: Carolina Geological Society Field Trip Guidebook.
Tull, 1982, Stratigraphic framework of the Talladega slate belt, Alabama Appalachians, in Bearce, D. N., and others, 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 LaTour, 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.
_____, 1991, Structure of the Tate culmination and origin of the Marble Hill Hornblende Schist, Georgia Blue ridge: Geological Society of America Abstracts with Programs, v. 15, no. 1, p. 95.
Tull, J. F., and Guthrie, G. M., 1983, Talladega Belt/Blue Ridge Belt Stratigraphies – Can They be Correlated?: Geological Society of America Abstracts with Programs, v. 15, no. 2, p. 95.
Tull, J. F., and Guthrie, G. M., 1985, Proposed stratigraphic linkages between the Talladega slate belt and the Appalachian mio-

geocline – tectonic implications, in Tull, J. F., Bearce, D. N., and Guthrie, G. M., eds., Early evolution of the Appalachian miogeocline: Upper Precambrian lower Paleozoic stratigraphy of the Talladega slate belt: Alabama Geological Society, 22nd, annual field trip guidebook, p. 1- 10.

Tull, J. F., Guthrie, G. M., and Groszos, M. S., 1986, Stratigraphic record of passive margin stabilization and destabilization in southern Appalachian crystalline rocks: Geological Society of America Abstracts with Programs, v. 18, p. 269.

Van Horn, E. C., 1948, Talc deposits of the Murphy Marble belt: North Carolina Department of Conservation, Div. Mineral Resources Bulletin 65, 54 p.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 89-97

STRATIGRAPHY OF THE NANTAHALA AND BRASSTOWN FORMATIONS, HIWASSEE RIVER GROUP, NORTH CAROLINA

Jospeh G. Aylor, Jr.
Department of Geology B-160, Florida State University,Tallahassee, Florida 32306

ABSTRACT

The Murphy belt, located within the Blue Ridge of North Carolina and Georgia, contains a sequence of siliciclastic and carbonate metasedimentary rocks. The lower portion of the sequence is represented by the Hiwassee River Group which includes siliciclastics of the Nantahala and Brasstown Formations and a carbonate unit, the Murphy Marble. This study deals with the siliciclastic portion of the Hiwassee River Group. These rocks conformably overlie the Great Smoky Group. The nantahala and Brasstown Formations have been correlated with the Lower Cambrian Chilhowee Group, which is exposed on the western edge of the Blue Ridge. These two areas are separated by many faults, which prevent direct correlation of the two groups.

The upper sandstone of the Nantahala Formation, previously named the Tusquitee Quartzite, forms the boundary between the Nantahala and the Brasstown Formations. The term Tusquitee Quartzite should no longer be used formally because similar quartzose sandstones are interbedded throughout the Nantahala Formation.

Although these rocks have been polydeformed and metamorphosed to middle amphibolite facies, they retain much of their sedimentary character. The presence of cross-bedding and asymmetric ripple marks, but the absence of symmetrical ripple marks, channels, and graded bedding suggest deposition on some type of margin such as a continental shelf, Atlantic-type margin below normal wave base.

INTRODUCTION

This paper is intended to be a preliminary description of the Hiwassee River Group and follows the nomenclature framework of Tull and others (1991a, this volume). The purpose of this paper is to describe the lower sequence of siliciclastic lithologies of the Hiwassee River Group. The nature of unit contacts will be discussed and the Nantahala-Brasstown Formations will be compared with the possibly correlative Chilhowee Group on Chilhowee Mountain in Tennessee. A depositional model for Hiwassee Group rocks will be proposed. These rocks are located in the Murphy syncline, in the western Blue Ridge province of southwestern North Carolina and northern Georgia (Fig. 1). The Hiwassee River Group includes siliciclastics of the basal Nantahala Formation, The Brasstown Formation, the Brasstown Formation, and carbonates of the Murphy Marble, which is the stratigraphically highest unit within the group. (Fig. 1). The Murphy Marble is not covered in detail in this discussion. The overall stratigraphy of the Murphy belt is reviewed by Tull and others (1991a, this volume). Although middle-amphibolite facies metamorphism and deformation have affected the Hiwassee River Group, many sedimentary structures in the siliciclastic units are preserved. For this reason, where rocks retain their sedimentary structures in the siliciclastic units are preserved. For this reason, where rocks retain their sedimentary character, sedimentary lithologic names are used throughout this paper.

REFERENCE SECTION OF THE HIWASSEE RIVER GROUP

The Hiwassee River Group as described by Tull and others (1991a, this volume) is subdivided into the Nantahala and Brasstown Formations and the Murphy Marble. The best exposed section of the Nantahala and Brasstown Formations is found on both banks of the Hiwassee River west of Murphy, North Carolina, in a proposed reference section where good primary sedimentary features can be observed (Fig. 2 and 3). The cut bank side of the river offers the best exposures for measuring and observing cross bedding, asymmetrical ripple marks, contact relationships, minor folds, and variations in alternating character of laminations and bedding of sandstone and siltstone. Note that in this reference section the lower part of the Nantahala Formation contains no sandstone units.

In Table 1 (Hiwassee River reference section H) the Nantahala Formation is shown to be 1550 meters in thickness. Sandstone is an aggregate of 484 meters of that thickness. The Brasstown Formation is approximately 1320 meters in thick at the reference section at the confluence of the Hiwassee and Valley Rivers (Fig. 1). Note the thickening toward a the northeast from the Georgia-North Carolina state line as may be observed in Figure 2.

NANTAHALA FORMATION

Lower Contact

The Jonica Gap measured section "A" on the overturned, southeastern limb of the Murphy syncline along the Georgia North Carolina state line east of Culberson (Fig. 1). On this limb of the Murphy syncline, sandstone of the basal Nantahala Formation is in contact with the Dean Formation, but on the northwestern limb siltstone of the Formation, but

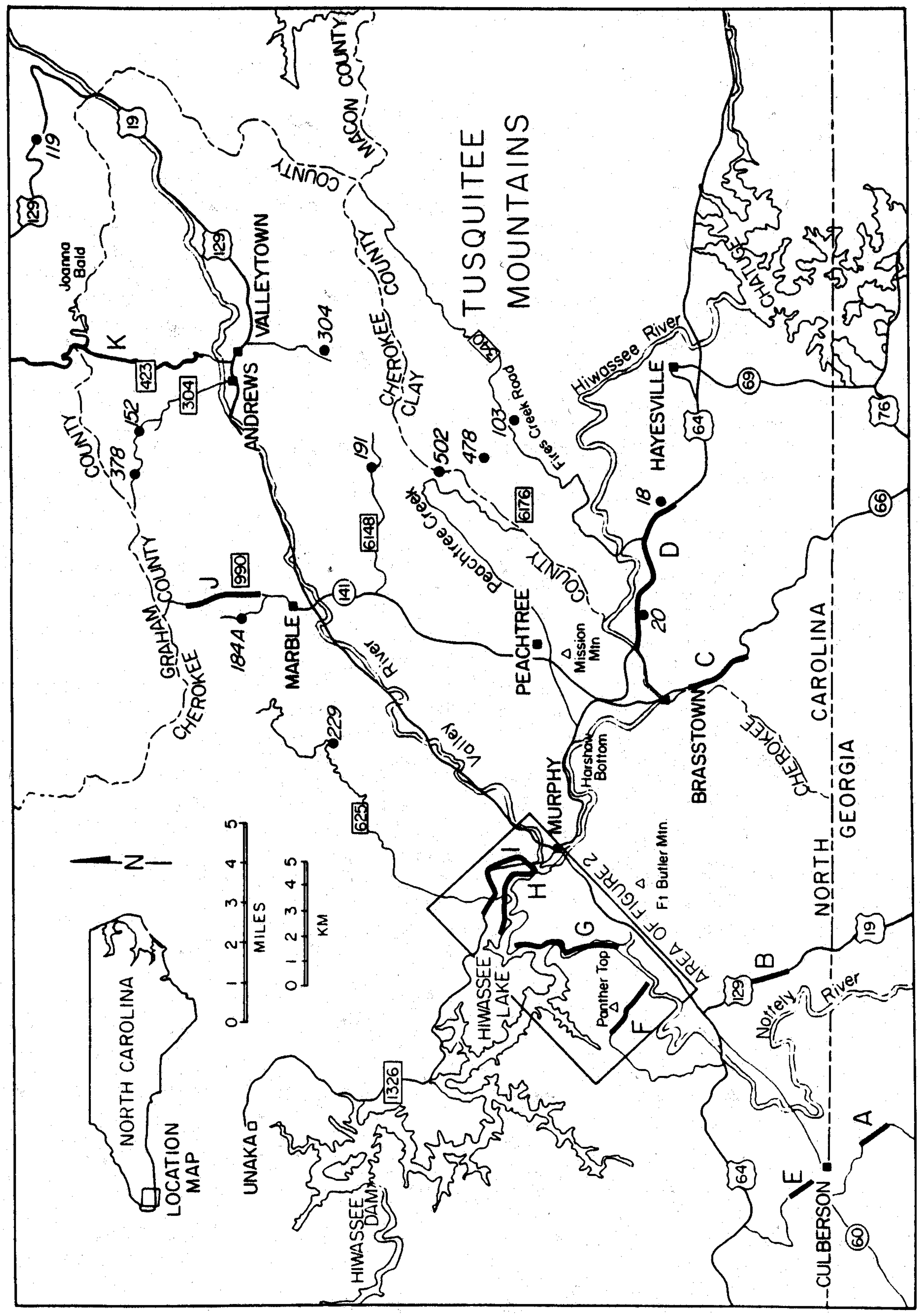


Figure 1. Location of measured sections in heavy lines and samples filled circles.

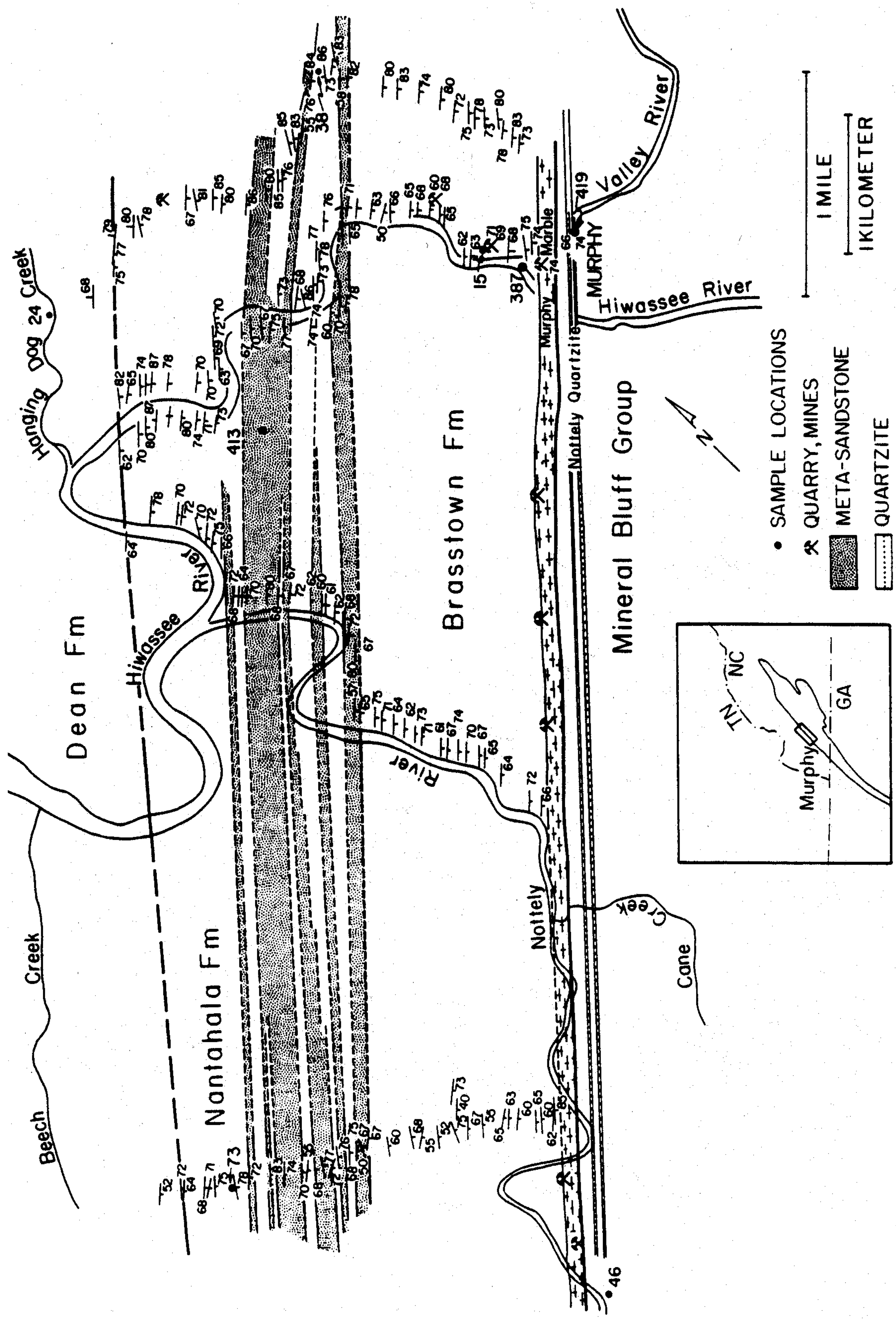


Figure 2. Geologic map through measured sections F-1 in Fig. 1. Quarries and prospects are from Van Horn (1948). Hiwassee Lake is at low water.

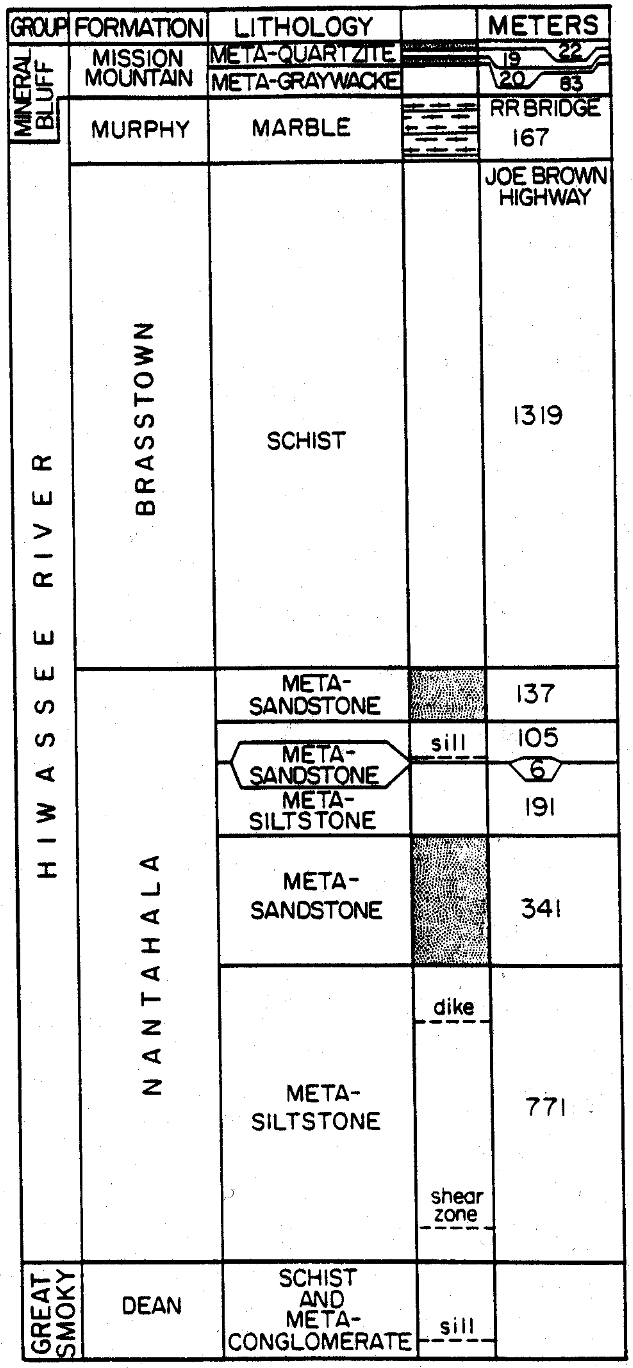


Figure 3. Hiwassee River reference section H in Fig. 1. The railroad (R. R.) bridge is 10 m west of the upper Murphy Marble contact, and Joe Brown Highway is 10 m west of the upper Brasstown Formation contact.

on the northwestern limb siltstone of the Nantahala Formation is in contact with the Dean Formation. Section "A" best illustrates the gradational contact between the basal unit of the Nantahala Formation and the underlying Dean Formation of the Great Smoky Group. The uppermost portion of the Dean Formation of the Great Smoky Group. The uppermost portion of the Dean Formation contains light-colored, medium-grained schist that grades upward into increasingly abundant black laminated siltstone and thin layers of light-colored subarkosic sandstones, which are the dominant lithologies within the lowermost portion of the Nantahala Formation. The gradation between the two formations may exceed 30 meters in thickness. For this study the contact is placed where siltstone and the sandstone exceed the schist in volume.

Mohr (1973, p. 58) and Kish and others (1975, p. 14) described the uppermost portion of the Dean Formation as light greenish-gray, laminated schist, arkosic metasandstone, and metagraywacke with beds of pebble metaconglomerate. Mohr (1973, p. 60) described a gradational contact of green, laminated schist 30 meters thick in the upper Dean Formation grading into Nantahala black schists. Except for the sandstones in the Jonica Gap sections, the section of Mohr (1973) south of Fontana Lake is very similar.

Siltstone of the Nantahala Formation

Keith (1904, p. 6; 1907, p. 4) first referred to the Nantahala Formation as black slate. Others described it as black and gray laminated argillite (Hadley, 1970, p. 255; Power and Forrest, 1971, p. 3) and metasiltstones and mica schists (Kish and others, 1975, p. 15). Most workers have adopted Keith's (1907, p. 4) lithologic description.

The siltstone of the Nantahala Formation of this study is a dark gray to black, laminated rock containing alternating dark and light colored bands, without a phyllitic or schistose appearance. The light colored layers and laminae contain tan to white quartz and less abundant feldspar plus minor graphite and biotite. The darker colored layers or laminae are more pelitic, containing biotite, muscovite and higher concentrations of graphite and pyrrhotite. Asymmetrical ripple makes interpreted to be ripple current structures are accentuated by these alternating light and dark laminae and layers.

Keith (1907, p. 4) and subsequent workers described the Nantahala Formation as containing slates. "Slate" is not an accurate term for describing the siltstone in this study of the Nantahala Formation because the mica (pelite) content of these rocks is too low and slaty cleavage is not well developed; however, mica may be enriched in very thin pelitic laminations. Siltstone is used here because the present grain size is dominantly silt and the mica content is low. The slabby "slate-like" character is due to breakage along original bedding planes. There are thin layers and laminations, averaging one centimeter, of alternating light colored quartz-rich units and darker colored more pelitic units. These laminations are wispy and delicate in form. Hurst (1955, p. 45) noted that laminations pinch and swell and pinch out over a few centimeters, or continue without change in thickness. Figure 4 is a sketch of these features.

Table 1. Thicknesses in meters of Nantahala and Brasstown Formations.

Measured Sections	A	B	C	D	E	F	G	H	I	J	K
Brasstown Formation	484	682	984	2311	940	1295	1199	1319	1275	1313	2469
Nantahala-sandstone*	65	160	65	268	182	412	445	484	345	312	724
Nantahala-siltstone*	661	462	973	1692	608	1011	1055	1066	1561	1009	1484
	-----	-----	-----	------	-----	-----	------	-----	-----	-----	-----
Total	1214	1304	2022	4271	1730	2718	2699	2869	3181	2634	4677

(see Fig. 1 for section locations, Fig. 2 for locations of F-I).
(Sections D and K are suspected of increased thickness due to folding.)
A Jonica Gap, Georgia, southeast of Culberson, North Carolina
B North of Cobb Creek toward Ranger on U.S. Highway 19 and 129.
C Town of Brasstown, CR 1100, parallels Brasstown Fm. Type area on Brasstown Cr.
D Sweetwater Community west of Hayesville on U.S. Highway 64.
E Northwest of Culberson toward Shields on CR 1120, North Carolina
F Panther Top fire tower SW of Murphy, National Forest Service (NFS) roads 85, 85A.
G Nottely River from Cane Cr. At U.S. 64, 19, 129 toward the Hiwassee River.
H Hiwassee River reference section west of Murphy
I Joe Brown Highway, CR 1326, north of Murphy
J Allmon Creek, NFS road 990, north of Marble
K Trail of Tears, NFS road 423, north of Andrews.
*Aggregated thickness

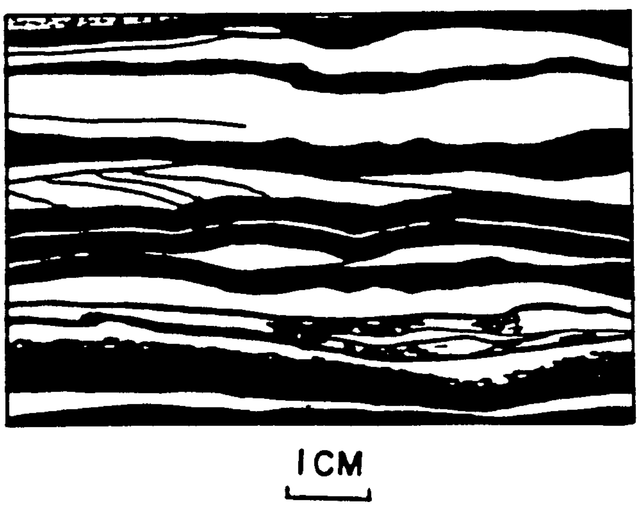


FIGURE 4. Laminations of dark-colored mica and light-colored, quartz rich siltstones of the Nantahala Formation oriented with the top up at location 413.

Nantahala Formation siltstone petrographic modal analyses are presented in Table 2. In thin section the darker-colored laminations result from concentrations of graphite and clear to dark orange pleochroic biotite. Generally in both dark and light colored layers, the muscovite content can vary from being nearly equal to biotite to being absent. The dark laminations contain micro-bands, where most of the graphite is found. The graphite is silt-sized, about one fourth the size of the dominant silt-sized quartz and feldspar (0.1 mm). These micro-bands contain foliated micas whereas the larger quartz-rich layers have randomly oriented micas. Within the darker layers, the graphite is greater than three percent and in some samples is speckled as irregular clusters, about the same size as the smaller silt grains. Micro-bands can contain more muscovite than biotite. In some micro-bands calcite, muscovite, plagioclase, microcline, and quartz occur. Only biotite is visible in hand specimens and detrital tourmaline is common.

Sandstone of the Nantahala Formation

Sandstones within the Nantahala Formation do not form a single prominent unit, the Tusquitee Quartzite, as defined by Keith (1907, p. 4), but are dispersed throughout the formation. Sandstone occurs in the upper part of the formation on the northwestern limb of the Murphy Syncline and throughout the formation on the southeastern limb. For example, sandstone may be observed in the lower levels of the formation at the Vengeance Quarry south of Andrews (Fig. 1, 304). However, there is still a sandstone present marking the top of the Nantahala Formation on the southeastern limb. The units range from feldspathic to quartz arenites and are fine to medium grained, white, yellow, and reddish, medium to thick-bedded sandstones. Granule and pebble conglomerates are rare. Light colored fine sand sized and dark colored coarse silt sized laminations are present.

For the Nantahala Formation as a whole, the contact between the sandstone and siltstone intervals are commonly

Table 2. Modal Analyses of Dean, Nantahala, and Brasstown Formations.

Formation	nf	nf	nf	nf	nf	nf	nf	tq	tq	tq	tq	tq	bf	bf	bf	bf	bf	bf	bf
Sample	24	18	38	73	133	378	502	92	119	191	229	304	15	20	103	152	184	387	478
Quartz	78.8	77.1	54.5	54.2	37.7	68.2	53.9	78.7	91.5	86.7	76.0	81.6	50.5	68.8	60.5	75.2	47.8	72.3	46.8
Plagioclase	1.8	0.7	0.5	0.7	tr	1.0	0.5	6.9	0.5	1.9	7.0	5.7	0.8	1.3	--	2.6	0.1	7.1	0.2
Microcline	0.6	0.1	0.2	0.1	--	1.7	0.5	6.8	7.3	2.6	1.0	--	--	1.1	0.1	0.6	--	1.0	--
Orthoclase	1.9	3.7	4.6	1.0	2.2	--	3.8	7.1	--	4.7	14.6	7.1	1.2	--	--	--	--	8.1	0.2
Biotite	9.8	2.6	24.3	26.0	21.9	13.0	10.5	--	--	--	--	--	22.7	20.9	12.9	15.7	13.3	9.3	15.8
White mica	4.7	--	6.8	10.3	30.8	10.8	25.3	0.4	0.5	3.6	1.2	5.5	22.7	3.8	16.7	0.4	33.6	--	31.3
Garnet	tr	--	0.4	--	tr	--	tr	--	--	--	--		0.3	1.1	2.9	2.6	3.6	1.7	2.1
Tourmaline	--	tr	0.1	0.1	0.2	0.3	0.1	--	--	--	--	--	0.1	--	--	0.1	tr	--	0.1
Zircon	0.3	--	0.1	0.3	0.1	0.1	tr	--	--	tr	0.1	--	0.1	--	0.2	--	0.1	0.1	tr
Staurolite	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.7	--	--	--	--
Chlorite	--	5.2	--	--	--	--	--	--	--	--	--	--	0.1	1.0	1.6	0.4	0.1	0.4	0.8
Hornblende	--	0.2	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	--
Zoisite	--	1.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sphene	0.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chert	--	--	--	--	--	--	--	--	0.1	0.6	0.1	--	--	--	--	--	--	--	--
Pyrrhotite	tr	0.5	0.5	4.3	4.8	3.2	0.3	tr	--	--	tr	0.1	1.4	2.0	2.0	1.9	1.3	--	1.3
Graphite	--	--	8.0	2.7	2.3	1.4	5.2	--	--	--	--	--	--	--	2.3	--	0.1	--	1.3
Calcite	2.0	8.7	--	--	--	0.4	--	0.1	--	--	--	--	--	--	--	0.5	--	--	--

(750-1000 point counts); datum on 7.5 minute quadrangles.
(Dean Fm. (df), Nantahala Fm. Siltstones (nf) and sandstones (tq), and Brasstown Fm. (bf).
15 Quarry near Joe Brown Highway on Hiwassee River, Murphy quadrange, 35'05'42"N;84'02'26"W.
18 CR 1304 and U.S. 64 on Carroll Mountain; Peachtree quadrangle, 35'0249"N;83'52'55"W.
20 Near Hiwassee River on U.S. 64 at Green CR 1131, Peachtree quadrangle, 35'03'24"N;83'55'42"W.
24 Conglomerate, Hanging Dog Creek at Joe Brown Highway, Murphy quadrangle, 35'06'43"N;84'04'08"W.
38 Jim Bell Gap on Joe Brown Highway, Murphy quadrangle, 35'06'38"N;84'06'31"W.
73 Panther Top fire tower, Murphy quadrangle, 35'03'50"N;84'06'31"W.
92 Wesser, Great Smoky Mountain R.R., Wesser quadrangle, 35'19'59"N;83'35'44"W.
103 Fires Creek road 0.4 kilometers west of NFS road 340A, Hayesville quadrangle, 35'06'06"N;83'50'35"W.
119 U.S. 129 to Robbinsville on Bear Creek, Hewitt quadrangle, 35'16'22"N; 83'43'33"W.
133 Quarry south of Robbinsville on NFS road 423, Robbinsville quadrangle, 35'16'42"N;83'49'06"W.
152 Beaver Creek road at Dan Holland Creek,NFS road 304, Andrews quadrangle, 35'14'01"N;83'51'04"W.
184A Fishermare Creek at Marble, Marble quadrangle, 35'11'47"N; 83'55'44"W.
191 Vengeance Creek road at Hogpen Gap, NFS road 6148, Andrews quadrangle, 35'09'09"N;83'51'59"W.
229 Colvard Creek on NFS road 625, Marble quadrangle, 35'10'01"N;83'58'58"W.
304 Vengence Quarry, Andrews at McClellan Creek, on CR 1509, Andrews quadrangle, 35'10'14"N;83'48'46"W.
378 Moody Stamp on Beaver Creek, NFS road 304, Andrews quadrangle, 35'14'21"N;83'52'17"W.
387 Confluence of Hiwassee and Valley Rivers, Murphy quadrangle, 35'05'33"N;84'02'21"W.
478 Leatherwood Creek, Tusquitee Mountains, NFS road 6176, Hayesville quadrangle, 35'06'43"N; 83'51'38"W.
502 Big Peachtree Bald, Tusquitee Mountains, Andrews quadrangle, 35'07'48"N;83'51'50"W.

gradational with laminations of sandstone gradually increasing from about 25 percent up to 100 percent within one to two meters. According to the terminology of Folk (1954, p. 354; 1974, p. 127) and Scholle (1979, p. 94 and 96) these dominantly sand sized lithologies are classified as subarkosic sandstone (5 to 25% feldspar).

The sand sized material has been in part recrystallized; however, detrital grains of microcrystalline quartz (chert), and detrital, rounded plagioclase and potassium feldspars are present. These detrital feldspar grains have, to varying degrees, been replaced by white micas. Feldspar grains generally contain quartz inclusions and may also be perthitic and myrmekitic. Some quartz is observed to have optically continuous overgrowth cementation suggesting a clean quartz surface (Orhan, 1989).

Upper contact

The most important mapping criterion for separating the interbedded sandstones and siltstones in the Nantahala Formation from rocks in the Brasstown Formation in southwestern North Carolina, is the sandstone at the top of the Nantahala Formation. Keith (907, p. 4) named this sandstone the Tusquitee Quartzite. Above the uppermost sandstone of the Nantahala Formation, there is gradual to abrupt change to siltstones because the Brasstown Formation commonly has a phyllitic schistose luster, which results from silt and sand sized mica along cleavage planes. The Brasstown Formation schists have larger sized micas than the siltstones of the Nantahala Formation, and these schists contain up to 1.5 mm garnet and/or biotite porphyroblasts in "polka dot" fashion. Though graphite is present in the Brasstown Formation, its overall appearance is dominated its micaceous character.

BRASSTOWN FORMATION

Keith (1907, p. 4) described the Brasstown Formation as an upper, banded biotite schist and banded slate with garnet, biotite, ± staurolite. Keith (1907, p.4) also placed an additional formation (the Valleytown Formation) between the Brasstown Formation and the Murphy Marble. According to Hadley (1970, p. 255), the darker, iron-rich beds were historically called Brasstown Formation and the sandier metashales were called the Valleytown Formation. He described the original Valleytown Formation, now the upper Brasstown Formation, as thin-bedded but lighter in color than the original type Brasstown Formation. Most workers following Hurst (1955, p.49) abandoned the Valleytown Formation and assigned all units between the Nantahala Formation and the Murphy Marble to the Brasstown Formation.

The Brasstown Formation is mostly light gray to dark gray siltstones and schists. Typically lithology consists of alternating one centimeter thick layers of light gray biotite "quartzite" and dark gray siltstone and mica schist.

In thin section, muscovite is essentially absent in the darker colored laminations whereas biotite is present. Muscovite is present in the lighter colored bands. Randomly oriented biotite porphyroblasts up to 1.5 mm in diameter. Detrital plagioclase is zoned and contains inclusions of quartz. Graphite may locally be present in the darker-colored pelitic layers or laminae of siltstones. In general graphite is less abundant than in the Nantahala Formation (Table 2). The rock is commonly not a true schist because schistosity is poorly developed and mica constitutes less than 50% of the rock.

SEDIMENTARY STRUCTURES

Primary features on a bed scale are measurable in the Hiwassee River reference section west of Murphy, North Carolina (Fig. 2). Cross bedding may be found in the sandstone units of the Nantahala Formation as trough-cross stratification and as a planar tabular type. The planar tabular type is in intervals 20 cm thick, dipping 35° from bedding, and has a paleocurrent direction S70°E (10 readings) in the blanket sandstones of the Nantahala Formation (Fig. 5).

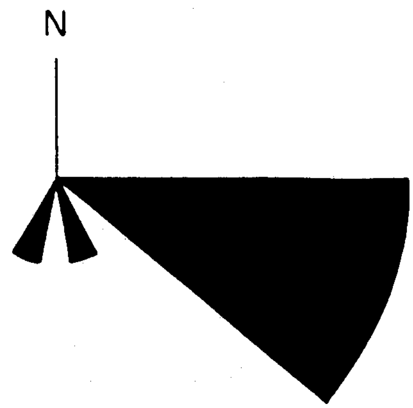


Figure 5. Paleocurrent direction of °, S70°E of Nantahala Formation sandstone from the Hiwassee River reference section, 10 observations.

This paleocurrent direction is comparable to the Chilhowee Group which has a provenance to the west and northwest (Schwab, 1986, p. 122; Walker and others, 1988 p. 43). Within all the Chilhowee Group sections located in eastern Tennessee, Whisonant (1970, p. 2782) demonstrated the paleocurrent direction for planar cross-bedding to be S82°E for the Hessee Quartzite, S52°E for the Nebo Quartzite and S46°E for the Cochran Formation, but his cross bed inclination average from bedding is 15° or less.

The absence of symmetric ripples is thought to indicate deposition below normal wave base, as seen in the alternating light (sandstone) and dark-colored laminations (siltstone) of the Nantahala Formation (Hurst, 1955, p. 57; Mohr, 1973, p. 61)(Fig. 4).

Large scale planar-tabular and trough-cross stratified beds in intervals 40 cm thick in the upper sandy unit of the Brasstown Formation are visible at the confluence of the Hiwassee andValley Rivers within the reference section. The planar-tabular beds of the Brasstown Formation have cross beds that dip 15° from bedding and a paleocurrent direction of N36°E (9 readings) which is different from the Chilhowee Group (Schwab, 1986, p. 122; Walker and others, 1988, p.

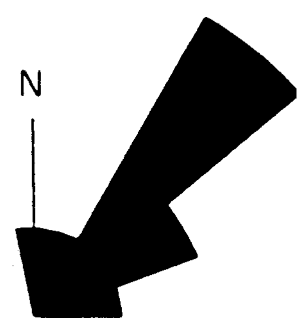


Figure 6. Paleocurrent direction of 15°, N36°E of sandstone in the Brasstown Formation from the confluence of the Valley and Hiwassee Rivers, 9 observations.

43) (Fig. 6). Cross bedding in both the Nantahala and Brasstown Formations for this study is accentuated by heavy mineral laminations and not by sorting of grain sizes.

No Bouma sequence rhythmites or graded beds, no symmetrical ripples, and no channels were found in these Hiwassee River section rocks during this study.

PREVIOUS CORRELATION

The age of the Chilhowee Group is considered Lower Cambrian by King (1949, p. 638). However, Walker and Driese (1991, p. 279) designated the upper Proterozoic Lower Cambrian contact to be imprecisely within the youngest part of the Cochran Formation, the oldest formation within the Chilhowee Group. The Chilhowee Group at parts of Chilhowee Mountain rests conformably on the Sandsuck Formation (Neuman and Nelson, 1965, p. 23 and 65; Walker and Driese, 1991, p. 262) and the entire Chilhowee Group is thought to be correlative to the siliciclastic portion of the Hiwassee River Group (Keith, 1907, p. 11; Hurst, 1955, p. 8; Hadley, 1970, p. 256). Keith (1907, p. 11) initially correlated conglomerates of the Dean Formation of the upper Great Smoky Group with the Cochran Formation, the Nichols Shale with the Nantahala Formation metasiltstones, and the Murphy Marble with the Shady Dolomite. However, King and others (1958, p. 964) stated there probably was no correlation between the Great Smoky Group and the Cochran Formation.

INTERPRETATION

Depositional models

The Nantahala Formation sandstone exhibits higher angle cross-bedding than beach-deposit cross bedding of 1º to 12º but lower than for eolian cross-bedded deposits of up to 45º (Ehlers and Blatt, 1982, p. 342). The 35º angle from bedding is interpreted to represent a shelf sand body.

One hypothesis to explain the origin of the sandstones in the Brasstown Formation is that they may possible be interpreted as part of offshore bars, formed from longshore currents, because both trough and planar-tabular cross-beds are present and because the sandstone lenses are irregular on both top and bottom. The paleocurrent direction is perpendicular to that of the Nantahala Formation. The 15º angle from bedding of the cross beds in the Brasstown Formation is smaller than that of crossbeds in the Nantahala Formation. The angle from bedding in cross-beds is consistent throughout the area and rules against local deformation and differential compaction.

The lower portion of the Chilhowee Group is interpreted to have formed in fluvial or coastal alluvial deposits (Walker and Driese, 1991, p. 261) from a western source representing a transition from rift to Atlantic-type margin of Laurentia (Hatcher, 1972, p. 2749; Rast and Kohles, 1986, p. 610-612) and the upper portion of the Chilhowee Group is of shallow marine foreshore, shoreface and shelf origin (Walker and Driese, 1991, p. 261-262; Walker and others, 1988, p. 50). If the Cochran Formation rocks are facies-transition equivalents to the sandstones and siltstones of the Nantahala Formation, then the Brasstown Formation may be equivalent in time to the transgressive sequences of the Nichols/Nebo and Murray/Hesse Formations (Aylor and others, 1991). An inner-continental shelf environment that is below wave base is possible for Nantahala Formation deposition. The distal marine facies of the Nantahala-Brasstown Formations could be equivalent to the continental to outer continental shelf transgressive sequence of Chilhowee Mountain. The Shady Dolomite and Murphy Marble would be carbonate "platform" equivalents.

CONCLUSIONS

The upper sandstone of the Nantahala Formation (previously the Tusquitee Quartzite) separates the Nantahala Formation from the Brasstown Formation. Generally, the Hiwassee River Group has conformable contacts with the strata below it. The upper contact of the Hiwassee River Group is an unconformity (Tull and others, 1991b, this volume). The formations within the Hiwassee River Group have conformable contacts with each other.

Siliciclastic rocks of the Hiwassee River Group probably represent deposition below normal wave base on the continental shelf of an Atlantic-type margin. This sequence of strata may therefore be an off-shore facies equivalent to Chilhowee Group strata exposed to the west at Chilhowee Mountain, Tennessee.

ACKNOWLEDGEMENTS

Supported in part by southeastern section of the Geological Society of America and Florida State University Banks Awards. I thank Jim Tull, Steve Kish, Dan Walker, Denny Bearce, Bill Tanner, and Mark Groszos for constructive reviews and discussions.

REFERENCES

Aylor, J.G., Jr., Tull, J. F., and Walker, Dan, 1991, Comparison of the Lower Murphy Group, North Carolina with the Lower Chilhowee Group, eastern Tennessee: Geological Society of America Abstracts with Programs, v. 23, p. 4.

Ehlers, E. G., and Blatt, Harvey, 1982, Petrology: Igneous, Sedimentary, and Metamorphic: New York, W. H. Freeman and Company, 732 p.

Folk, R. L., 1954, The distinction between grain size and mineral composition in sedimentary rock nomenclature: Journal of Geology, v. 62, p. 344 – 359.

Folk, R. L., 1974, Petrology of Sedimentary Rocks: Austin, Texas, Hemphills, 170p.

Hadley, J. B., 1970, The Ocoee Series and its possible correlatives, p. 247 – 259, in Fisher, G. W., Pettijohn, F. J., Reed, J. C., Jr., and Weaver, K. N., eds., Studies of Appalachian geology: central and southern: New York, Wiley-Interscience, 460 p.

Hatcher, R. D., Jr., 1972, Developmental Model for the Southern Appalachians: Geological Society of America Bulletin, v. 83, p. 2735 – 2760.

Hurst, V. J., 1955, Stratigraphy, structure, and mineral resources of the Mineral Bluff quadrangle, Georgia: Georgia Geological Survey Bulletin 63, 137 p.

Keith, Arthur, 1904, Description of the Asheville quadrangle, North Carolina: U. S. Geological Survey Geologic Atlas, Folio 116, 10p.

Keith, Arthur, 1907, Description of the Nantahala quadrangle, North Carolina and Tennessee: U. S. Geological Survey Geologic Atlas, Folio 143, 17 p.

King, P. B., 1949, The base of the Cambrian in the southern Appalachians: American Journal of Science, V. 247, p. 622 – 645.

King, P. B., Hadley, J. B., Neuman, R. B., and Hamilton, Warren, 1958, Stratigraphy of Ocoee Series, Great Smoky Mountains, Tennessee and North Carolina: Geological Society of America Bulletin, v. 69, p. 947-966.

Kish, S. A., Merschat, C. F., Mohr, D. W., and Wiener, L. S., 1975, Guide to the geology of the Blue Ridge south of the Great Smoky Mountains, North Carolina: Carolina Geological Society Annual Field Trip Guidebook, 49 p.

Mohr, D. W., 1973, Stratigraphy and structure of the Great Smoky and Murphy Belt Groups, western North Carolina: American Journal of Science, v. 273-A, p. 41 – 71.

Neuman, R. B., and Nelson, W. H., 1965, Geology of the western Great Smoky Mountains, Tennessee: U. S. Geological Survey Professional Paper 349-D, 81 p.

Orhan, Hukmu, 1989, Diagenetic history of Entrada and Dakota Formations in Ghost Ranch area, New Mexico [PhD thesis]: Tallahassee, Florida State University, 156 p.

Power, W. R., and Forrest, J. T., 1971, Stratigraphy and structure of the Murphy belt, North Carolina: North Carolina Department of Natural Resources, Carolina Geological Society Field Trip Guidebook, 29 p.

Rast, Nicholas, and Kohles, K. M., 1986, The origin of the Ocoee Supergroup: American Journal of Science, v. 286, p. 593 – 616.

Scholle, P. A., 1979, Constituents, textures, cements, and porosities of sandstones and associated rocks: American Association of Petroleum Geologists Memoir 28, 201 p.

Schwab, F. L., 1986, Latest Precambrian-earliest Paleozoic sedimentation, Appalachian Blue Ridge and adjacent areas: review and speculation, in McDowell, R. C., and Glover, Lynn, III, eds., The Lowry volume: Studies in Appalachian geology: Blacksburg, Virginia Tech Department of Geological Sciences, Memoir 3, 137 p.

Tull, J. F., Thompson, T. W., Groszos, M. S., Aylor, J. G., Jr., and Kish, S. A., 1991a, Murphy belt lithostratigraphic nomenclature, in Kish, S. A., ed., Studies of Precambrian and Paleozoic Stratigraphy in the Western Blue Ridge: Carolina Geological Society Field Trip Guidebook.

Tull, J. F., Thompson, T. W., and Groszos, M. S., 1991b, Stratigraphic arguments against faulting in the Murphy belt, in Kish, S. A., ed., Studies of Precambrian Paleozoic stratigraphy in the western Blue Ridge: Carolina Geological Society Field Trip Guidebook.

Van Horn, E. C., 1948, Talc Deposits of the Murphy Marble Belt: North Carolina Division of Mineral Resources Bulletin 56, 54 p.

Walker, Dan, Skelly, R. L., Cudzil, M. R., and Driese, S. G., 1988, The Chilhowee Group of east Tennessee: Sedimentology of the Lower Cambrian fluvial to marine transition, in Driese, S. G., and Walker, Dan, eds., Depositional history of Paleozoic sequences, southern Appalachians, Knoxville, Tennessee, University of Tennessee, Department of Geological Sciences, Studies in Geology 19, p. 30 – 61.

Walker, Dan, 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.

Whisonant, R. C., 1970, Paleocurrents in basal Cambrian rocks in eastern Tennessee: Geological Society of America Bulletin, v. 81, p. 2781 – 1786.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 99-113

STRATIGRAPHY OF THE MINERAL BLUFF GROUP, SOUTHWESTERN NORTH CAROLINA

Troy W. Thompson, and James F. Tull
Department of Geology B-160, Florida State University, Tallahassee, Florida 32306

INTRODUCTION

Near the geographic center of the Blue Ridge lies the sinuous Murphy belt (Fig. 1) which outcrops in a doubly plunging isoclinal synclinorium that is overturned to the west. The stratigraphically lower part of the Murphy belt is comprised of the proposed Hiwassee River Group (Tull and others b, this volume): Nantahala Formation, Brasstown Formation and Murphy Marble, which is an internally conformable metasedimentary sequence that conformably overlies the Great Smoky Group. The Mineral Bluff Group resets in the core of the Murphy syncline, atop the Hiwassee River and Great Smoky Groups and may be the youngest sequence of metasediments in the western Blue Ridge (Hurst, 1955). The nature of the proposed Hiwassee River Group and overlying Mineral Bluff Group contact has been debated, but recent work by Tull and Groszos (1988) indicates that boundary is unconformable.

The Mineral Bluff Group reaches its greatest thickness (>2 km) in southwestern North Carolina (USGS Murphy and Peachtree 7.5 minute quadrangles), and our recent mapping efforts reveal a distinctive and mappable internal stratigraphy within this group in this region (Fig. 2). Because of the lower angle unconformity below the Mineral Bluff Group and the presence of an internally mappable stratigraphy, we are proposing the elevation of the Mineral Bluff Formation of Hurst (1955) to Group status and the subdivision of the Mineral Bluff Group into the following formations: a) Mission Mountain Formation (including the Nottely Quartzite Member), b) Fort Butler Mountain Formation, c) Harshaw Bottom Quartzite, and d) Peachtree Creek Formation (Fig. 3).

Our objectives for this paper are: A) to describe and define the internal stratigraphy of the proposed Mineral Bluff Group, and B) to discuss the possible age and correlations of the Mineral Bluff Group.

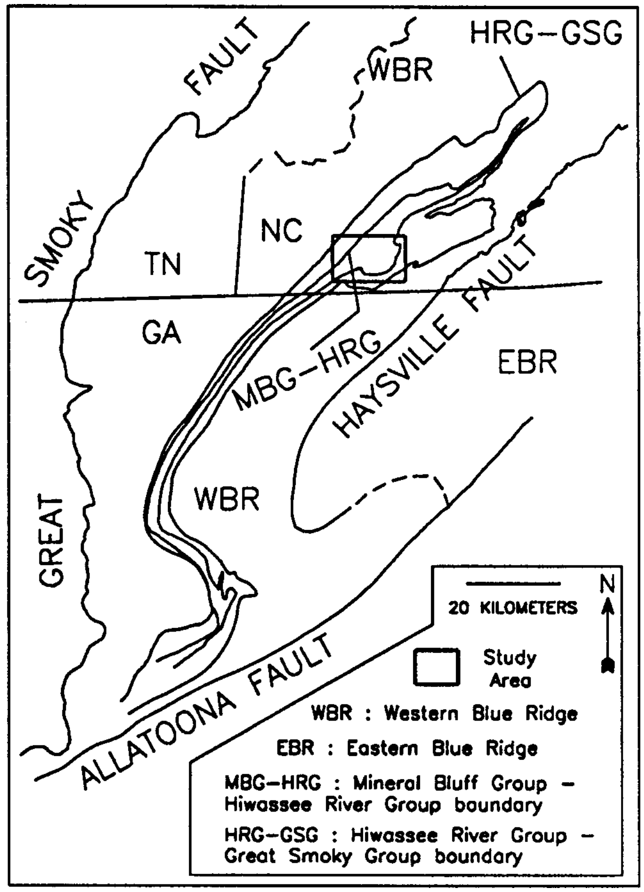


Figure 1. Location map of Murphy belt and study area.

MISSION MOUNTAIN FORMATION

The Mission Mountain Formation is the lowermost unit in the Mineral Bluff Group in North Carolina (the Marble Hill Hornblende Schist is the basal unit in Georgia, see Tull and others, b, this volume), reaching approximately 1 km in thickness, and is named for exposures found on the east limb of the regionally developed Murphy syncline along the northern slope of Mission Mountain, approximately 1 km southeast of Peachtree, North Carolina. We propose that the type section for this unit be established along the Hiwassee River, approximately 1 km north of Brasstown, North Carolina, where excellent, relatively continuous exposures for up to 1 km perpendicular to strike can be seen. Exposures on the west limb of the syncline are locally excellent (see Thompson and Tull, SUNDAY Stop 2A and 2B, this volume), but not as continuous. The Mission Mountain rests unconformably above the various units of the Hiwassee River Group, and depending upon the extent of the pre-Mineral Bluff Group erosional level, rocks in this stratigraphic position in Georgia are locally in stratigraphic contact with the Great Smoky Group (Tull and Groszos, 1988).

The Mission Mountain Formation is a grayish-green rhythmically layered turbidite-dominated sequence that is thinly laminated and dominantly metagraywacke. Carbonate-rich calc-silicate ("pseudodiorite") layers are less common (accounting for approximately 8 percent by volume of SUNDAY Stop 2A and 2B) and rare siliceous marbles also occur. Additionally, the formation contains mappable

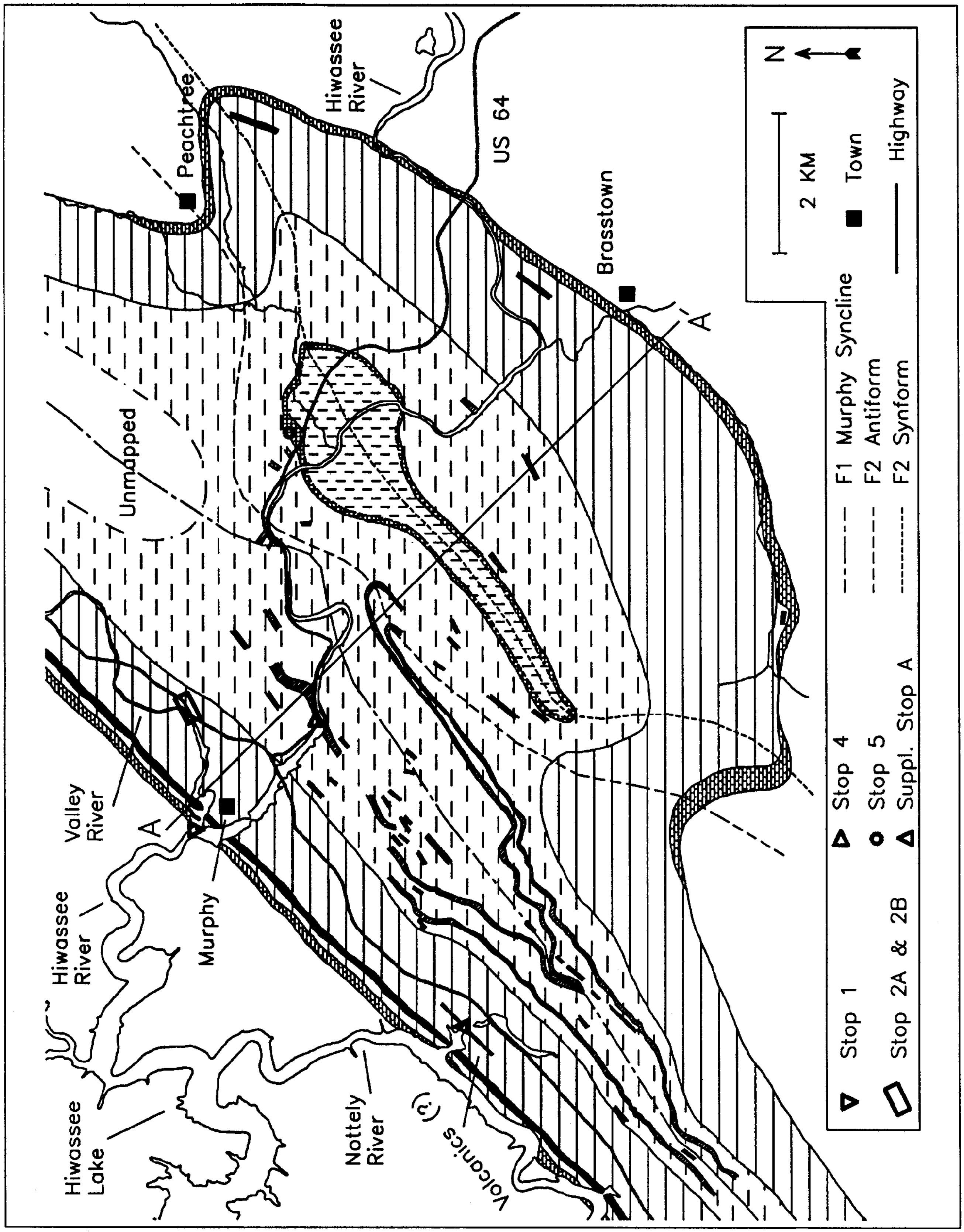


Figure 2. Murphy Marble and Mineral Bluff Group stratigraphy, southwestern North Carolina. See Figure 3 (stratigraphic column) for interpretation of stratigraphic symbol.

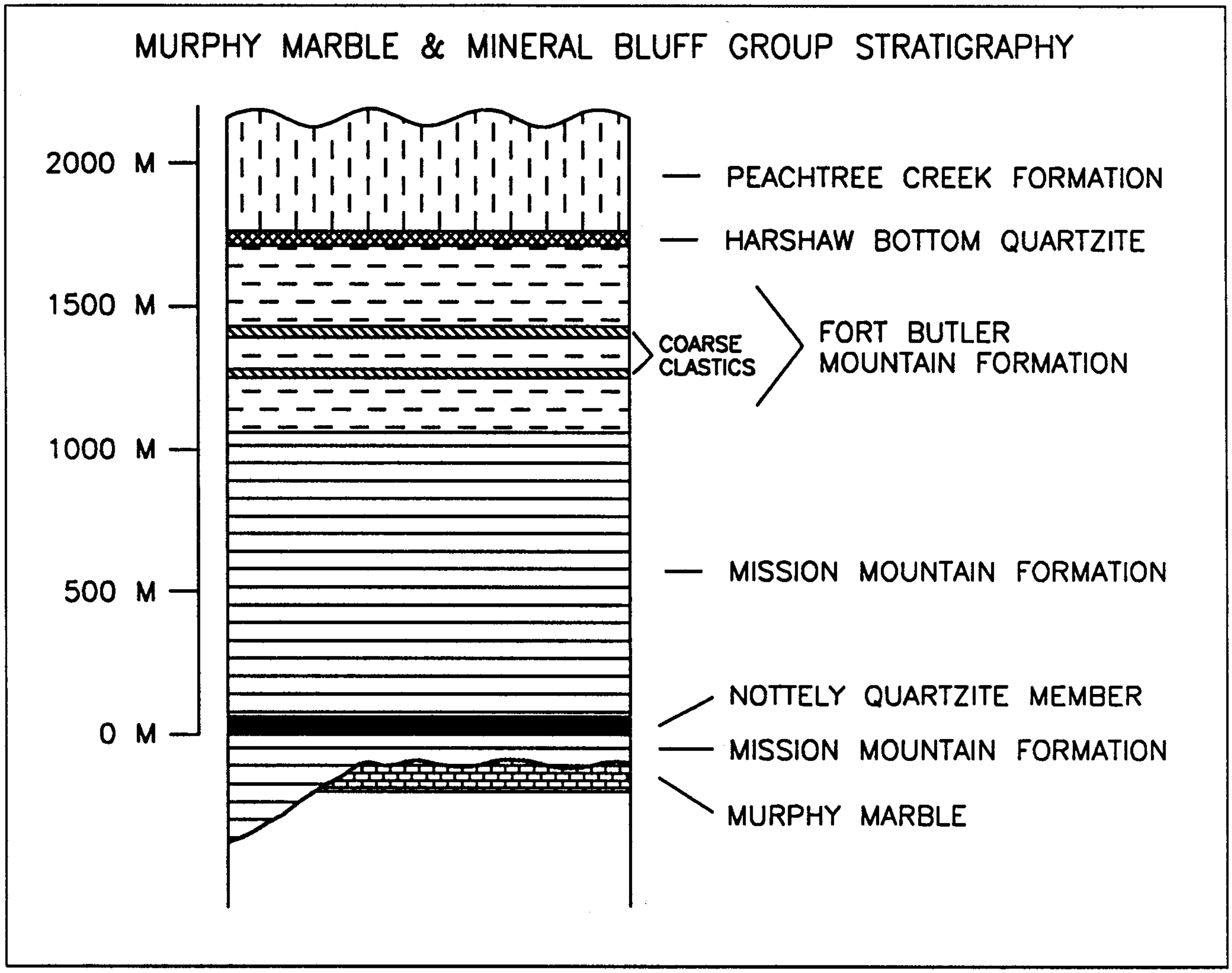


Figure 3. Generalized stratigraphic column of Murphy Marble and unconformably overlying Mineral Bluff Group stratigraphy.

metasandstone units, mostly near the base (Nottely Quartzite Member) and also contains zones of possible mafic metavolcanic and/or volcaniclastic rocks, also near the base. The Mission Mountain Formation has the most diverse mineral assemblage within the Mineral Bluff Group and is composed dominantly of fine-grained quartz, plagioclase, muscovite, biotite, chlorite, epidote, carbonate, and opaques, with minor occurrences of perthite, garnet, amphibole, hematite, sphene, and traces of tourmaline (Table 1). The Mission Mountain Formation is characteristically rich in carbonate or calcium-bearing mineral phases (epidote, sphene), plagioclase, chlorite, and opaques, and is relatively quartz-poor. Detailed field mapping, interpretation of preserved primary structures, and petrographic study indicate that the Mission Mountain Formation is a carbonate-rich turbidite-dominated sequence. LaTour and Fritz (1988), who examined the origin of Mineral Bluff Calc-silicates within a restricted interval in the upper part of the mission Mountain Formation, reached a similar conclusion.

Interlayered within the Mission Mountain Formation, in at least one locality on the west limb, are mafic metaigneous rocks previously mapped as a diorite sill by Van Horn (1948). At this locality (Thompson and Tull, SUNCAY Supplemental Stop 1) a conspicuous zone of interlayered metagraywacke (Table 1; 251-2A, 251-3A2, and 251-3D) and amphibolite (mafic metaigneous rocks) is very well exposed at low river levels. Geochemical analyses of this mafic section (Table 2; 251-1E) and calculated CIPW norms (Table 3; 251-1E) indicate a probable basaltic source for these interlayered mafic rocks, based on their high Ti02, Ca0, and transition metal values (see Thompson and Tull, SUNDAY Supplemental Stop 1, for a more complete description of the outcrop).

Numerous geochemical analyses of Mission Mountain

Table 1. Modal Analases of Mineral Bluff Group Stratigraphy

Stratigraphy	Nottely Quartzite Member					
Station Number	30C	61C	90	249	377M	377U
Quartz	80.8	78.6	86.9	91.4	93.3	95.0
Plagioclase		0.8				
Perthite						
Feldspar (total)	18.4	19.7	12.3	1.8	5.4	3.3
Muscovite	0.5	0.6	0.6		0.9	1.1
Biotite				1.5		
Chlorite				2.3		
Garnet						
Amphibale						
Epidote						
Tourmaline	Tr	Tr	Tr	Tr		Tr
Sphene						
Carbonate						
Hematite		Tr	Tr	0.4	0.3	0.2
Opaques			Tr	Tr	Tr	Tr
Total Counts	847	1092	1035	1092	1092	1075
Latitude	35 01 04	35 05 06	35 04 37	35 05 28	35 07 22	35 07 22
Longitude	84 00 21	83 55 45	84 03 17	84 02 14	83 59 55	83 59 55

Stratigraphy	Mission Mountain Formation											
Station Number	64	701	251-2A	251-3A2	251-3D	262A	307	342	376A	377	457B	476
Quartz	34.2	14.7	47.8	62.3	36.9	18.4	35.0	33.1	55.1	46.2	33.5	21.8
Plagioclase	1.5	1.9	14.3	1.1	3.4	Tr	18.3	2.0	2.2	19.8	16.3	16.4
Perthite			2.7	1.8			Tr	Tr				
Feldspar (total)							0.2					
Muscovite	22.4	2.7	12.3		10.3		7.1	28.3			5.8	27.9
Biotite	5.4	2.4	20.9	1.0	23.3		1.0	9.1		16.8		
Chlorite	15.7	0.2	Tr	8.2	17.0	45.9	9.5	12.1	0.9	2.3	10.0	27.1
Garnet	0.2										1.0	
Amphibale									5.2		2.7	
Epidote	4.2		0.7	25.2	4.6	27.1		2.7	8.3		29.3	2.4
Tourmaline	Tr						Tr			Tr		Tr
Sphene								Tr		6.6		
Carbonate		76.4					26.7	17.5	27.8			
Hematite	Tr	0.3			0.6	Tr					Tr	
Opaques	15.8	0.9	1.0	Tr	3.4	8.1	1.5	5.0	Tr	7.7	0.8	3.8
Total Counts	1092	1075	1092	1092	1092	1092	1092	1074	1053	1092	1092	1092
Latitude	35 03 42	35 05 14	35 05 53	35 05 53	35 05 53	35 02 14	35 03 08	35 03 50	35 05 37	35 07 22	35 02 18	35 04 31
Longitude	83 5647	83 56 17	84 01 24	84 01 24	84 01 24	84 05 42	84 03 57	84 03 21	84 01 14	83 59 55	84 01 35	84 02 40

Stratigraphy	Fort Butler Mtn. Formation (coarse clastics)					Harshaw Bottom Quartzite		
Station Number	16A	34-2A	34-2B	35A	136 A3	42A	146F	394
Quartz	77.8	71.9	76.0	79.4	62.6	73.9	98.5	99.9
Plagioclase					0.2			
Perthite		6.0	0.5	8.3	13.6			
Feldspar (total)								
Muscovite			15.5	11.5	6.2	0.6	1.4	Tr
Biotite	21.6	4.7	3.2			Tr		
Chlorite		16.7			12.8	3.2		
Garnet								
Amphibale								
Epidote						21.7		
Tourmaline					Tr			
Sphene								
Carbonate								
Hematite			0.7	0.6				
Opaques	0.5	0.6	3.8		4.3	0.3	Tr	
Total Counts	1092	999	1092	1092	1092	1092	1092	1092
Latitude	35 01 43	35 04 56	35 04 56	35 04 54	35 03 26	35 03 53	35 04 50	35 03 50
Longitude	84 05 15	84 0109	84 0109	84 05 54	83 58 26	83 59 37	83 58 39	83 59 18

metasediments (?) sampled on the west limb over a 10 km strike interval (Table 2; 251-3F-1, 251-3F-2, 252A, 252B, 242C, 242C-S2, and 262A) and their accompanying CIPW norm calculations (Table 3; 251-3F-1, 251-3F-2, 252A, 252B, 252C, 252C-S2, and 262A) indicate that a significant metaigneous component may be associated with these samples, which are found in the lower part of the Mission Mountain Formation. Four anomalous geochemical characteristics stand out for the Mission Mountain Formation (Table 2): 1)SiO_2 values range from 34.0 to 51.6 and average 43.6 percent, 2) TiO_2values range from 3.28 to 5.40 and average 4.28 percent, 3) CaO values range from 1.70 to 7.23 and average 5.13 percent, and 4) trace element (transition metals) values are significantly higher than expected for normal sedimentary lithologies. The extent of metasomatism has never been sufficiently addressed in this region, and thus, we are cautious in interpreting the major element chemistry as diagnostic of the original composition of the Mission Mountain Formation. However, the high TiO_2 and high transition metal values (particularly Ni and Cr) are clear diagnostic indicators that a mafic to ultra-mafic component must be associated with at least part of the Mission Mountain Formation. Refer to the Volcanogenic origin of some Mineral Bluff Group rocks section (below) for a more detailed discussion.

Nottely Quartzite Member

The Nottely Quartzite Member rests near the base of the Mission Mountain Formation and was defined by Keith (1907) for exposures along the Nottely River near Culberson, North Carolina. Excellent exposures can be seen along U.S. Highway 19-129 approximately 5 kilometers northeast of Murphy, North Carolina (Thompson and Tull, SUNDAY Stop 3), along the Valley River near the Hiwassee River confluence, and along the Nottely River near the U.S. Highway 64 intersection. The Nottely Quartzite is a thick to thin bedded, medium to coarse-grained, and locally cross-bedded metasandstone ranging from subarkose to quartz arenite (Table 1) (~ 55 meters thick near Murphy, North Carolina), and represents the lowermost mappable coarse clastic unit in the Mineral Bluff Group. The Nottely has only a sporadic distribution on the southeast limb of the Murphy syncline (Fig. 2) throughout much of the strike of the Murphy belt, but when present, is easily recognized relative to other rocks of the Mission

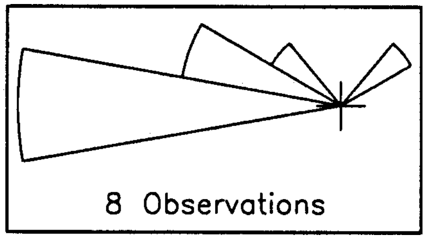


Figure 4. Paleocurrent directions-Nottely Quartzite Member.

Mountain Formation (see above). A limited number of small scale planar cross-beds indicate that the average Nottely cross-bed angle is 18-19 degrees and the direction of current transport was westward (Fig. 4). This direction is highly oblique to the structural strike of the Murphy belt and also probably highly oblique to the depositional strike of the Nottely, given its sparse distribution on the southeast limb of the Murphy syncline. This current directions although based upon very few data because of the rarity of finding these structures, sharply contrasts with data from the Chilhowee Group, located to the northwest (Schwab, 1986) and to possibly Chilhowee – equivalent rocks in the Murphy belt (Nantahala Formation), which are directed to the east southeast (Aylor, this volume). The Nottely current directions also strongly contrast with cross-bed current directions in the underlying Brasstown Formation which are north northeast (Aylor, SUNDAY Stop 1A.

Keith (1907) considered the Nottely Quartzite to be the youngest unit in the Murphy belt, existing in the trough of a small scale syncline, and he mapped the base of the Nottely as the upper contact of the Andrews Schist. Tull and others (b, this volume) have proposed the abandonment of the Andrews Schist based on the following reasons: a) The Andrews is not a calc-schist as defined by Keith (1907); only the lowermost part of the unit has this characteristic, and the Andrews does not contain the large diagnostic porphyroblasts of "ottrelite" as originally identified by Keith (1907). Thus Keith's Andrews cannot be distinguished lighologically from other schists of the Mission Mountain Formation (Table 1, sample no. 377 is from the "abandoned" Andrews Schists interval, see Thompson and Tull, SUNDAY Stop 3). b) The conspicuous layers or concretions of botryoidal hematite are post-metamorphic secondary deposits that are not primary features of the Andrews Schist (see Tull and others, b, this volume for a more complete discussion of the Andrews Schists). We contend that the Andrews is petrographically similar to schists of the Mission Mountain Formation (Tull and Groszos, 1988; Tull and others, b, this volume), and where the Nottely Quartzite or the Murphy Marble is missing in the section (over 50% of the strike length on both limbs of the Murphy syncline), differentiation of the Andrews becomes impossible. Thus based on Tull and others' (b, this volume) analysis of Keith's definition of the Andrews Schists and the similar petrographic nature of the Andrews Schist and Mission Mountain Formation, we proposed that the Andrews be abandoned and the interval be reassigned to the Mission Mountain Formation. The reassignment of the Andrews Schist to the Mission Mountain Formation would require that the Nottely Quartzite be lowered to member status because the Nottely would occur within the Mission Mountain Formation. Thus, we concur with Forrest (1969) and Tull and Groszos (1988), who proposed that the Nottely become a member of the Mineral Bluff Formation (Mission Mountain Formation).

FORT BUTLER MOUNTAIN FORMATION

The Fort Butler Mountain Formation grades up from the Mission Mountain Formation and represents the second thickest formation in the Mineral Bluff Group (~ 650 meters). This unit is named for exposures found along Fort Butler Mountain approximately 4 km southwest of Murphy, North Carolina. Excellent exposures are found in the mountains on the west limb of the Murphy syncline that trend parallel to and east of U. S. Highway 74-19-129 from near Ranger to Andrews, North Carolina, and include Bell, Fort Butler, Wildcat, and Will Scott Mountains and Hayden and Doll Tops. Like the Mission Mountain Formation, the Fort Butler Mountain Formation is a turbidite-dominated sequence, but the transition into Fort Butler Mountain marks a significant change in composition (Table 1). The Fort Butler Mountain and Mission Mountain Formation contact is poorly exposed, but it appears to be gradational over several 10's of meters. The most common lithology is a silver-gray thinly laminated to massive fine-grained sericitic metapelite that is locally graphite-bearing and sandy (excellent exposures can be seen forming dip slopes on the north side of U. S. Highway 64, east of Murphy, North Carolina). Interlayered within the metapelites are thick-bedded metasandstone-metaconglomerate layers that range from 2 cm to 2 m thick with total coarse clastic intervals ranging from 30 to 75 m thick (see Thompson and Tull, SUNDAY Stop 4). Several coarse clastic intervals have been mapped continuously for up to 6 km on the east and west limbs of the F_1 Murphy syncline, with one east-limb layer mappable for 10 km (Fig. 2). Dispersed throughout the Fort Butler Mountain Formation are numerous thinner coarse clastic zones that are discontinuous over relatively short distances along strike. The metasandstone-metaconglomerate layers are locally monomictic, but dominantly polymictic, with mineral assemblages of quartz, feldspar, muscovite (sericite), biotite, with less abundant chlorite, opaque, and hematite, and a trace of tourmaline (Table 1, Fort Butler Mountain Formation analyses are of coarse clastic intervals). In the study region, the coarse clastic assemblage indicative of diverse source rock material, including chert, argillite, sandstone, blue quartz and coarse perthitic microcline. We therefore agree with Tull and Groszos (1988), that coarse clastic rocks of the Mineral Bluff Formation (Fort Butler Mountain Formation) were derived from both a sedimentary cover sequence and a granitic basement terrain.

HARSHAW BOTTOM QUARTZITE

The Harshaw Bottom Quartzite is the uppermost mappable quartz-rich unit in the Mineral Bluff Group and grades up from the Fort Butler Mountain Formation. Outcrop distribution and the quality of exposures of the Harshaw Bottom Quartzite are poor except for the type section, where this quartzite obtains a thickness of up to 100 meters, but most outcrops expose only from 5 – 30 m of the unit. The Harshaw Bottom Quartzite was named for Harshaw Bottom, which is a flood plain of the Hiwassee River (southern bank) near the confluence with Peachtree Creek, and approximately 0.5 km south of the type section (see Thompson and Tull, SUNDAY Stop 5). This unit is a fine grained white quartzite that is locally epidote-rich (Table 1). Primary blue quartz grains (1 mm diameter) are very rarely seen and represent the only detrital component to be recognized in the Harshaw Bottom Quartzite. The quartzite is usually massive but commonly shows a friable papery texture, parallel to bedding. The composition, texture, and white color are very diagnostic of the Harshaw Bottom Quartzite, making this the most distinctive and easily identifiable unit in the Mineral Bluff Group. Superficially, white vein quartz may locally resemble the Harshaw Bottom Quartzite, but close inspection allows differentiation.

The type section of the Harshaw Bottom Quartzite is a small abandoned quarry near the hill top approximately 200 meters north of the U. S. Highway 64 and Cherokee County Road 1531 intersection, which is approximately 1.5 km west of the Murphy Medical Center (see Thompson and Tull, SUNDAY Stop 5, for a more complete description of the type locality). Here, bedding is clearly seen as the Harshaw Bottom Quartzite is interlayered with the overlying Peachtree Creek Formation. Another outstanding exposure can be seen on the Cherokee Hills Golf Course, along the left fairway of hole #12.

An intriguing characteristic of the Harshaw Bottom Quartzite is its purity and grain size. Samples from the type locality are >97 percent quartz and grain sizes are in the range of 0.1 – 0.4 mm, making this a fine to very fine grained quartzite. The quartz fabric consists of recrystallized dimensionally oriented quartz grains which define the schistosity and produce a friable papery texture upon weathering. Grain boundaries are well sutured and highly interlocked, but most crystals are optically strain – free. Some layers of the quartzite contain up to 10 – 15 percent of what appears to be rounded detrital blue quartz sand up to 1 mm in diameter, floating in the finer grained white matrix. Other exposures of the unit locally contain significant quantities (22%) of epidote in a matrix identical to that of the type locality.

The protolith of the Harshaw Bottom Quartzite is somewhat speculative because of the lack of preserved primary structures and substantial recrystallization of primary grains. The grain size and purity suggests two possible alternatives: A) very fine grained quartz arenite or B) bedded chert. Either of these protoliths could have had a calcareous component (matrix) which could account for the epidote at some localities. The ithofacies and stratigraphic position of the Harshaw Bottom Quartzite are strikingly similar to the Lower Devonian Jemison Chert in the Talladega slate belt in Alabama, relative to other formations in the Mineral Bluff and Talladega Groups respectively. Compare, for example, the exposures from the type section of the Harshaw Bottom Quartzite (see Thompson and Tull, SUNDAY Stop 5) with exposures of the Jemison Chert described in Tull and Stow (1979; stop 2, p. 44; stop 5, p. 48 – 50; stop 7, p. 54 – 55; stop 11, p. 59 – 60; stop 12, p. 60). The Jemison Chert is believed to grade upward into the Hillabee Greenstone through an interval of mixed epiclastic and volcaniclastic rocks (Tull, 1979). The Harshaw Bottom Quartzite grades upward into the Peachtree Creek Formation. Although volcanic rocks have not been documented within the poorly exposed Peachtree Creek Formation, a volcanogenic origin for some rocks exposed along the Hiwassee River cannot be ruled out (see below).

The outcrop distribution of the Harshaw Bottom Quartzite is clearly controlled by a post F_1 (Murphy syncline) fold phase (F_2 synform) which exposes the youngest units of the Mineral Bluff Group on the east limb of the F_1 Murphy syncline (Fig. 2 and 5). Refer to the General Structure section (below) for discussion of the overall structure of the study area.

PEACHTREE CREEK FORMATION

The Peachtree Creek Formation is the stratigraphically highest mappable unit in the Mineral Bluff Group and perhaps the youngest formation in the western Blue Ridge. It rests in the core of a doubly plunging synform which has refolded the eastern (overturned) limb of the Murphy syncline (Fig. 5). It exhibits relatively minor topographic relief, and is flanked by the more resistant Fort Butler Mountain Formation and Harshaw Bottom Quartzite and approaches 450 meters in thickness near the Hiwassee River transect, but thins to the south as it closes around the northeast plunging F_2 synformal hinge zone (Fig. 2). This unit was named after Peachtree Creek which flows into the Hiwassee River near the highest stratigraphic portion of the peachtree Creek Formation. The lithologies of the Peachtree Creek Formation are primarily very fine grained (generally <0.01 mm), very thinly laminated metapelites and metagraywackes with minor occurrence of calc-silicate. Thin section petrography indicates that the Peachtree Creek Formation consists mainly of quartz, plagioclase, chlorite, muscovite, biotite, epidote, opaques, and minor amounts of amphibole and garnet. Several "mafic" units were sampled and geochemically analyzed following canoe traverses down the Hiwassee River, with the results compiled in Table 4. These rocks are composed dominantly of plagioclase, quartz and chlorite, with minor epidote, opaque and actinolite (?). We consider the type section for the Peachtree Creek Formation to be located in the Hiwassee River (starting approximately 400 m south of McComb Branch and continuing past Peachtree Creek), where continuous exposures can be seen for up to 1 km at relatively low water levels (Fig. 2). Good exposures can also be found on the north face of a ridge, 200 m west of the Hiwassee River and McComb Branch confluence. No definitive igneous signatures are evident in the whole rock analyses (Table 4), but several characteristics indicate that the Peachtree Creek Formation may be derived in part of a mixed sedimentary and volcanic source (see section below on Volcanogenic origin of some Mineral Bluff Group rocks for a more complete discussion).

VOLCANOGENIC ORIGIN OF SOME MINERAL BLUFF GROUP ROCKS

The Mineral Bluff Group appears to contain zones of mafic metaigneous rocks, and is anomalies in this regard relative to the underlying Hiwassee River and Great Smoky Groups. Thus far the mafic metaigneous rocks have been found dominantly near the base of the Mineral Bluff Group, within the Marble Hill Hornblende Schist (southern region of the Murphy belt, see Tull and others, b, this volume) and the lower section of the Mission Mountain Formation (north of the Murphy belt), but metaigneous rocks may also occur in the highest stratigraphic unit (Peachtree Creek Formation) of the Mineral Bluff Group. We will briefly present our current understanding of these units in the discussion that follows. We interpret these rocks to have a stratified volcanic origin, and it is important to note that we have recognized such rocks only above the proposed unconformity at the base of the Mineral Bluff Group. Dikes and sills of mafic igneous rock also occur lower in the section in the Hiwassee River and Great Smoky Groups, but no volcanic rocks have been found (see Aylor and Kish, SUNDAY Supplemental Stop 2).

Marble Hill Hornblende Schist

The Marble Hill Hornblende Schist is found in the southern part of the Murphy belt, and represents the lowest unit in the Mineral Bluff Group. This unit was defined by Fairley (1965) for exposures near Tate, Georgia. It is dominantly an amphibolite that lies directly above units of the lower Hiwassee River Group and is overlain by the Mineral Bluff Group undifferentiated. Kish and others (1991, p. 53) suggest that the Marble Hill Hornblende Schist is of igneous parentage based on measured present-day whole rock $^{87}Sr^{86}Sr$ ratios (0.7045 – 0.7060) and they also cite the following geochemical characteristics: 1) low SiO_2 (45 – 49 wt.%), 2) high TiO_2 (2 – 3 wt.%), and 3) high concentrations of high field strength elements (Nb30 – 60 ppm, Th 3 – 8 ppm). Fairley (1988) and Tull and Groszos (1991) have proposed that the Marble Hill is of volcanic origin based on its chemistry, thin sheet-like geometry, and mappable distribution at the base of the Mineral Bluff Group. Two "metagabbro" bodies of Fairley (1965) are considered to be equivalent to the Marble Hill. One is physically contiguous with the Marble Hill, and the other occurs in an isolated fold core but is at the same stratigraphic level as the Marble Hill. Tull and others (this volume, b) offer a more detailed description of this unit.

Mission Mountain Formation

We have recently discovered that the lower section of the Mission Mountain Formation contains a sequence which is in part comprised of volcanic material (see above). In at least one locality, metaigneous rocks (Table 2, 251-1E, for example) are interlayered with metagraywacke and possible volcanogenic schists (Table 2, 251 –3F) (see Thompson and Tull, SUNDAY Supplemental Stop 1 for a detailed description of this locality). At present we do not have geochemical data from the upper part of the Mission Mountain Formation, but initial petrographic work suggest that volcanogenic material may be restricted to the lower portion of the formation. Major element analyses of the metaigneous layer (Table 2, 251-1E) show high CaO and MgO, and low SiO_2, possibly indicating a basaltic source. Because of uncertainties related to possible mobilizaton of many major elements however, we feel that these values (major element) should be used with caution and prefer to use trace element TiO_2 values (Table 2) as source rock discriminators. Thus, we feel confident that this amphibolite layer is of igneous origin, based on the high transition metal (Nb47 ppm; Ni505 ppm; and Cr 956 ppm) and TiO_2 values (4.09 wt.%) (Table 2). An extrusive origin seems most likely (see Thompson and Tull, SUNDAY Supplemental Stop 1). CIPW norm computations (Table 3) show that this metaigneous layer is not quartz or nepheline normative, and is olivine and hypersthene normative. All of these characteristics suggest a possible "mafic" igneous affinity for this layer. The remaining geochemical analyses (Table 2) represent metasediments (?) of the Mission Mountain Formation sampled over a 10 km strike distance from near Ranger, to Murphy, North Carolina. The geochemistry of these samples is similar to the metaigneous layer described above: high TiO_2 (3.28 – 5.40 wt.%) and trace element (Nb 20 – 110 ppm; Ni 289 – 445 ppm; and Cr 601 – 954 ppm) values (Table 2). The CIPW norms (Table 3) for these metasediments (?) give mixed results compared to the metaigneous layer: generally quartz and corundum normative. Whether or not the metaigneous layer and the interlayered volcanogenic (?) section of the Mission Mountain

Table 2. Chemical Analyses — Mission Mountain Formation

Sample	SiO2	Ti02	A1203	Fe203*	MgO	CaO	Na20	K2O	MnO	P205	LOI	Total	Zr	Nb	Cu	Zn	Ni	Co	Cr
#251-1E	39.6	4.09	12.6	18.51	11.33	7.96	0.93	0.52	0.23	0.55	3.3	99.62	215	47	111	140	505	83	956
251-3F-1	35.2	5.69	18.7	19.95	7.44	1.83	2.18	1.82	0.27	0.53	5.7	99.31	337	115	108	244	375	69	1076
251-3F-2	32.8	5.11	20.8	20.50	7.62	1.57	1.87	1.98	0.25	0.44	5.2	98.14	394	104	--	--	--	--	755
252A	37.5	5.20	19.4	19.18	6.48	5.14	0.95	2.16	0.18	0.54	2.8	99.53	316	54	47	165	366	76	954
252B	51.6	3.65	15.7	14.09	5.90	3.93	0.96	0.85	0.07	0.47	2.5	99.72	252	49	27	162	303	71	641
252C	50.6	4.01	14.2	13.81	5.34	7.23	1.06	0.69	0.13	0.57	1.9	99.58	244	100	49	128	289	69	715
*252C-S2	49.5	3.69	16.0	15.30	5.12	7.11	1.00	0.61	0.15	0.41	1.1	99.97	231	81	--	--	--	--	746
262A	44.9	3.28	16.4	15.33	7.70	5.69	0.11	0.05	0.19	0.32	5.8	99.75	256	20	50	145	445	84	601

Fe_2O_3* = Total Iron; # = metaigneous sample;* = duplicate analysis

Table 3. CIPW Norms — Mission Mountain Formation

Sample	Q	Co	Or	Ab	An	Hy	Di	O1	Mt	I1	Ap	Total	Lat	Lon
#251-1E	0.0	0.0	3.2	8.2	29.6	22.7	6.3	12.3	8.4	8.1	1.4	100.0	350331	840410
251-3F-1	0.0	11.9	11.5	19.7	6.0	21.8	0.0	5.2	11.1	11.5	1.4	100.0	350331	840410
*251-3F-2	0.0	14.8	12.6	17.0	5.3	15.0	0.0	13.5	10.3	10.4	1.1	100.0	350331	840410
252A	0.4	7.7	13.2	8.3	22.7	26.2	0.0	0.0	10.0	10.2	1.3	100.0	350553	840124
252-B	24.6	7.4	5.2	8.4	16.9	21.6	0.0	0.0	7.7	7.1	1.1	99.9	350553	840124
252-C	18.4	0.0	4.2	9.2	32.6	18.0	0.2	0.0	8.2	7.8	1.4	100.0	350553	840124
*252C-S2	16.0	1.7	3.7	8.5	33.0	21.5	0..0	0.0	7.6	7.1	1.0	100.0	530553	840124
262A	17.6	7.0	0.3	1.0	27.8	31.5	0.0	0.0	7.4	6.6	0.8	100.0	350214	840542

= metaigneous sample;* = duplicate analysis;Fe_2O_3 calculated using formula by Irvine and Baragar (1971)

Table 4. Chemical Analyses — Peachtree Creek Formation

Sample	Si02	Ti02	A1203	Fe203*	MgO	CaO	Na2O	K2O	MnO	P205	LOI	Total	Zr	Nb	Cu	Zn	Ni	Co	Cr
G1 118A1	65.7	1.09	12.5	8.02	2.06	3.84	3.47	0.05	0.09	0.25	2.9	99.97	172	20	28	108	29	40	48
GI 118A3	63.7	1.09	14.1	10.34	2.55	1.29	4.79	0.05	0.11	0.16	1.7	99.88	147	23	11	112	29	5	55
GI 118B	58.1	1.35	16.9	11.36	3.22	1.03	2.60	1.48	0.14	0.24	3.6	100.02	180	30	102	144	55	46	55
GI 118E	59.8	1.05	15.6	12.11	3.42	0.65	2.38	1.26	0.15	0.18	3.3	99.90	126	50	35	151	62	32	62
GI 118F	59.8	1.08	15.9	11.82	3.38	0.75	2.56	1.17	0.14	0.20	3.2	100.00	128	20	46	151	57	28	55
GI 118-1	58.3	1.28	14.7	12.90	3.05	0.45	1.41	1.74	--	0.18	4.0	98.01	<500	--	--	<200	57	48	110
GI 118-3	56.9	1.11	15.3	13.60	3.45	1.45	2.77	0.94	--	0.09	3.1	98.74	<500	--	--	<200	54	57	76
GI 118-4	55.9	1.45	17.4	10.70	2.97	1.36	3.25	1.78	--	0.10	3.4	98.26	<500	--	--	<200	<50	41	92
GI 128-B	59.2	1.29	14.8	11.80	2.99	1.40	3.58	0.51	--	0.03	2.8	98.44	<500	--	--	<200	<50	44	95
G2 119	56.7	1.28	20.3	9.33	2.62	0.69	1.48	2.91	0.114	0.22	4.1	99.77	156	26	93	105	57	23	75
G2 119-1	54.6	1.31	18.2	12.70	3.67	0.66	1.11	2.74	--	0.14	4.5	99.61	<500	--	--	<200	<50	50	100
G2 119-3	56.4	1.14	18.5	10.70	2.84	0.69	1.31	3.05	--	0.25	4.0	98.90	<500	--	--	<200	<50	41	120
G2 132	55.8	1.10	20.1	10.10	1.86	0.65	1.20	3.74	--	0.10	3.8	98.48	<500	--	--	<200	<50	29	130
G2 133	54.9	1.26	19.9	10.70	2.16	0.70	1.09	3.79	--	0.18	3.8	98.43	<500	--	--	<200	<50	31	100
G2 145A	53.5	1.29	19.3	12.00	3.08	0.66	1.13	2.86	--	0.07	4.5	98.38	<500	--	--	<200	<50	43	95
G2 145B	54.6	1.25	19.0	12.30	2.10	0.71	0.96	3.45	--	0.16	4.4	98.90	<500	--	--	<200	<50	41	82
G2 150	55.3	1.11	19.6	11.50	1.36	0.55	1.42	4.47	--	0.08	3.6	98.95	<500	--	--	<200	<50	27	72
G2 151-2	50.6	1.38	20.3	14.20	2.05	0.95	1.34	3.33	--	0.35	4.4	98.94	<500	--	--	<200	57	40	110

Fe_2O_3* = Total Iron;GI = group 1;G2 = group 2

Table 5. CIPW Norms — Peachtree Creek Formation

Sample	Q	Co	Or	Ab	An	Hy	Mt	I1	Ap	Total	Lat	Lon
GI 118-A1	33.0	0.4	0.3	30.2	18.0	11.7	3.9	2.1	0.6	100.0	350355	835826
GI 118-A3	25.3	4.3	0.3	41.2	5.5	17.2	3.8	2.1	0.4	100.0	350355	835826
GI 118-B	26.9	10.1	9.1	22.8	3.7	20.1	4.3	2.7	0.6	100.1	350355	835826
G1 118-E	29.9	9.9	7.7	20.8	2.1	23.3	3.8	2.1	0.5	100.0	350355	835826
GI 118-F	29.3	9.9	7.2	22.3	2.5	22.4	3.9	2.1	0.5	100.0	350355	835826
GI 118-1	34.0	10.7	11.0	12.7	1.1	23.1	4.3	2.6	0.5	100.0	350355	835826
GI 118-3	22.8	7.6	5.8	24.5	7.0	25.9	4.0	2.2	0.2	100.0	350355	835826
GI 118-4	19.9	8.3	11.1	28.9	6.4	17.7	4.5	2.9	0.3	100.0	350355	835826
GI 128-B	24.7	6.2	3.1	31.6	7.1	20.5	4.2	2.6	0.1	100.0	350406	835831
G2 119	29.9	14.6	18.0	13.1	2.1	15.1	4.2	2.5	0.5	100.1	350414	835825
G2 119-1	26.2	13.2	17.1	9.9	2.4	24.0	4.3	2.6	0.4	100.0	350414	835825
G2 119-3	28.7	13.0	19.0	11.7	1.9	18.8	4.0	2.3	0.6	99.9	350414	835825
G2 132	27.7	13.9	23.4	10.7	2.7	15.3	4.0	2.2	0.3	100.1	350437	835835
G2 133	26.7	13.9	23.7	9.7	2.4	16.5	4.2	2.5	0.5	100.0	350438	835833
G2 145A	26.1	14.2	18.1	10.1	3.0	21.5	4.3	2.6	0.2	100.0	350433	835812
G2 145B	27.1	13.5	21.6	8.6	2.6	19.5	4.2	2.5	0.4	100.0	350433	835812
G2 150	22.4	12.1	27.8	12.6	2.4	16.5	4.0	2.2	0.2	100.0	350413	835825
G2 151-2	19.7	14.4	20.8	12.0	2.6	22.4	4.4	2.8	0.9	100.0	350416	835827

G1 = group 1;G2 = group 2;Fe_2O_3 calculated using formula by Irvine and Baragar (1971)

Formation are genetically related, they possibly represent (with the exception of the Talladega belt's – Hillabee Greenstone) the youngest volcanogenic rocks of the western Blue Ridge. We are currently studying these metaigneous rocks of the Mission Mountain Formation in an effort to determine their relationships with the Marble Hill Hornblende Schist of Georgia, but regardless of these findings, these metaigneous rocks of the lower Mineral Bluff Group indicate a significant change in tectonic setting relative to the underlying rift to drift facies of the western Blue Ridge. We consider this change in tectonic setting, not coincidentally at the boundary between the Hiwassee River and the Mineral Bluff Groups, to be further evidence for an unconformity (see Tull and Groszos, 1988, p. 41 – 42, for a discussion of evidence for the unconformity) at the base of the Mineral Bluff Group. Unpublished trace element data (yttrium) indicates (2Nb – Zr/4 – Y, after Meschede, 1986) that the tectonic setting for these Mission Mountain Formation volcanic rocks may have been within-plate (alkali basalts or tholeiites), and using Irvine and Baragar's (1971) alkaline vs. subalkaline and calcalkaline vs. tholeiitic bivariate rock series plots, these samples were likely subalkaline tholeiites. Based on the high TiO_2, Cr, Ni, Nb, and Zr, we feel that these volcanic rocks were not N-type MORB or island arc basalts, and the tectonic environment indicates that they could not have been oceanic island basalts. We postulate that the Mission Mountain Formation contain "exhilarative" deposits intermittently mixed (?) with clastic detritus via turbidity flows. An extensional continental margin back-arc basin setting may best fit overall Mineral Bluff Group deposition.

In their detailed investigation of the Mineral Bluff Group along U. S. Highway 19 – 129 near Murphy, North Carolina, La Tour and Fritz (1988) speculated that some metasediments of the Mineral Bluff Formation (Mission Mountain Formation) may have a volcanogenic component based on $Na_2O/A1_2O_3$ vs. $K_2O/A1_sO_3$ ratio plots. We believe several factors regarding these analyses and conclusions should be addressed: a) Four of the five supposed volcanogenic samples of LaTour and Fritz (1988, Table 3 – zones A1, A2, C1, and C2) come from biotite-rich or chlorite-rich layers that flank a middle calc-silicate zone, while the fifth comes from a metasandstone (metagraywacke) not associated with the calc-silicate layers. Although they mention the possibility of metasomatic alternation of the calc-silicate and surrounding zones, their hypothesis is that these zones are primary depositional features resulting from mixing of carbonate and silicate (volcanogenic?) material during successive turbidity flows. We feel that the evidence put forth by La Tour and Fritz (z1988, p. 88) does not conclusively omit significant alkali (or other mobile element) metasomatic alternation of these zones, and hence their sampling methods (analysis of each "zone") my reflect altered source rock chemistries. B) La Tour and Fritz (1988, p. 84) use a 3 oxide-ratio variation diagram ($Na_2O/A1_2O_3$ vs. $K_2O/A1_2O_3$) to discriminate the field (sedimentary or igneous) in which their samples plot. This is in spite of their claim (p. 88) that"…there appears to have been a large variation in K from bed to bed in the original sediments of the Mineral Bluff, and this variation, perhaps enhanced locally by metasomatism, can explain the paired Bi (biotite) layer – Ch (chlorite) layer above and below each CS (calc-silicate) layer". Considering the scale of the zones surrounding each calc-silicate layer (a few mm to cm), the existence of local metasomatism would possibly have a profound effect upon diffusion of the alkali metals. Thus, while we agree with the conclusion of LaTour and Fritz (1988) that the Mission Mountain Formation may contain a volcanogenic component (although not at the locality they described), we disagree with their choice of using the alkalis as the discriminating factor in distinguishing this component for the restricted interval of this formation which they examined. C) Given the possibility of major element diffusion, we feel that the best chemical method of source rock discrimination involves the use of trace elements. La Tour and Fritz (1988, Table 3) post several immobile trace elements for the rock interval which they examined, but unfortunately none of them show conclusive igneous characteristics.

PEACHTREE CREEK FORMATION

The Peachtree Creek Formation as described above is a very fine grained (generally < 0.01 mm) and thinly laminated metapelite and metagraywacke that locally contains zones of calc-silicate and mafic schist. Detailed petrographic analysis of this unit is virtually impossible given the extremely fine grain size. However, with geochemical analyses (Table 4) we can speculate on the possible source rock compositions of the Peachtree Creek Formation. Unweathered samples of this unit are not very common, and our samples basically reflect "fresh" outcrop distributions. Discrimination diagrams of the Peachtree Creek Formation major and trace element geochemistry (Table 4) tend to show the data partitioning into 2 groups. This separation is clearly seen when comparing the Na/K ratios of Table 4: Group 1 (all 118 samples and 128-B) Na/K ratios range from 0.81 to 7.02 and average 2.64 (samples 118A1 & A3 were omitted because of their extremely high ratios, which may or may not reflect original bulk rock chemistries) and group 2 (all 119 samples and 132, 133, 145A & B, 150, and 151-2) Na/K ratios range from 0.28 to 0.51 and average 0.37. Group 1 data generally show mixed igneous and sedimentary (correlation) trends using a variety of discrimination diagrams, while group 2 show dominantly sedimentary trends. Both groups have TiO_2 values? 1.0 wt. Percent. It is important to note that in almost every plot, there is a consistent grouping of each data set. One possible explanation for the apparent division of Peachtree Creek geochemical data is that this formation represents a continuum of mixed sedimentary and volcanic (primary or volcaniclastic) material. In this scenario, group 1 would contain a higher percentage of volcaniclastic material relative to the sedimentary detritus than would group 2. CIPW norm calculations also show the same data set partitions. Group 1 and 2 are quartz normative, while group 1 is more albite and anorthite normative, and group 2 is more corundum and orthoclase normative. As in the case of the lower Mission Mountain Formation geochemistry, we feel that the metasomatic effects on the Peachtree Creek Formation are unknown, but should be taken into account when utilizing major element chemistry. Unfortunately, the source rock discriminators used for the Mission Mountain Formation (TiO_2 and transition metals) and other trace elements (unpublished) do not reveal conclusive igneous characteristics for the Peachtree Creek Formation. Despite the lack of conclusive igneous trends on discriminating diagrams, we feel that the consistent grouping of our Peachtree Creek data into 2 sets indicates some type of continuum(?) or mixing of either sedimentary and volcaniclastic material or an unusual source composition relative to other western Blue Ridge lithologies of post-Grenville age.

GENERAL STRUCTURE

A detailed and thorough discussion of the structure of this region is not the focus of this guidebook and is therefore beyond the scope of this paper. However an overview of the map-scale structure is needed to understand the stratigraphic sequence.

The regional F_1 Murphy syncline is well documented in the Murphy belt (Keith, 1907; LaForge and Phalen, 1913; Hurst, 1955; Fairley, 1965; Power and Forrest, 1971; Tull and Groszos, 1988) and our detailed mapping supports this interpretation. The symmetry of the F_1 Murphy syncline is clearly expressed by the mapping of earlier workers of units of the Hiwassee River Group. This study shows that the mirror image symmetry is also clearly expressed by the internal stratigraphy of the Mineral Bluff Group, and in detail by the Fort Butler Mountain Formation with the repetition of the coarse clastic layers on both the east and west limbs (Fig. 2 and 5). Among the most convincing evidence for the existence of the Murphy syncline is the closing to the southwest of the uppermost coarse clastic layer in the Fort Butler Mountain Formation (Fig. 2), which can be seen along a new road cut, connecting Cherokee County Road 1577 to 1305, that parallels Lindsey Branch. This upper coarse clastic layer closes in the "keel" of the F_1 Murphy syncline several hundred meters southwest of Lindsey Branch and can be mapped at least 3 km (on both limbs) to the northeast (Fig. 2). Facing direction established by cross-beds within the Fort Butler Mountain Formation also supports the synclinal geometry. These relationships reinforce other evidence for the existence of the syncline, summarized by Tull and Groszos (1988, p. 36).

Very little detailed field mapping in the Mineral Bluff Group of this study region has been completed by previous authors, except for Keith (1907) and Forrest (1975). The conclusion of these authors and other compilation studies is that one or more significant faults exists in the study area (see Tull and others, this volume, a, Fig. 2 and 6). However, our detailed field investigations in this region refute the previous claims for the presence of major faults, and the only faults which we have been able to observe involve only minor offsets (1 – 2 m). These offsets are generally coplanar with F_2 axial planes within the sericitic phyllites of the Fort Butler Mountain Formation. In fact, we have mapped stratigraphy cutting across the proposed east limb fault on the North Carolina State Map (1985) and in Hatcher and others (1990).

The increased stratigraphic thickness of the Mineral Bluff Group east of Murphy, North Carolina relative to other regions of the Murphy belt is a result of the fact that the erosional level of the Murphy syncline is structurally higher in this region, as well as the fact that a later fold phase is superimposed on this syncline. An F_2 phase synform exposes the youngest rocks (Harshaw Bottom Quartzite and Peachtree Creek Formation) of the Mineral Bluff Group, and involves refolding of the east limb of the F_1 Murphy syncline in such a way that rock units are downfolded into map view which apparently do not reach ground level in the core of the Murphy syncline *sensu stricto* (Fig. 2 and 5). Bedding and S_2 schistosity intersections from 2 subareas (C. R. 1558 – Hiwassee Road near Racetrack Bend and along U. S. Highway 64 near Burnthouse Branch) indicate that the later F_2 antiform is locally reclined and plunges ~ 45° east. Bedding and S_2 intersection lineations from the core of the F_2 synform (near the Hiwassee /River transect) indicate that this fold phase is doubly plunging (southwest and northeast) and results in an axial depression along the Hiwassee River. The Harshaw Bottom Quartzite and the Peachtree Creek Formation appear to close to the southwest in the "keel" of the F_2 synform, but exposures are very poor to the north, and these units may extend somewhat farther in this direction than shown on Figure 2.

AGE AND CORRELATION OF THE MINERAL BLUFF GROUP

Introduction

The lithologies of the Mineral Bluff Group show some general similarities to underlying sequences like the lower Hiwassee River Group (carbonanceous metapelites) and the Great Smoky Group (metaturbidites and arkosic metaconglomerates), and various geologists have proposed structural explanations to allow correlation of the Mineral Bluff with these groups (Keith, 1907; Hadley and Nelson, 1971). However, recent workers since Hurst (1955) have presented extensive data which show that the Mineral Bluff Group is a younger sequence which cannot be correlated with underlying groups. In addition, in our interpretation the Mineral Bluff Group is separated from the Hiwassee River Group by a regional unconformity. Because rocks of the Mineral Bluff Group are paleontologically undated, ideas of what geologic units may be correlative with the Mineral Bluff Group are dependent upon estimation of the age of metamorphism of the Mineral Bluff and the age of the underlying Murphy Marble. Unfortunately, in our view neither of these bracketing ages are well constrained.

Most workers since Keith (1907) have correlated the Murphy Marble with the Shady Dolomite of Early Cambrian age, which is found to the northwest at the edge of the Blue Ridge front and to the southwest in the Talladega slate belt (Jumbo Dolomite). We agree with this correlation and feel that recent studies strengthen it (see Aylor, this guidebook). This would imply that the Mineral Bluff Group is post-Chilhowee Group and is Early Cambrian or younger. Interpretations of the age of metamorphism are perhaps more speculative, being dependent upon evaluation of mineral isotopic ages or arguments relating to metamorphism of fossiliferous strata elsewhere in the Blue Ridge (Talladega belt or Foothills belt). These age estimates for metamorphic peak range between Middle Ordovician and Carboniferous (Butler, 1972; Kish and Harper, 1973; Dallmeyer, 1975, 1979, Tull and others, 1988; Kish, 1990; Unrug and others, this volume). These brackets potentially allow the Mineral Bluff to range in age between Early Cambrian and Carboniferous.

Talladega Group Correlation

Tull and Guthrie (1985) and Tull and Groszos (1988) have suggested that the Mineral Bluff Group lies unconformably atop the Murphy Marble and underlying units, and represents a "successor" basin sequence post-dating the drift facies in the underlying Appalachian miogeocline. Given the brackets suggested above, this would indicate that if the Mineral Bluff is correlative with a clastic wedge exposed in the edge of the Appalachian foreland, that it could be Middle Ordovician, Silurian – Devonian, or possibly Carboniferous.

In the Talladega belt the Talladega Group is believed to be Silurian – Early Devonian based upon paleontologic data (Tull and others, 1988), and Tull and Guthrie (1983, 1985) and Tull and Groszos (1988, 1990) suggested a potential correlation between this group and the Mineral Bluff Group. This correlation was based upon the fact that both belts have similarities in stratigraphic setting, internal lithofacies and thickness, as well as the fact that the Murphy belt is directly along strike to the northeast of the Talladega belt and various geologists have published maps showing stratigraphic continuity between the belts. Our most recent studies further strengthen but do not prove a Talladega Group – Mineral Bluff Group correlation, as more details of the Mineral Bluff stratigraphy become understood. This includes a possible Lay Dam Formation – Mission Mountain Formation correlation, Butting Ram (Cheaha) Quartzite – Fort Butler Mountain Formation correlation, and Jemison Chert – Harshaw

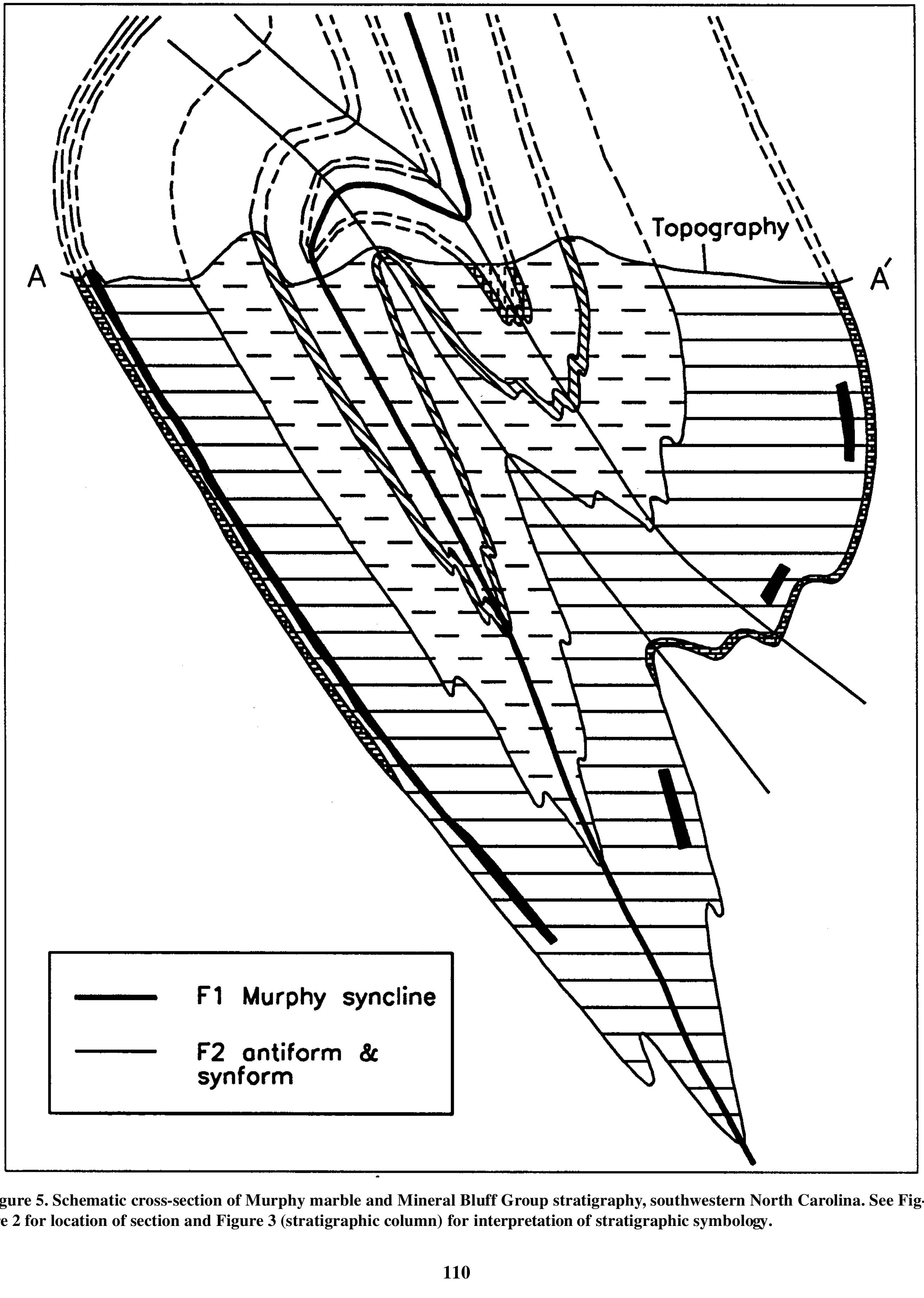


Figure 5. Schematic cross-section of Murphy marble and Mineral Bluff Group stratigraphy, southwestern North Carolina. See Figure 2 for location of section and Figure 3 (stratigraphic column) for interpretation of stratigraphic symbology.

Bottom Quartzite correlation. Additionally, metavolcanic rocks may occur within the Marble Hill Hornblende Schist and Mineral Bluff Group (see above, and Thompson and Tull, SUNDAY Supplemental Stop 1), as they do in the Talladega belt. Alternatively, if the Mineral Bluff Group is pre-Silurian or post Early to Middle Devonian, then it probably cannot correlate with the Talladega Group.

Walden Creek Group Correlation

A second dominantly clastic sequence in the region is also a good candidate for correlation with the Mineral Bluff Group. This is the Walden Creek Group (or parts thereof) in the extreme western Blue Ridge Foothills belt. Correlation between the Walden Creek Group and the Mineral Bluff Group (Tull and Groszos, 1990) seems possible (if not probable) for several reasons:

A) The distinctive lithofacies contained within the two groups are strikingly similar (compare the Walden Creek descriptions of King and others, 1958; Neuman and Nelson, 1965; and Hadley, 1970 with those presented here and in Tull and Groszos, 1988 from the Mineral Bluff). Both sequences are turbidite-dominated and both appear to have both a crystalline basement and sedimentary cover provenance. An abundance of carbonate detritus is distinctive for both units.

B) Hurst and Schlee (1962, p. 10 – 13 and 27) recognized that the uppermost Great Smoky Group (Dean Formation of Hurst, 1955; Buck Bald Formation of Wiener and Merschat, 1978) in the Ocoee Gorge of Tennessee was stratigraphically overlain by carbonaceous rocks which they correlated with the lower Hiwassee River Group (Nantahala Formation) (see Tull and others, b, this guidebook) in the Murphy belt. In this interpretation, rocks of the Murphy belt were repeated on the western overturned limb of an anticline west of the Murphy syncline. The rocks in question in Ocoee Gorge were correlated along strike to the northeast with either the Walden Creek Group (King, 1964; Hadley, 1970) or the Snowbird Group (Wiener and Merschat, 1981) of the Ocoee Supergroup. The Murphy belt – Foothills belt (Walden Creek Group) correlation of Hurst and Schlee (1962) requires the regional structure to be dominated by folding, whereas the Snowbird Group correlation assumes thrusting beneath the Great Smoky in the Ocoee Gorge (Wiener and Merschat, 1978).

In Ocoee Gorge, Tennessee, Hurst and Schlee (1962, p. 11) describe a sequence at least 700 meters thick overlying the Dean Formation. This sequence consists of 200 meters of dark pyritic slate at the base (which they correlate with the Nantahala Formation), overlain by a 10 – 15 meter quartzite, which in turn is overlain by at least 500 meters of gray – green laminated phyllite. The stratigraphic top of the section is decapitated by the Sylco Creek fault. It is the thick "Phyllite" section of Hurst and Schlee which is lithologically quite similar to the Mineral Bluff Group. The quartz-mica rocks are laminated on a scale of centimeters and interbedded with carbonate-rich layers, very similar to the turbidite-dominated Mission Mountain Formation of the Mineral Bluff Group.

These relationships lead us to speculate that the Hiwassee River Group (of Tull and others, b, this volume) is present in the Ocoee Gorge as either the Nantahala Formation or Nantahala/Brasstown Formations undifferentiated above the Great Smoky Group just as it is in the Murphy belt to the east. We further speculate that the Murphy Marble is missing beneath an erosional unconformity, that the Nottely Quartzite Member is present as Hurst and Schlee's "Quartzite Zone", and that the "Phyllite" section of Hurst and Schlee is equivalent to the Mission Mountain Formation of the Mineral Bluff Group. This speculation is merely a modification of Hurst and Schlee's novel ideas of correlation between the Ocoee Gorge and Murphy belt. Recent paleontologic discoveries by Unrug and Unrug (1990) and Unrug and others (this volume) have brought into question the Precambrian age assignment of the Walden Creek Group (King and others, 1958). These discoveries suggest that at least part of the Walden Creek Group may be as young as Silurian – Devonian, or even Early Carboniferous(?). Although we consider these age assignments tentative and subject to serious debate, they indicate that ideas of the age of at least part of the Ocoee Supergroup are in a current state of flux. It is also not clear at this time whether or not the rocks described here in Ocoee Gorge are in fact correlative with the fossiliferous Walden Creek rocks described above. Therefore confirmation of a Walden Creek – Mineral Bluff correlation awaits much more work, but should be pursued as a serious working hypothesis at this time.

ACKNOWLEDGMENTS

We would like to thank Hecla Mining Corporation for partial financial support of the geochemical analyses and the North Carolina Geological Survey for field related grant support. Thanks to Denny Bearce and Roy Odom for their insightful reviews of the manuscript and to Paul Ragland for his assistance in interpreting the geochemistry. Special thanks to Steve Kish who provided a critical review for the volcanogenic section of this manuscript and to Mark Groszos who has assisted in our field related studies and participated in many helpful discussions.

REFERENCES CITED

Aylor, J. G., 1991, Stratigraphy of the Nantahala and Brasstown Formations, Hiwassee River Group, North Carolina, in Kish, S. A., ed., Studies of Precambrian Paleozoic Stratigraphy in the western Blue Ridge: Carolina Geological Society Field Trip Guidebook.

Butler, J. R., 1972, Age of Paleozoic regional metamorphism in the

Carolinas, Georgia, and Tennessee southern Appalachians, American Journal of Science, v. 272, p. 319 – 333.

Dallmeyer, R. D., 1975, Incremental $^{40}Ar/^{39}Ar$ ages of biotite and hornblende from retrograded basement gneisses of the southern Blue Ridge, their bearing on the age of Paleozoic metamorphism: American Journal of Science, v. 275, p. 444 – 460.

Dallmeyer, R. D., 1979, $^{40}Ar/^{39}Ar$ dating: principles, techniques, and applications in orogenic terrains: in Jager, E., and Hunziker, J. C., eds., Lectures in isotope geology: Berline, Springer-Verlag, p. 77 – 103.

Dallmeyer, R. D., Courtney, P. S., and Wooten, R. M., 1978, Stratigraphy, structure, and metamorphism east of the Murphy syncline: Georgia – North Carolina: Georgia Geological Society Guidebook, no. 17, 74 p.

Fairley, W. M., 1965, The Murphy Syncline in the Tate Quadrangle, Georgia: Georgia Geological Survey Bulletin 75, 71 p.

Forrest, T. J., 1969, Stratigraphy and structure of the Murphy belt in the Murphy, N. C. 7.5' Quadrangle: Geological Society of America Abstracts with Programs, Part 4, p. 23-24

_____, 1975, Geologic evolution of a portion of the Murphy Marble belt in southwestern North Carolina [PhD Dissertation]: Rice University, Houston, Texas, 76 p.

Hadley, J. B., 1970, The Ocoee Series and its possible correlatives, in Fisher, G. S., and others, eds., Studies in Appalachian Geology: Central and Southern: New York, Wiley Interscience, p. 247 – 259.

Hadley, J. B., and Nelson, A. E., 1971, Geologic map of the Knoxville quadrangle, North Carolina, Tennessee, and South Carolina: U. S. Geological Survey Miscellaneous Geological Investigation Map I-654.

Hatcher, R. D., Jr., Osberg, P. H. Drake, A. A., Jr., Robinson, P., and Thomas, W. A., 1990, Plate 1 – Tectonic map 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, Colorado, Geological Society of America, The Geology of North Americium v, F-2.

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 southeast Tennessee: Georgia Dept. of Mining and Geology, 3rd Annual Field Trip, Guidebook, 28 p.; and southeastern section GSA Guidebook #3, 220p.

Irvine, T. N., and Baragar, W. R. A., 1971, A guide to the chemical classification of the common volcanic rocks: Canadian Journal of Earth Science, V. 8, p. 523 – 548.

Keith, A., 1907, Description of the Nantahala quadrangle, North Carolina and Tennessee: U. S. Geological Survey Geologic Atlas Folio no. 143, 11 p.

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., 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., 1990, Timing of middle Paleozoic (Acadian) metamorphism in the southern Appalachians: K-Ar studies in the Talladega belt, Alabama: Geology, v. 18, no 7, p. 650-653.

Kish, S. A., Campbell, S. K., Groszos, M. S., and Tull, J. F., 1991, Geochemistry and petrology of metaigneous rocks in the Murphy syncline, Tate, Georgia: Geological Society of America Abstracts with Programs, v. 23, no. 1, p, 53.

Kish, S. A., and Harper, C. T., 1973, Potassium argon geochronology of a portion of the southwestern Blue Ridge: Geological Society of America Abstracts with Programs, v. 5, no. 5, p. 409.

LaForge, L., and Phalen, W. C., 1913, Description of the Ellijay quadrangle, Georgia, North Carolina and Tennessee: U. S. Geological Survey Geologic Atlas, Folio no. 187, 17 p.

LaTour, T. E., and Fritz, W. J., 1988, Volcanogenic character of parts of the Mineral Bluff Formation: Evidence from field and geochemical studies, in Fritz, W. J., and LaTour, T. E., eds., Geology of the Murphy belt and related rocks Georgia and North Carolina: Georgia Geological Society Guidebook, v. 8, no. 1, p. 75 – 93.

Neuman, R. B., and Nelson, W. H., 1965, Geology of the western Great Smoky Mountains, Tennessee: U. S. Geological Survey Professional Paper 349-D, 81 p.

North Carolina Department of Natural Resources and Community Development, 1985, Geologic map of North Carolina: North Carolina Geological Survey, scale 1:500,000.

Power, W. R., and Forrest, J. T., 1971, Stratigraphy and structure of the Murphy belt, North Carolina: Carolina Geological Society, Annual Field Trip Guidebook, 29 p.

Schwab, F. L., 1986, Latest Precambrian – earliest Paleozoic sedimentation, Appalachian Blue Ridge and adjacent areas: review and speculation, in McDowell, R. C., and Glover, Lynn III, eds., The Lowry Volume: Studies in Appalachian geology: Blacksburg, Virginia Tech Department of Geological Sciences, Memoir 3, 137 p.

Thompson, T. W., and Tull, J. F., 1991, Mineral Bluff Formation: Internal stratigraphy of the Murphy syncline in the western Blue Ridge of North Carolina: Geological Society of America Abstracts with Programs, v. 23, no. 1, p. 138.

Tull, J. F., and Groszos, M. S., 1988, Murphy belt: stratigraphic complexities and regional correlations, in Fritz, W. J., and LaTour, 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.

_____, 1991, Structure of the Tate culmination and origin of the Marble Hill Hornblende Schist, Georgia Blue Ridge: Geological Society of America Abstracts with Programs, v. 23, no. 1, p. 141.

Tull, J. F., and Guthrie, G. M., 1983, Talladega Belt/Blue Ridge Belt Stratigraphies – Can They be Correlated?: Geological Society of America Abstracts with Programs, v. 15, no. 2, p. 95.

Tull, J. F., and Guthrie, G. M., 1985, Proposed stratigraphic linkages between the Talladega slate belt and the Appalachian miogeocline – tectonic implications, in Tull, J. F., Bearce, D. N., and Guthrie, G. M., eds., Early evolution of the Appalachian miogeocline: Upper Precambrian – lower Paleozoic stratigraphy of the Talladega slate belt: Alabama Geological Society, 22nd, annual field trip guidebook, p. 1 – 10.

Tull, J. F., Harris, A. G., Repetski, J. E., McKinney, F. K., Garrett, C. B., and Bearce, D. N., 1988, New paleontologic evidence constraining the age and paleotectonic setting of the Talladega slate belt, southern Appalachians: Geological Society of America Bulletin, v. 100, p. 1291 – 1299.

Tull, J. F., and Stow, S. H., 1979, eds., The Hillabee metavolcanic complex and associated rock sequences: Alabama Geological Society, 17th Annual Field Trip, Guidebook, p. 33 – 36.

Tull, J. F., Thompson, T. W., and Groszos, M. S., 1991, Stratigraphic arguments against faulting in the Murphy belt, in Kish, S. A., eds., Studies of Precambrian Paleozoic Stratigraphy in the western Blue Ridge: Carolina Geological Society Field Trip Guidebook.

Unrug, R., and Unrug, S., 1990, Paleontological evidence of paleozoic age of 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, in Kish, S. A., eds., Studies of Precambrian Paleozoic Stratigraphy in the western Blue Ridge: Carolina Geological Society Field Trip Guidebook.

Van Horn, E. C., 1948, Talc deposits of the Murphy Marble belt: North Carolina Department of Conservation, Div. Mineral Resources Bulletin 56, 54 p.

Wiener, L. S., and Merschat, 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., Field trips in the southern Appalachians: Tennessee Division of Geology Report of Investigation No. 37, p. 23 – 29.

Wiener, L. S., and Merschat, C. E., 1981, Provisional geologic map of southwest North Carolina, southeast Tennessee and north Georgia: North Carolina Geological Survey Open File Map, scale 1:250,000.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 115-122

STRATIGRAPHIC ARGUMENTS AGAINST FAULTING IN THE MURPHY BELT

James F. Tull, Troy W. Thompson, and Mark S. Groszos
Department of Geology B-160, Florida State University,Tallahassee, Florida 32306

INTRODUCTION

Several major faults have been proposed by various geologists to exist at different structural levels within the Murphy belt (Fig. 1). Review of the literature reveals however that evidence cited to support the existence of these faults is not structural, but is almost entirely stratigraphic. Surprisingly, in almost every case, reinterpretation of the stratigraphic relationships has indicated that no reason now exists to map the proposed faults.

We feel that the evolution of study of this region is a good example of how an incomplete understanding of stratigraphic complexities and isoclinal folding can combine with insufficient detailed field mapping and examination of key contacts to result in erroneous fault interpretations. Major faults have been mapped with this belt, but our thesis is that no major faults exist here. We will discuss the reported evidence for existence of each proposed fault has eventually been questioned by subsequent workers and these subsequent workers have chosen to reinterpret the proposed fault contacts as stratigraphic.

LaForge and Phalen (1913) conducted one of the earliest studies of the Murphy belt and their work seems to have had a profound effect on the literature in terms of ideas of the existence and location of faults in the belt, and their concepts continue to affect present day compilations (see for example Hatcher and others, 1990, and Rankin and others, 1990). LaForge and Phalen (1913, p. 9) proposed faults striking essentially the entire length of the belt on both limbs of the Murphy syncline. The northwestern fault they termed the "Murphy fault" and the southeastern fault they termed the "Whitestone fault". They considered these faults to be major structures and referred to the Murphy fault (p. 9) when they noted, "The outcrops afford little direct evidence of faulting, and the positions of the faults are determined primarily from the distribution and known sequence of the formations."

Interestingly, examination of the position of most of the proposed faults in the Murphy belt shows that these faults are mapped at or near the boundary of the proposed Hiwassee River and Mineral Bluff Groups (as defined by Tull and others, this volume) on both limbs of the Murphy syncline. This places both faults essentially at the level of the Murphy Marble or the horizon at which it is missing (see Tull and Groszos, 1988). For example, LaForge and Phalen (1913, p. 9) noted that in north Georgia the Murphy fault "forms the southeast boundary of the western row of exposures of marble", and "In the Ellijay quadrangle the eastern row of areas of Murphy Marble lies along or just west of the Whitestone fault." Tull and Groszos (1988), in their discussion of the hypothesis that the Hiwassee River and Mineral Bluff Groups are separated by an unconformity, pointed out that the recognition of an unconformity at this level eliminates the original stratigraphic arguments for the existence of these faults.

MURPHY FAULT

In his pioneering study of the Murphy belt, Keith (1907) proposed several faults to support his stratigraphic interpretation of this region. Subsequent work has shown that the stratigraphic interpretations upon which the faults are based are in error. For example, Keith (1907, cross section E, p. 16) interpreted that the Nottely Quartzite on the west limb of the Murphy syncline was located in the core of a smaller scale isoclinal syncline overturned to the northwest. In this interpretation, the Nottely is flanked on both sides by the stratigraphically underlying Andrews Formation. On the northwest, the Andrews contact the stratigraphically underlying Murphy Marble, but on the southeast limb the Marble is missing above the Andres. Instead, the overturned Andrews is in contact with what Keith (1907) interpreted to be Valleytown Formation, a unit stratigraphically below the marble (see Tull and others, this volume). Thus, Keith also mapped what later became known as the Murphy fault (LaForge and Phalen, 1913) along this contact (Fig. 2). Additionally, there is not tight syncline cored by Nottely, which would be expected to repeat the Murphy Marble to the east in the first place. Well preserved cross beds found near the easternmost exposures of the Nottely demonstrate that the entire Nottely section is upright and not repeated in a tight syncline. Rocks to the east of the Nottely are thus younger than Nottely and do not include Keith's Andrews Schist. Thus, when the stratigraphy is reinterpreted (Van Horn, 1948; power and Forrest, 1971; Forrest, 1975; Thompson and Tull, this volume) arguments in support of Keith's Murphy fault are completely removed (Fig. 2).

Hurst (1955) argued for an extension of the Murphy fault to the southwest into the Mineral Bluff, Georgia area, but drew the fault at a somewhat different stratigraphic and structural level than Keith (1907). Although Hurst (1955, p. 95) cited structural evidence for faulting, such as "localized crinkling, distortion, and small-scale shearing in the Nottely quartzite", his main evidence for the fault seems to have been stratigraphic, the supposed loss on the west limb of the Murphy syncline of 1500 feet of rocks he correlated with the

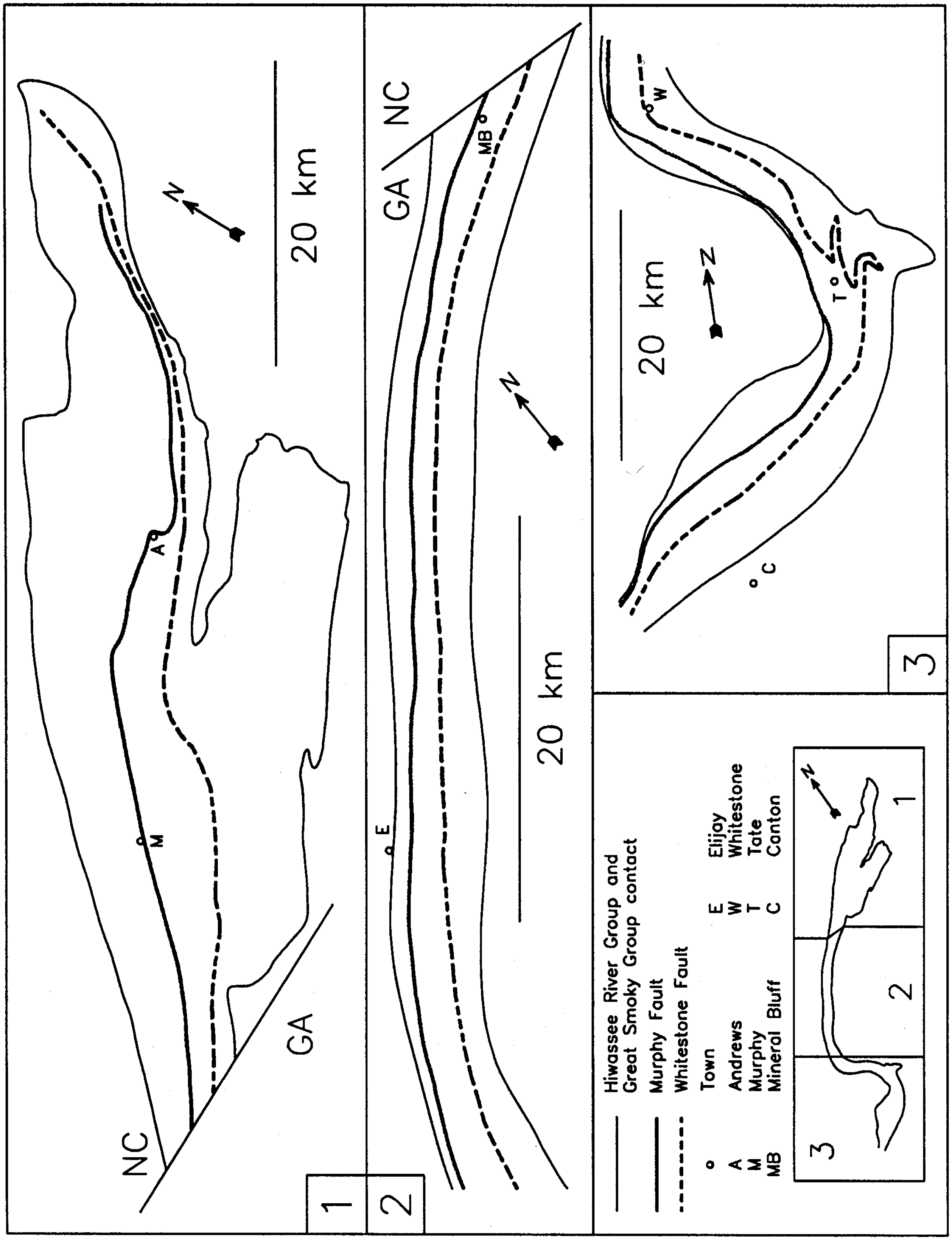


Figure 1. Generalized distribution of regional faults (Murphy and Whitestone) in the Murphy belt proposed by previous authors. See test for detailed description.

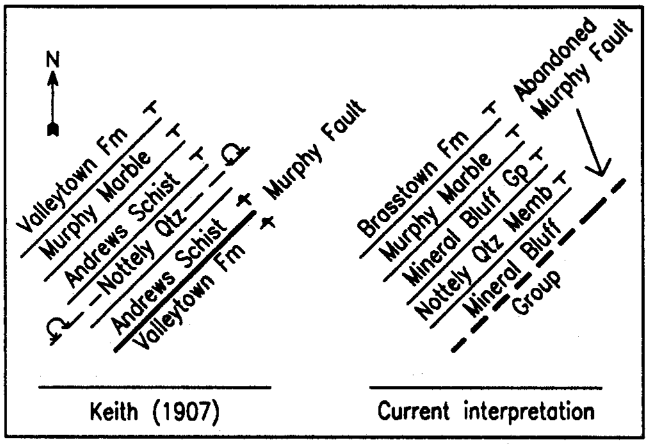


Figure 2. Keith (1907) and present geologic interpretation near Murphy, North Carolina.

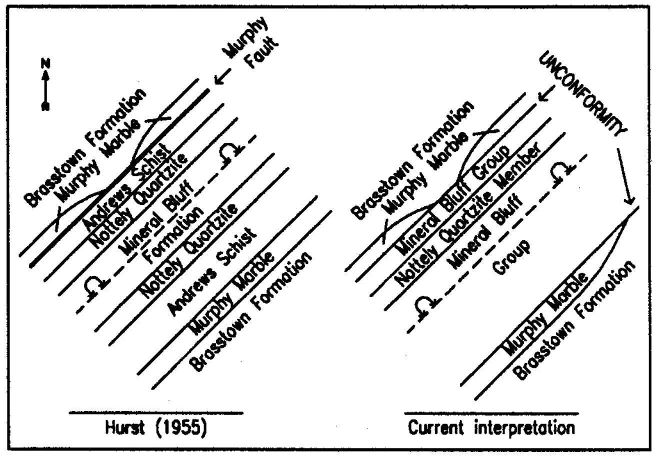


Figure 3. Hurst (1955) and present geologic interpretation (modified from Power and Forrest (1971) and Dallmeyer and others (1978) near Mineral Bluff, Georgia.

Andrews Formation of Keith (1907). We believe that Hurst (1955) was forced to hypothesize the major fault because he correlated a quartzite stratigraphic higher on the east limb of the Murphy syncline with the Nottely Quartzite on the west limb. The east limb quartzite is separated from the east limb Murphy Marble by approximately 1500 feet of schist. Power and Forrest (1971, Figure 4b) proposed an alternative interpretation that placed the schist sequence in question within the Mineral Bluff Formation and this interpretation does not require fault removal of the exceptional thickness of Andrews. The arguments of Power and Forrest are cited in detail (p. 10 and 11) and we concur with this interpretation (Fig. 3). Twelve kilometers northeast of Mineral Bluff along strike of the section mapped by Hurst (1955) near the state border, Dallmeyer and others (1978, p. 48) concurred with this interpretation as well and mapped no fault at the level Hurst (1955) had proposed.

Southwest of the Mineral Bluff area of Hurst (1955), the only geologists other than LaForge and Phalen (1913) to draw the trace of a fault in the position of the Murphy fault were McConnell and Costello (1980) and McConnell and Abrams on the Atlanta 1:100,000 map (1984). These authors present no explanation of this interpretation in the text but place a fault at the base of the Mineral Bluff Group (McConnell and Abrams, 1984, Plate I, West) (Fig. 4). This fault traces southwestward to the closure of units around the hinge area of the Murphy syncline, but no stratigraphic offsets of units is shown by McConnell and Costello (1980) or McConnell and Abrams (1984) and the fault is discontinued. To the northeast of the fold hinge, these authors map a fault between Mineral Bluff Group and Nantahala Formation. About eight kilometers northeast of the fold hinge along the trace of the proposed fault, these authors draw the fault as climbing up section in the footwall and occurring between the Mineral Bluff Group and Murphy Marble/Marble Hill Hornblende Schist undifferentiated, yet no stratigraphic section is missing at this contact (Fig. 4). In fact, these authors do not continue the fault across the quad boundary to the northeast (McConnell and Abrams, 1984, Plate I, East), interpreting the same contact as stratigraphic. LaForge and Phalen (1913) suggested that the Brasstown Formation did not occur southwest of the Ellijay, Georgia quadrangle because of nondeposition. Bayley (1928) concurred with this explanation in the Tate, Georgia area and did not extend the Murphy fault through this region. Many geologists working in Georgia, however, have noted the difficulty in differentiating the Nantahala and Brasstown Formations in the absence of a distinctive metasandstone sequence (formerly referred to as the Tusquitee Quartzite – see Tull and others, this volume). We are not convinced that the and others, this volume). We are not convinced that the Brasstown Formation is in fact missing southwest of the Tate area and omitted the Murphy fault along this limb.

We would conclude from this extended discussion that the Murphy fault does not exist. No definitive structural evidence has been cited for its existence and the stratigraphic evidence that has been cited to support it is based upon misinterpretation of stratigraphy and/or structure. This seems to be the conclusion of most modern workers who have presented detailed maps encompassing the trace of the proposed Murphy fault.

WHITESTONE FAULT

A number of geologists have proposed that major faults exist on the east limb of the Murphy syncline, mostly at or near the proposed Hiwassee River Group/Mineral Bluff Group contact, as mentioned above. Keith (1907) was the first geologist to map a fault on the east limb of the syncline, near Peachtree, North Carolina, but LaForge and Phalen (1913) extended this fault essentially the entire length of the

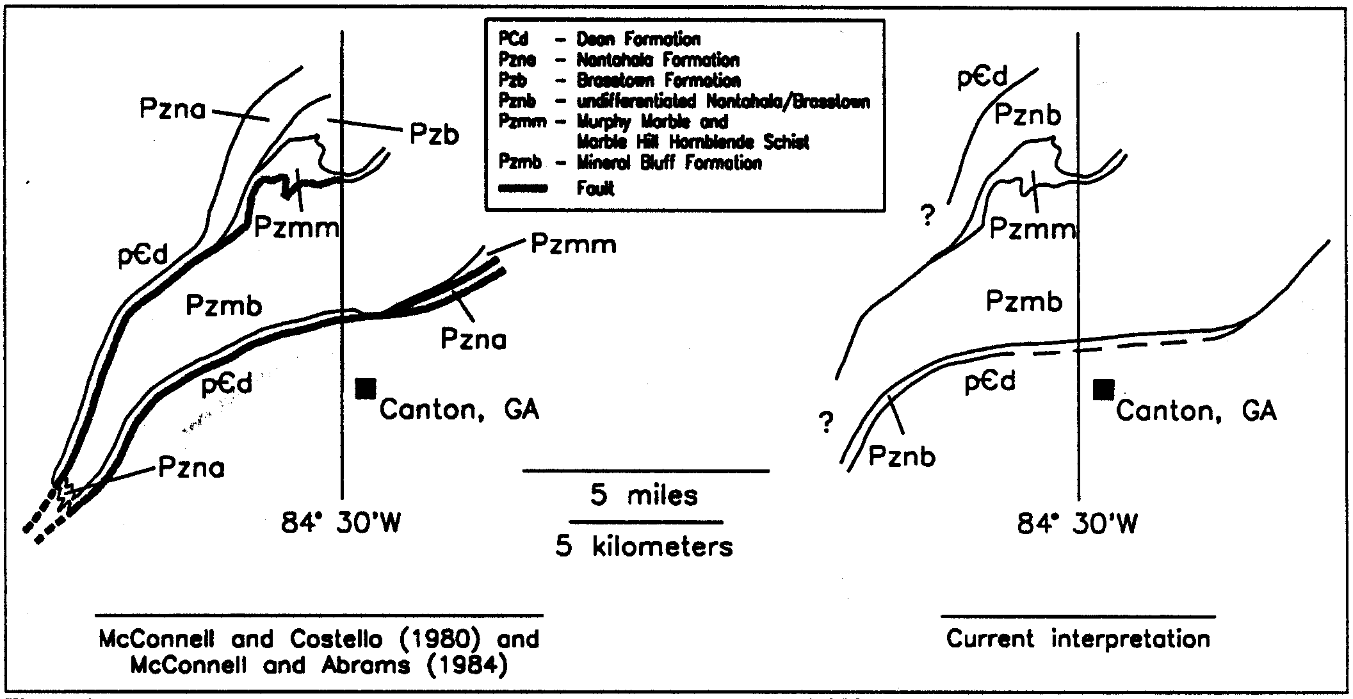


Figure 4. McConnell and Costello (1980) and McConnell and Abrams (1983), and present geologic interpretation of the southern portion of the Murphy belt.

east limb and coined the term "Whitestone fault" for this structure. Various other authors have mapped individual fault segments at this structural position and we will discuss these under the heading "Whitestone fault".

On the east limb of the Murphy syncline at Peachtree (Fig. 5), Keith (1907) mapped a "V" shaped slice of Murphy Marble and Andrews Schist in the core of a southwest plunging anticline (Valley River anticline of Forrest, 1975). On the concave side of the "V", Murphy Marble was mapped as bounded below by Valleytown Formation. On the west limb of the concave side Keith mapped the boundary as a fault, but he interpreted the east limb as a stratigraphic contact (Fig. 5). Most geologists since Keith have considered the Valleytown Formation to be upper Brasstown Formation and have abandoned the name Valleytown Formation (see Tull and others, this volume). Forrest (1975) and Thompson and Tull (this volume) map the entire concave side of the "V" at Peachtree as a stratigraphic contact between Murphy Marble and Brasstown Formation (Fig. 5). No structural or stratigraphic evidence exists for a fault at this boundary.

On the east limb of convex side of the "V" at Peachtree, Keith (1907) mapped Andrews Schist and then Murphy Marble progressively in fault contact with Valleytown Formation, and then discontinued the fault where Brasstown contacts Brasstown to the northeast. In our interpretation and that of Power and Forrest (1971) and Forrest (1975), no fault exists on the east limb of the convex side of the "V". The Valleytown Formation along this limb is reinterpreted to be Mineral Bluff Group stratigraphically above the Murphy Marble. The Murphy Marble on the east limb of the "V" is not faulted off, but instead folds back to the southwest in the core of a syncline and traces into the belt of Murphy Marble trending southwest through Brasstown, North Carolina which Keith showed to be stratigraphically bounded on both sides (Fig. 5).

On the west limb of the convex side of the "V" at Peachtree, Keith (1907) mapped a fault that died out to the northeast but continued across the Hiwassee River southwestward to the edge of his map (Fig. 5). Power and Forrest (1971) and Forrest (1975) also mapped a fault along the west limb of the convex side of the "V" to explain truncation of the Murphy Marble but discontinued this fault immediately to the southwest where Mineral Bluff is in contact with Mineral Bluff. Unlike Keith however, they extended this fault continuously to the northeast to near Andrews to explain the truncation of Murphy Marble and eventually the Brasstown Formation. Forrest (1975) termed this fault the "Braden Mountain slide", interpreting it to be a premetamorphic tectonic slide temporally associated with what he called the F_1 "Valley River anticline". We interpret the truncation of the Murphy Marble north of Peachtree to be stratigraphic, below an unconformity (see Tull and Groszos, 1988), but believe that evidence may exist for a late normal (?) fault along the trace mapped by Power and Forrest (1971) and Forrest

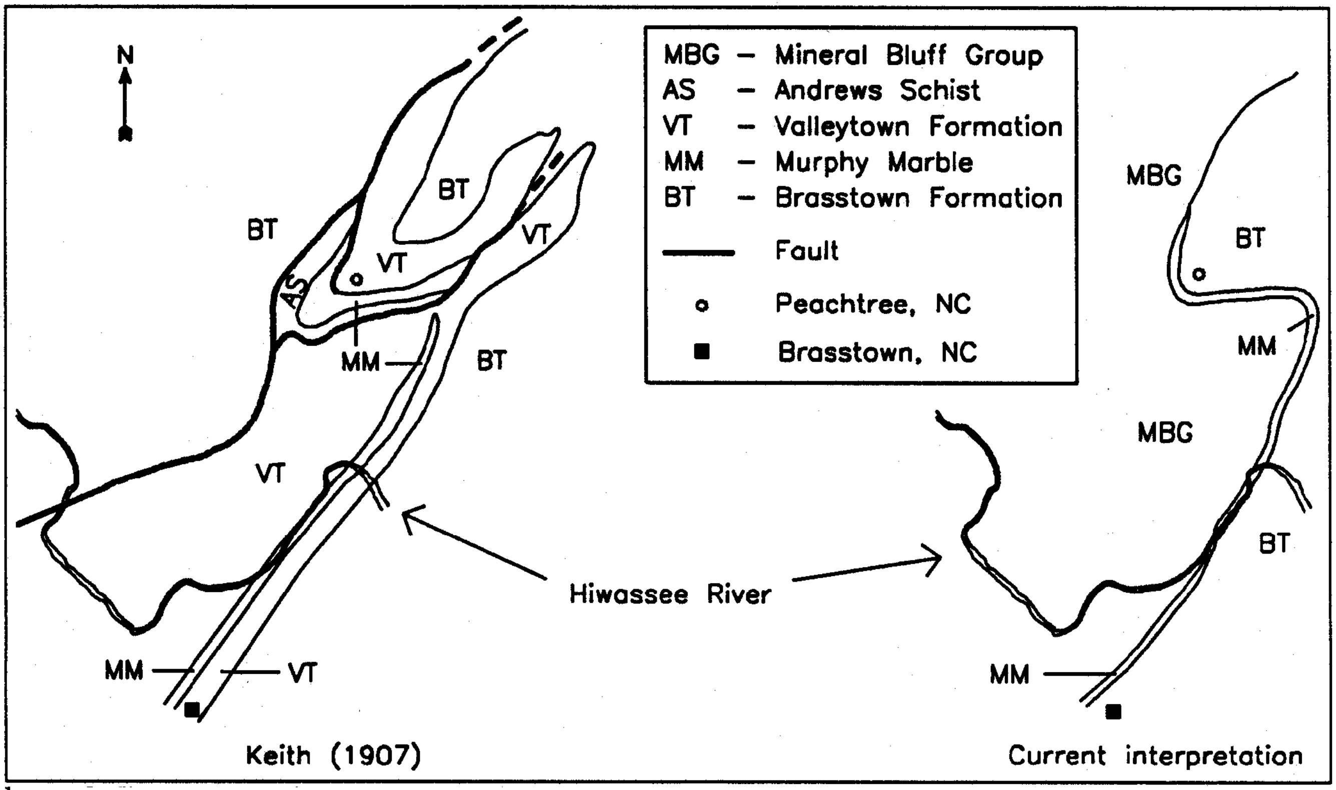


Figure 5. Keith (1907) and present interpretation near Peachtree, North Carolina.

(1975) northeast of Andrews, North Carolina (Kish, 1974).

Power and Forrest (1971) and Forrest (1975) mapped a fault with similar geometry to the "Braden Mountain slide" along strike to the southwest, and Forrest (1975) termed this structure the "Mary King slide". Forrest (1975, p. 55) believed that his fault had relatively minor displacement because it produced only small stratigraphic throw. In his interpretation it is fortuitous that these slides occur along strike from each other because they occur as slides along different limbs of two different folds (Forrest, 1975 p. 55). Unfortunately, compilation maps post-dating Power and Forrest's (1971) and Forrest's (1975) work returned to the ideas of LaForge and Phalen (1913) and connected Forrest's slides, tracing the Whitestone fault as a continuous thrust along much of the east limb of the Murphy syncline (see North Carolina State Map, 1985; Hatcher and others, 1990; and Rankin and others, 1990). In our interpretation, the Mary King slide of Forrest (1975) does not exist. Only the Murphy Marble is absent in the stratigraphy in this area south of Murphy, North Carolina and we believe that it has been removed by erosion along an unconformity at the base of the Mineral Bluff Group.

A few kilometers along strike to the southwest of the Mary King slide of Forrest (1975), just south of the North Carolina – Georgia border near Culberson, Dallmeyer and

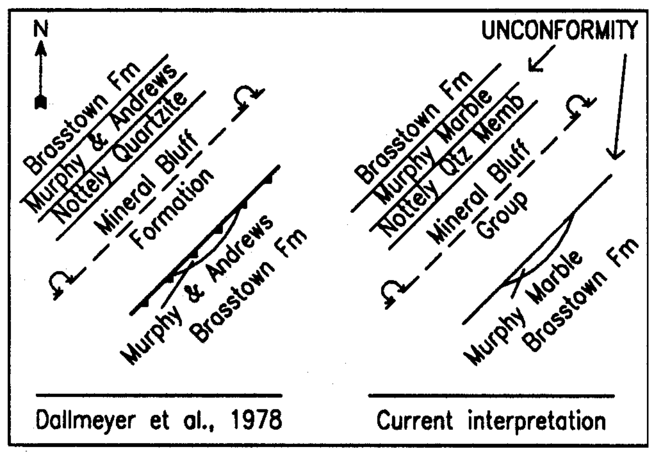


Figure 6. Dallmeyer and others (1978_ and present geologic interpretation near Culberson, North Carolina.

others (1978, p. 47) mapped a fault in the same stratigraphic position on the east limb of the Murphy syncline (Fig. 6). They cited no structural evidence for this fault but apparently used it to explain the discontinuous nature of the Murphy Marble (and Andrews Formation), a lense of which is shown on the overturned limb of the Murphy syncline to be stratigraphically bounded above by Brasstown Formation but fault bounded by a normal overturned section of Nottely Quartzite

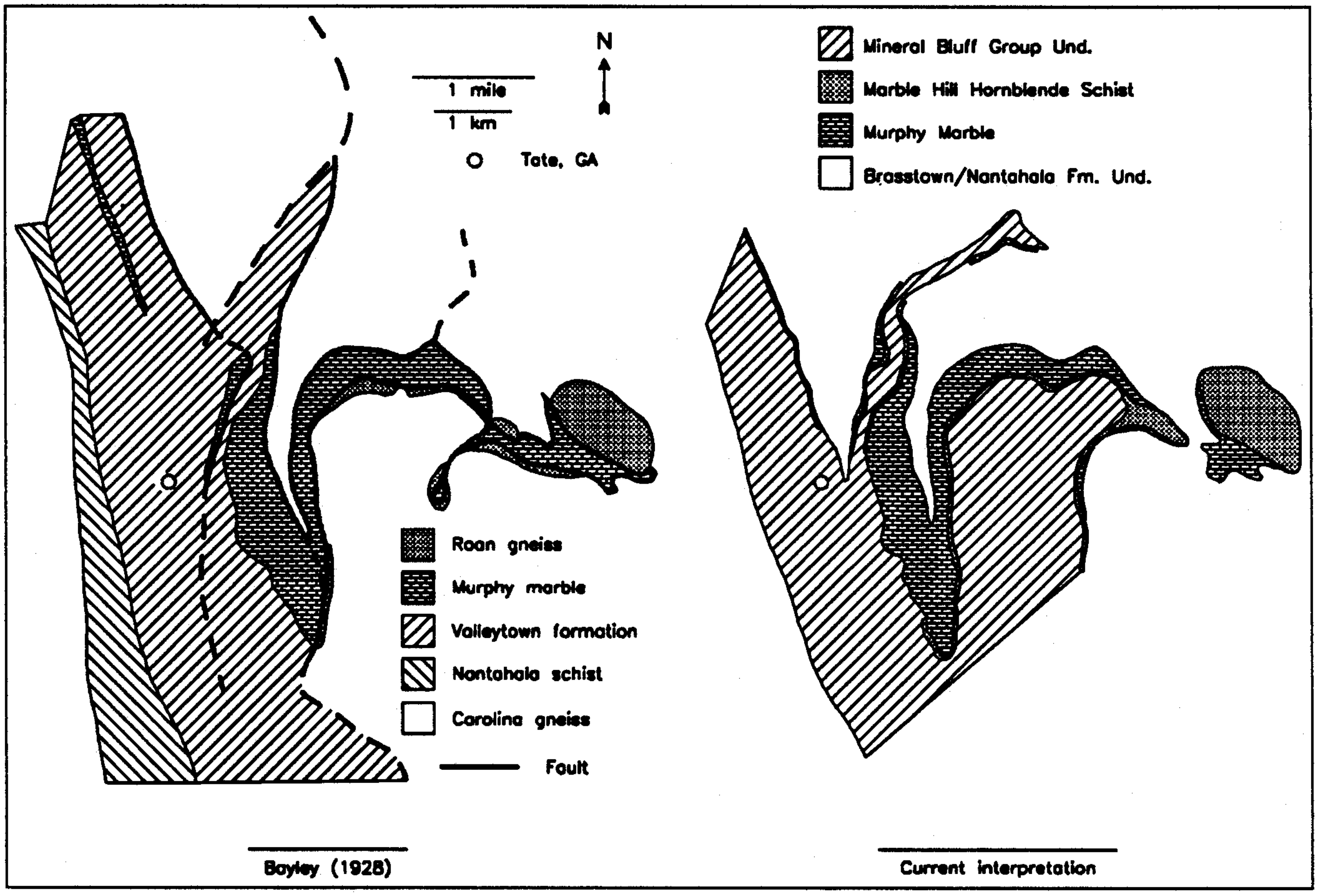


Figure 7. Bayley (1928) and present geologic interpretation near Tate, Georgia.

and Mineral Bluff Formation (Fig,. 6). At the latitude of their cross section, all unites are in stratigraphic order, yet they show about 250 meters of dip separation on the "fault". We have interpreted the discontinuous nature of the Murphy Marble below the Mineral Bluff Group to be the result of erosional removal below a regional unconformity (Tull and Groszos, 1988) and find no compelling reason for the fault interpretation of Dallmeyer and others (1978) at Culberson.

The Whitestone fault was first proposed by LaForge and Phalen (1913) to explain stratigraphic relationships on the overturned limb of the Murphy syncline at Whitestone, Georgia. In this area they interpreted the Murphy Marble to be directly overlain by the Nantahala Formation with the intervening Brasstown and Valleytown Formations missing. Because of these relationships and the presence of secondary iron ore associated with the Murphy Marble, which was believed to mark the fault trace, LaForge and Phalen extended the Whitestone fault the entire length of the Murphy belt, connecting it with the fault in a similar structural position which Keith (1907) had mapped at Peachtree, North Carolina (mentioned above).

As noted earlier, and in Tull and others (this volume), Valleytown Formation of earlier studies is considered to be upper Brasstown Formation and little work has been done to establish criteria for differentiating the Brasstown and Nantahala Formations in the absence of an intervening sandstone sequence (formerly named the Tusquitee Quartzite). This sandstone sequence is not well developed throughout much of the Murphy belt in Georgia. It has not been documented that the schist sequence directly overlying the Murphy Marble at Whitestone is actually Nantahala Formation. In fact, we have mapped these rocks as Nantahala/Brasstown Formation undifferentiated immediately east of Talona Valley where Whitestone is located and feel that an entire section of Brasstown/Nantahala Formation is present here on the east limb of the Murphy syncline. Power and Reade (1962) also interpret the rocks directly overlying the Murphy Marble at Whitestone to be Brasstown Formation has been removed by faulting at this location as LaForge and Phalen (1913) proposed, this would imply no more than a few hundred meters of dip slip separation on the fault, hardly making this a major Appalachian thrust which is implied by LaForge and Phalen and the regional compilation maps such as Hatcher and others (1990), which show the trace of the Whitestone fault for greater than 100 km. Power and Reade (1962) map a late normal fault immediately east of Whitestone to explain truncation of the Murphy Marble, but show no other units cut out by this fault. This fault is not mapped in the same position as the Whitestone fault of LaForge and Phalen (1913) and has to opposite sense of slip of the proposed Whitestone fault.

Exposures of the contact between the Murphy Marble and the overlying schists on the east limb of the Murphy syncline are not common but do occur at many locations, including Whitestone. At none of these localities are faults obvious to us at this boundary (see Tull and Groszos, 1988 p. 47 – 51 for a detailed description of this boundary between Tate and Whitestone).

Bayley (1928), following the lead of LaForge and Phalen (1913), traced the Whitestone fault from just south of Whitestone through the Tate, Georgia area to the southern tip of the Murphy belt near Canton, although he noted that "No fault planes were seen…". He believed that the presence of the Whitestone fault was "the dominating cause of the distribution of most of the marble in this area" (Bayley, 1928 p. 1122). The Tate area is a structurally complex region that repeats the Murphy belt sequence in three isoclinal synclines (the Murphy syncline being the westernmost), which are obliquely refolded about a regional synform resulting in a Ramsay Type – 3 interference patter (Fig. 7). Detailed mapping by Fairley (1965) and Tull and Groszos (1991) has shown that Bayley's interpretation of much of the regional stratigraphy is in error. For example, throughout most of the Tate quadrangle Bayley maps the hanging wall of the proposed Whitestone faults as Precambrian Carolina gneiss. At different localities we (and Fairley, 1965) map these same rocks as Great Smoky Group, Nantahala/Brasstown Formation, and Mineral Bluff Group (Fairley's Andrews Formation) (Fig. 7). Fairley (1965, p. 5 – 10) provided extensive discussion to argue against the presence of the Whitestone fault in the Tate Quadrangle, but unfortunately these arguments have not been accepted by many subsequent compilations.

Bayley extended the Whitestone fault southwestward from Tate along the eastern boarder of the "Keithsburg" marble belt between the marble and slices of Nantahala Formation, which we map as Mineral Bluff Group undifferentiated. This fault, and a parallel fault a few hundred meters to the southeast, bounded slices of Nantahala Formation between the Keithsburg marble and the "Carolina gneiss". We map a continuous section of Mineral Bluff Group across the eastern fault of Bayley (1928) (Fig. 4).

At least two recent publications have included faults at approximately the position of the Whitestone fault on the southeast limb of the Murphy syncline near its southern termination similar to the interpretation of Bayley (1928). McConnell and Abrams (1984) placed faults east of the Keithsburg marble belt apparently after Bayley (1928), but provided no explanation in the text. Following Cressler and others (1979), Costello (1988) place a fault (Cressler and others North Canton fault) in the position of Bayley's eastern fault (east of the proposed Whitestone fault), but did not map a fault in the position of the Whitestone fault as Bayley fault as Bayley and McConnell and Abrams had done.

We have examined exposures along the southeast boundary of the Keithsburg marble and have confirmed that throughout most of its length, this boundary is stratigraphic rather than faulted. This is also the interpretation of Fairley (1965). We therefore see no rationale for placing a fault at this contact. Additionally, we see no reason for placing a fault in the position of Costello's North Canton fault, at least where it is drawn in the Murphy belt. No stratigraphic offsets has been demonstrated at this position. A key location for examining the effects of this proposed fault occurs where the proposed fault passes southwestward from the southeast limb of the Murphy syncline to the hinge area of this fold at the contact between the Hiwassee River and Great Smoky Groups (Nantahala and Dean Formations). Costello (1988) emphasized the symmetrical nature of the syncline at this latitude which he illustrated by mapping the repetition of the Dean/Nantahala Formations contact on both limbs. If the southeast limb is faulted, as Costello (1988) shows on his map, then this fault must have both negligible dip and strike stratigraphic separation for the stratigraphic symmetry to be maintained from the limb to the hinge of the fold, as shown by Costello. In his field trip stop description of the contact in this area, Costello (1988, p. 21) does not mention a fault at this boundary. Additionally, Costello and others (1982, p. 32) show no fault in this position on their geologic map of the same area. For these reasons therefore we do not believe that a significant fault can exist at this location. Costello (1988, p. 15 – 16), however considers this fault to be part of a major thrust that merges to the southwest into the thrust at the base of the Talladega belt (Talladega fault).

CONCLUSIONS

In the foregoing discussion, we have attempted to analyze the arguments presented by other geologists for faults within the Murphy belt. We have shown that in essentially every stratigraphic relationships, fault interpretations are either not required or are unsupported. No structural data has been presented to support a fault interpretation and no fault zone materials have been described from any of the proposed faults. In each case, we have presented an alternative interpretation (many of which have also been presented by other geologists) of the stratigraphy and structure which does not involve faulting. We argue that faults should only be mapped in this belt when evidence is presented for which a fault solution is the best interpretation.

It is also important perhaps to point out that even if the original stratigraphic interpretations upon which the fault interpretations were based are accepted (and we and others have argued that they are not valid), then significant fault displacements (greater than a few 100 meters) are not possible. The isoclinally folded geometry of the stratigraphy requires significant stratigraphic separations are not seen. For these reasons we think it is important to emphasize (plead?) that regional compilations should discontinue drawing traces of the "Murphy" and "Whitestone" faults through this region. If these faults existed as they were originally believed to, they would represent very minor displacement faults, not meriting placement on a regional map. When the overwhelming evidence indicates that these faults do not in fact exist, there should be even more reason to abstain from including these faults on compilations.

ACKNOWLEDGMENTS

John Costello and Bill Fairley reviewed this manuscript and their review is appreciated. Some of our work in the Murphy belt has been supported by the National Science Foundation (ERA-8313740 to J. F. T.). This support is gratefully acknowledge.

REFERENCES CITED

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 Paleozoic Stratigraphy in the western Blue Ridge: Carolina Geological Society Field Trip Guidebook.

Bayley, W. S., 1928, Geology of the Tate Quadrangle: Georgia Geological Survey Bulletin 43, 167 p.

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, 40 p.

Costello, J. O., 1988, Structural controls on southern Murphy syncline geometry, 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 Guidebooks, v. 8, no. 1, p. 7 – 19.

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.

Dallmeyer, R. D., Courtney, P. S., and Wooten, R.M., 1978, Stratigraphy, structure, and metamorphism east of the Murphy syncline: Georgia – North Carolina: Georgia Geological Society Guidebook, no. 17, 74 p.

Fairley, W. M., 1965, The Murphy Syncline in the Tate Quadrangle, Georgia: Georgia Geological Survey Bulletin 75, 71 p.

Forrest, J. T., 1975, Geologic evolution of a portion of the Murphy Marble belt in southwestern North Carolina [Doctoral Dissertation]: Rice University, Houston, Texas, 76 p.

Hatcher, R. D., Jr., Osberg, P. H., Drake, A. A., Jr., Robinson, P., and Thomas, W. A., 1990, Plate I – Tectonic map 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, Colorado, Geological Society of America, The Geology of North America, v. F-2.

Hurst, V. J., 1955, Stratigraphy, structure, and mineral resources of the Mineral Bluff quadrangle, Georgia: Georgia Geological Survey Bulletin 63, 137 p.

Keith, A., 1907, Description of the Nantahala quadrangle, North Carolina and Tennessee: U. S. Geological Survey Geologic Atlas, Folio 143, 11p.

Kish, S. A., 1974, The structural and metamorphic history of the northern terminus of the Murphy belt [M. S. thesis]: Florida State University, Tallahassee, Florida, 131 p.

LaForge, L., and Phalen, W. C., 1913, Description of the Ellijay quadrangle, Georgia, North Carolina and Tennessee: U. S. Geological Survey Geologic Atlas, Folio no. 187, 17 p.

McConnell, K. I., and Abrams, C. E., 1984, Geology of the greater Atlanta region: Georgia Geological Survey Bulletin 96, 127 p.

McConnell, K. I., and Costello, J. O., 1980, Geologic guide to the geology along a traverse through the Blue Ridge and Piedmont of north Georgia: in Frey, R.W., ed., Excursions in southeastern geology: American Geological Institute, v. 1, p. 241 – 258.

North Carolina Department of Natural Resources and Community Development, 1985, Geologic map of North Carolina: North Carolina Geological Survey, scale 1:500,000.

Power, W. R., and Reade, E. H., 1962, The Georgia Marble District Guidebook no. 1, Georgia Geological Survey.

Power, W. R., and Forrest, J. T., 1971, Stratigraphy and structure of the Murphy belt, North Carolina: Carolina Geological Society, Annual Field Trip Guidebook, 29 p.

Rankin, W. R., Drake, A. A., 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.

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 Paleozoic Stratigraphy in the western Blue Ridge: Carolina Geological Society Field Trip Guidebook.

Tull, J. F., and Groszos, M. S., 1988, Murphy belt: stratigraphic complexities and regional correlations, in Fritz, W. J., and LaTour, 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.

_____, 1991, Structure of the Tate culmination and origin of the Marble Hill Hornblende Schist, Georgia Blue Ridge: Geological Society of America Abstracts with Programs, v. 23, no. 1, p. 141.

Tull, J. F., Thompson, T. W., Groszos, M. S., Aylor, J. G., and Kish, S. A., 1991, Murphy belt litho stratigraphic nomenclature, in Kish, S. A., ed., Studies of Precambrian Paleozoic Stratigraphy in the western Blue Ridge: Carolina Geological Society in the western Blue Ridge: Carolina Geological Society Field Trip Guidebook.

Van Horn, E. C., 1948, Talc deposits of the Murphy Marble belt: North Carolina Department of Conservation, Div. Mineral Resources Bulletin 56, 54 p.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 123-142

CAROLINA GEOLOGICAL SOCIETY

1991 FIELD TRIP ROAD LOG

SATURDAY, NOVEMBER 9, 1991

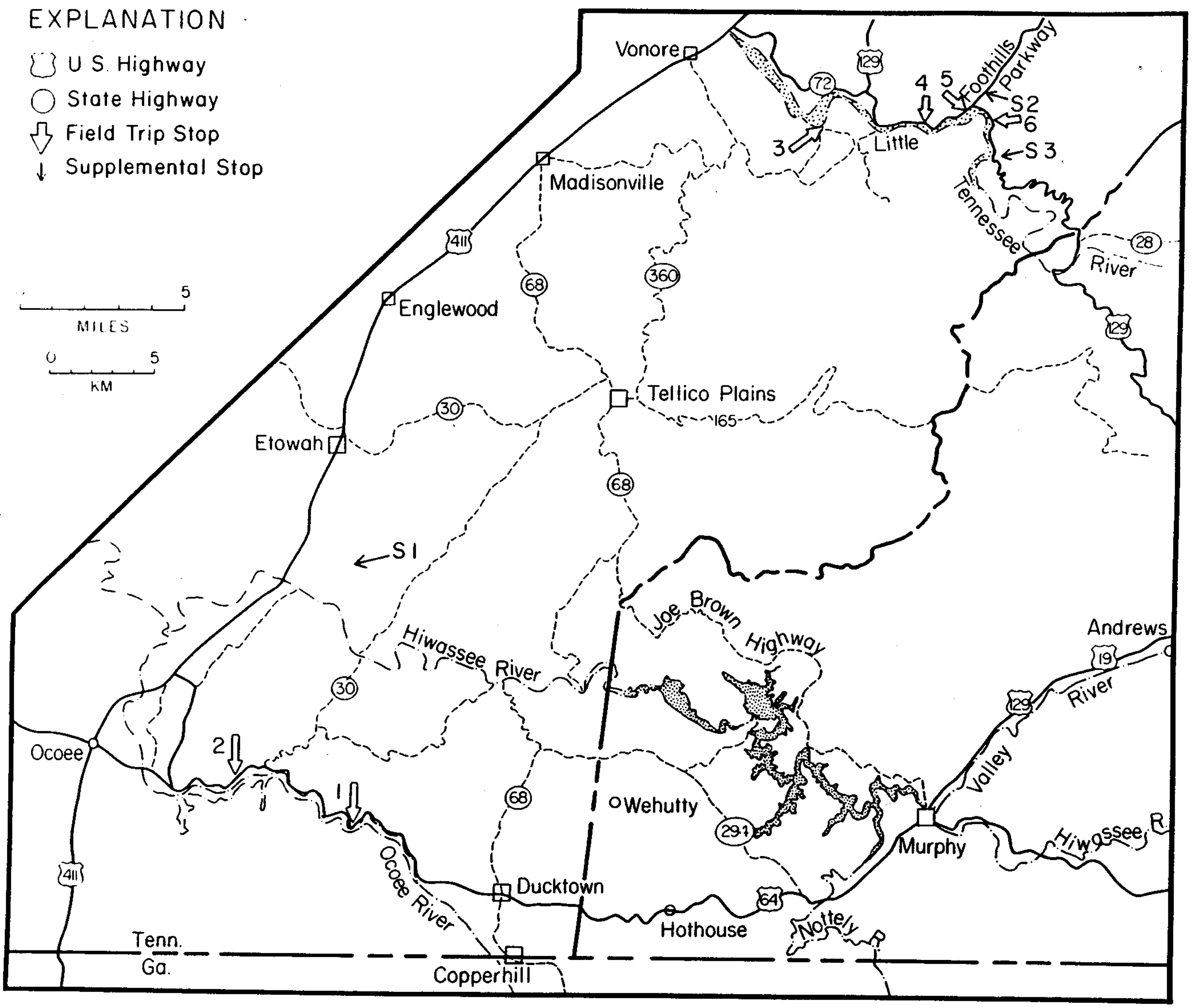


Figure 1. Location map for Saturday field trip.

Mileage	Description
	Econo Lodge, Murphy, North Carolina. Proceed uphill.
00.2	Turn right onto U. S. Highway 64 – 74. For the next several miles the highway will be in a valley formed within the Mission Mountain Formation of the Mineral Bluff Group (Thompson and Tull, this volume). The prominent ridge on the right is formed by the Nottely Quartzite.
00.4	Intersection with U. S. Highway 64. Continue south.
00.6	Cross Hiwassee River.
06.1	Intersection of U. S. Highways 64 – 74 and 19 – 129. Continue south on U. S. 64 – 74.
06.8	Intersection with N. C. Highway 60 on left. Continue on U. S. 64. The highway is now turning west. The field trip will now be going down section from rocks of the Murphy belt into rocks of the Great Smoky

Group.

07.0 Bridge over the Nottely River. The Nottely Quartzite forms the ridge on the east side of the bridge.

08.5 Exposures of the Nantahala Formation.

08.7 Junction with N. C. Highway 294.

09.4 Contact between the Nantahala Formation (lowest stratigraphic unit in the Murphy belt and the Dean Formation (to the west), uppermost unit of the Great Smoky Group.

12.0 Approximate contact between Hothouse Formation (to west and Dean Formation (to east).

15.9 Nealy Gap. Mapping by Hernon (1964) indicates that the contact between the Hothouse Formation and Hughes Gap Formation is approximately 500 feet (150 m) east of the gap.

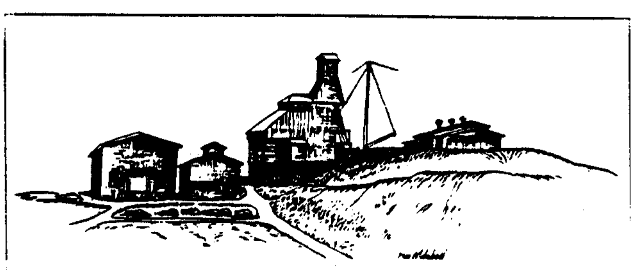
16.8 Contact between the Wehutty Formation (to west) and Hughes Gap Formation (to east).

18.6 Franklin Gap. Wehutty Formation exposed in eastbound lane roadcuts.

18.8 View of the Unaka Range. The most prominent peak is Big Frog Mountain (4,224 feet).

20.8 Angelico Gap. North Carolina-Tennessee State Line. Roadcut on right exposes Copperhill Formation rocks of the Great Smoky Group (Hurst, 1955; Hernon, 1964). Proceed west on U. S. Highway 64 from Cherokee County, North Carolina into the Ducktown basin in Polk County, Tennessee.

The Ducktown basin is the site of several massive sulphide ore bodies and a historic mining district. Following the removal of the Cherokee Indians in 1838, eastern Tennessee was enthusiastically prospected for gold. In 1843, native copper were panned from a stream near the Burra Burra lode.. Four years later the first ore, bearing about 25 percent copper was removed from this body. Within a decade, fourteen mines were operating in the Ducktown basin and ores were locally smelted or open roasted in large heaps. Charcoal fuel for these processes was derived from native timber which was also widely cut for mine shoring. Coupled with regular burning of the woods, the use of wood and charcoal fuel and the toxic sulphurous fumes released by heating the ores depleted mature forests in the basin and killed the younger trees and understory vegetation. The denuded landscape was rapidly eroded into deep gullies. Today the chief product of the district is sulfuric acid.



Headframe - Burra Burra Mine. Illustration by Sue Mitchell in Ducktown Basin Museum.

23.3 View to north of badlands landscape that dominated the Copper Basin prior to reforestation.

24.0 North Potato Creek. Historic Burra Burra Mine visible on the near ridge to the northwest.

24.1 Ducktown, Tennessee city limits. The town is named after Duck, a Cherokee chieftain who governed this region prior to the "Trail of Tears" displacement.

24.7 Tennessee Highway 68 Interchange. Continue west on U. S. Highway 64. Excellent exposures of conglomerate and garnet schist of the Copperhill Formation are present along the east side of Tennessee Highway 68, just south of the Ducktown City limits and turn of to the site of the Burra Burra Mine and the Ducktown Basin Museum. This exposures has been described in detain by Granath (1978). Note headframe at the Boyd Mine to the south.

27.0 Approximate contact between the Copperhill Formation (to east) and Slaty Unit of Hernon (1964) (Farmer Formation of Wiener and Merschat, 1978; 1981).

27.9 Brush Creek. Approximate contact between the Salty Unity (to east) and the Boyd Gap Formation of Wiener and Merschat (1978; 1981).

29.0 Boyd Gap. Type area of the Boyd Gap Formation and the location of Stop 6 on Hatcher and others (1978) SE GSA Trip. The rocks at this location are composed of beds of dark gray, laminated phyllite and metagraywacke.

29.7 Location of Stop 5 on 1978 SE GSA Trip. The exposure contains highly deformed units of the Boyd Gap Formation.

30.0 Rock Creek.

32.4 Ocoee No. 3 Powerhouse. Water is run about 4 km via a tunnel from the Ocoee No. 3 Dam just west of Boyd Gap to the hilltop above the powerhouse. It is then dropped through the large-diameter pipes to drive turbines.

32.6 Gassaway Creek.

33.0 Approximate contact between the Boyd Gap Formation and Wiener and Merschat's (1978; 1981) Buck Bald Formation (to west).

33.3 Rogers Branch. Entrance to Ocoee River recreation area at Ocoee No. 2 Dam. Note the steeply dipping, massive feldspathic conglomerate and sandstone along the northern wall of the gorge. Graded beds in this exposure indicate the rocks are overturned. Hurst and Schlee (1962) regarded this sequence as the uppermost portion of the Great Smoky Group.

Also note the wooden flume and tramway that originate on the south abutment of the dam. The flume had fallen into disrepair prior to the late 1970's which allowed the Ocoee segment between the No.2 Dam and just below the No. 2 Powerhouse to run freely and become established as one of the south's premier whitewater streams. During power demand periods the river is almost totally routed this structure much to the disappointment of "river rats".

STOP 1. Great Smoky Group – Walden Creek contact in the Ocoee River west of Short Creek

J. O. Costello and R. D. Hatcher, Jr.

PLEASE USE EXTREME CAUTION ALONG THE ROADWAY AT THIS STOP

Great Smoky Group-Walden Creek Group (Wilhite Formation) contact. From this point westward to Greasy Creek, rocks exposed in the riverbed and in abundant roadcuts are predominantly slate with minor interbedded sandstone that Costello and Hatcher (this volume) correlate with the Walden Creek Group.

Stop 1 generally coincides with the location of Stop 34 of the Hurst and Schlee (1962) Southeastern Section Geological Society of America Field Trip. This is the contact zone between the foothills and the highlands geologic/physiographic belts of the Unaka Mountains. We correlate the coarser highlands succession to the east with the Great Smoky Group and the finer, green dominant foothills succession to the west with the Walden Creek Group.

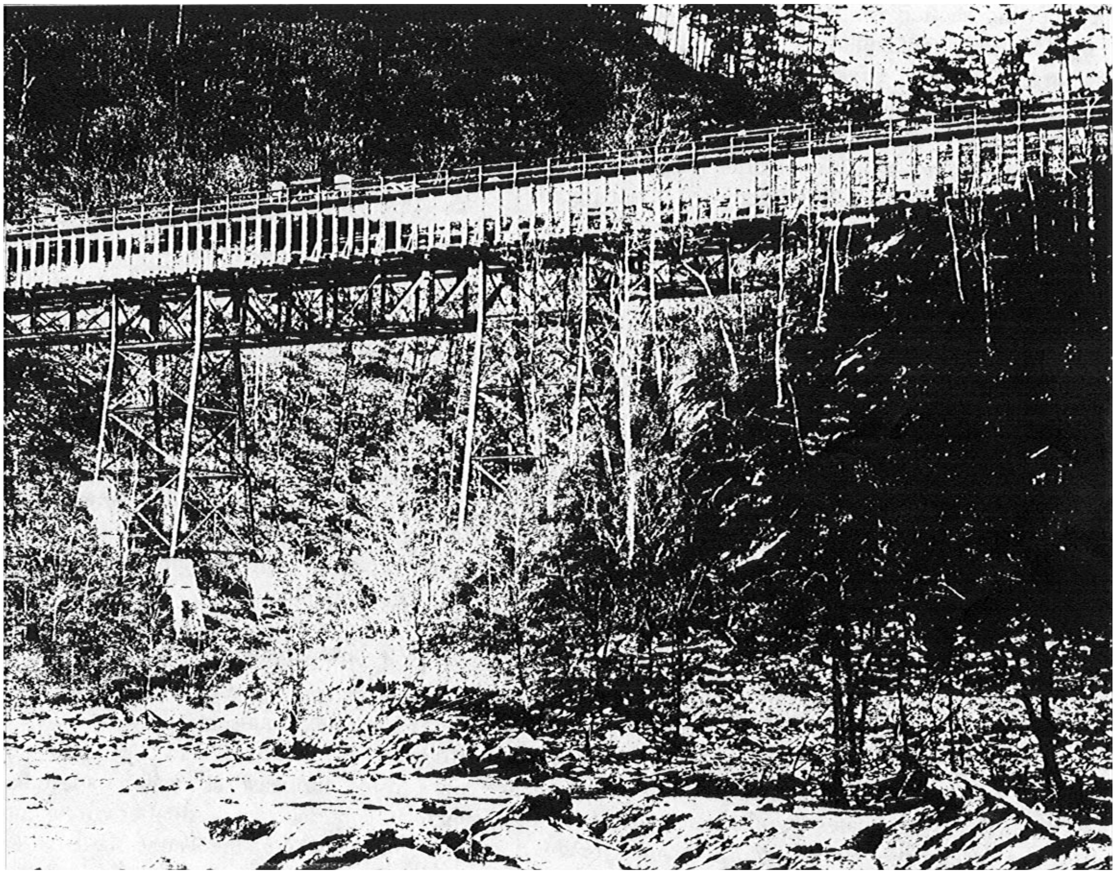
If the river level is low (flume running), climb down rip rap-covered embankment to riverside outcrops. Note the point where rocks upstream are mostly massive sandstone and conglomerate and those downstream are siltstone and slate. Carefully (rocks can be extremely slippery) proceed along the contact zone about 10 m into the riverbed.

From the contact eastward into the upper reaches of Ocoee Gorge, Ocoee Supergroup rocks of the Great Smoky Group consist of massive coarse-grained to conglomeratic feldspathic arenite interlayered with variably thick black to dark gray, locally sulfitic slaty phyllite. This succession has been subdivided into two lithostratigraphic sequences: the Buck Bald Formation to the west and the Boyd Gap Formation to the east (Wiener and Merschat, 1978). Graded bedding in the coarse-grained layers and cleavage-bedding relationships throughout indicate that these units are locally overturned (downward facing) and young toward the west.

From the contact zone westward to Greasy Creek on Parksville Lake, Ocoee Gorge rocks are predominantly fine grained consisting of locally ankeritic, grayish green to dark gray slaty phyllite interlayered with buff to light tan siltstone and local coarse-grained arenite. This segment of Ocoee Gorge contains world-class examples of asymmetrical, modified-concentric folds and slaty cleavage (Holcombe, 1973; Hatcher and Milici, 1986), but, while minor faults with small displacement occur locally, there is no conspicuous evidence that these rocks are disrupted by major faults.

Rocks west of the Great Smoky Group in Ocoee Gorge were assigned to the basal Ocoee Supergroup, Snowbird Group by Wiener and Merschat (1978; 1981) who portrayed the Greenbrier fault as separating the units. The Greenbrier which controls Great Smoky Group distribution in the Great Smoky Mountains was also mapped along strike to the northeast by Merschat and Hale (1983) as forming the western margin of the Great Smoky Group strike belt through the Farner, Tennessee and North Carolina quadrangle. In both of these maps the Greenbrier is shown as a linear (therefore moderately to steeply dipping) structure. In contrast, Slack and others (1982) and Gair and Slack (1982) mapped a moderately dipping to subhorizontal and folded Greenbrier fault largely by inference in the Big Frog and Cohutta wilderness areas south of Ocoee Gorge. We regard the abrupt change in the orientation of the hypothetical Greenbrier as puzzling and we argue that the mapped distribution of rocks to the south is mostly a result of folding.

Our mapping north of the Ocoee River along Greasy Creek in the Caney Creek, Tennessee, quadrangle, and in the McFarland quadrangle, along the Hiwassee River east of Reliance, Tennessee and north of the Hiwassee along Childers Creek and north of Springtown Branch supports correlating the foothills rock sequence with the Walden Creek Group. In addition to the fine-grained rocks described above, the foothills sequence west of the Buck Bald Formation contains lenticular "Citico" type, roundstone, grain-supported conglomerate, as well as sandy limestone and limestone breccia. Identical conglomerates, some with characteristic dolostone lasts, have also been mapped along strike south of the Ocoee River in the Tennga, Georgia, quadrangle. All of these rock types are representative lithofacies of the Wilhite Formation of the



Flume crossing Short Creek, south bank of the Ocoee River. Opposite Stop 1.

Great Smoky Mountains (Hamilton, 1961; Neuman and Nelson, 1965). Hamilton (1961) subdivided the Wilhite Formation south of English Mountain into a lower siltstone and fine-grained sandstone (Dixon Mountain Member) and an upper, conformable sequence (Yellow Breeches Member), which is characterized by beds of sandy or conglomeratic limestone. Neuman and Nelson (1965) did not formally subdivide the Wilhite Formation through the western Great Smoky Mountains, although lithologies that distinguish both members were noted along with the roundstone conglomerate lithofacies.

The contact between the foothills and highlands sequences in Ocoee Gorge has been interpreted as conformable (Hurst and Schlee, 1962), the Greenbrier fault (Wiener & Merschat, 1978) and an unconformity (Tull and Grosses, 1990). Although we conclude that an abrupt, east-to-west transition from coarse-grained to fine-grained rocks exists at this point in the gorge, we view the contact as conformable.

Sedimentary load and flame structures (see Figure 3 in Costello and Hatcher, this volume) are preserved in riverbed outcrops of interlayered sandstone, siltstone, and shale that strike generally N to50º E and dip about 60º SE. These structures confirm that rocks in the contact interval are overturned and that the sequence youngs to the west, consistent with most of the rocks throughout the gorge.

We conclude that foothills rocks west of and stratigraphically above the Great Smoky Group in Ocoee Gorge correlate with the Wilhite Formation of the Great Smoky Mountains area. This exposure preserves the Great Smoky Group-Walden Creek Group stratigraphic continuity indicating that the Greenbrier fault terminates to the northeast in the unmapped area south of the Great Smoky Mountains National Park. Hurst and Schlee (1962) recognized this contact interval as an analog to the succession at the top of the Great Smoky Group farther east in the Murphy syncline. Acknowledging the absence of the Greenbrier fault and assuming that the Buck Bald Formation and the Dean Formation (both at the top of the Great Smoky Group) are lithostratigraphic equivalents, the Walden Creek Group probably correlates with at least part of the Murphy belt sequence.

35.0 Quarry on right. Reboard buses.

35.7 Go forth Creek.

37.7 Ocoee No. 2 Powerhouse.

38.0 Caney Creek.

40.0 Madden Branch. Stop 4 on the 1978 SE GSA Trip. Folds and slaty cleavage in Walden Creek Group (Wilhite Formation) slate and silty carbonate.

40.7 Greasy Creek. Named after Cherokee Chief Greasy Belly. The historical marker west of the bridge describes a former halfway house that served mule trains hauling Ducktown district ore along the Copper Road to Cleveland, Tennessee

41.2 Intersection of U. S. Highway 64 and Tennessee Highway 30. Approximate trace of the Sylco Creek fault. Hurst and Schlee (1962) presented fifteen X-ray diffraction patterns of phyllitic slate samples from Ocoee Gorge. The diffraction pattern from a sample obtained east of this point shows a conspicuous increase in the height of the 14A chlorite peak and the 7 A kaolin + chlorite peak versus the pattern of a sample obtained just to the west. This change occurs the break between more strongly metamorphosed and cleaved rocks to the east and weakly cleaved subgreenschist facies rocks to the west.

West of the Sylco Creek fault, Sandsuck Formation shale and siltstone with minor conglomerate and limestone is conformably overlain by the Chilhowee Group. Proceed west on U. S. 64.

43.4 Intersection of U. S. 64 and Oswald Dome Road. Proceed west on U. S. 64.

44.6 **STOP 2.** Carbonate in Walden Creek Group-Sandsuck Formation.

R. D. Hatcher, Jr., J. O. Costello, and T. W. Broadhead

Generally subhorizontal, but locally chevron-folded, laminated, medium to dark gray, fine-grained limestone is exposed in road cuts along the north side of U. S. Highway 64 about 800 m (2500 ft) east of Prince Branch (Parksville, Tenn. 7.5 minute quadrangle). Sutton (1971) mapped the geology in the vicinity of this locality. The carbonate is locally sandy and are texturally and compositionally gradational, without evidence of chaotic deposition, into the overlaying shale. Uniformity of dip between the carbonate and overlying rocks, and uninterrupted bedding strongly argues against interpreting this and other large tabular carbonate bodies in the Wilhite Formation (Walden Creek Group) as olistoliths. Smaller chaotic block-in-matrix zones up to two meters thick clearly do exist elsewhere in the Wilhite Formation near the Little Tennessee River.

A limestone thin section from this locality cut perpendicular to bedding reveals the rock is composed mostly of microcrystalline calcite, but contains carbonate allochems and subrounded to rounded detrital quartz sand (Fig. 2a). These quartz grains are internally slightly strained (undulatory extinction indicating poorly developed subgrains), but have undergone no recrystallization. Some weak recrystallization of calcite is evident in pressure shadows next to quartz grains. The matrix (>80 percent of the rock) consists of recrystallized calcite (probably diagenetically neomorphosed micrite) that contains no obvious tectonic fabric. Allochems, including ooids, peloids, coated grains, grapestone aggregates, and rare small fossil-like fragments are clearly preserved without any distortion by penetrative deformation, except for slight suturing by pressure solution at grain boundaries. Insoluble residues from pressure solution are probably composed of iron oxide and clay, the latter is not apparent elsewhere in the thin section.

In thin section, the Parksville Reservoir carbonate exhibits a pervasive and generally uniformly fine neomorphic microspar texture. The dominant relict features are superficial ooid coatings on quartz grains, well-developed ooids with thick cortices surrounding unidentifiable nuclei (possibly neomorphosed micritic pelloids?), and grapestone aggregates of ooids (Fig. 2a). There are at least two grains that possess distinctive shapes and much finer neomorphic textures and possibly are akeletal allochems (Fig. 2b).

Allochems in this rock (Fig. 2a) clearly indicate formation in a shallow, agitated, carbonate-saturated environment into which relatively little terrigenous clastic sediment (represented chiefly by fine to medium quartz sand) was introduced. These conditions promoted the precipitation of ooid coatings on some quartz grains, but also on carbonate allochems. Unfortunately, diagenetic recrystallization has obliterated the original structures of these carbonate nuclei, rendering them unidentifiable. Individual ooids also coalesced and were, in turn, coated to produce small grapestone aggregates. Overall, as Keller (1980) concluded, carbonate sediment found in rocks of the Walden Creek Group overwhelmingly indicates formation of carbonate allochems and mud in shallow marine settings. Subsequently, grains and clasts were transported downslope into deeper environments by gravity flow and were intermixed with pelagic carbonate mud.

Hanselman and others (1974) described the carbonate rocks near the Little Tennessee River along U. S. 129 to the north. These rocks have been mapped by Neuman and Nelson (1965) and Hanselman and others

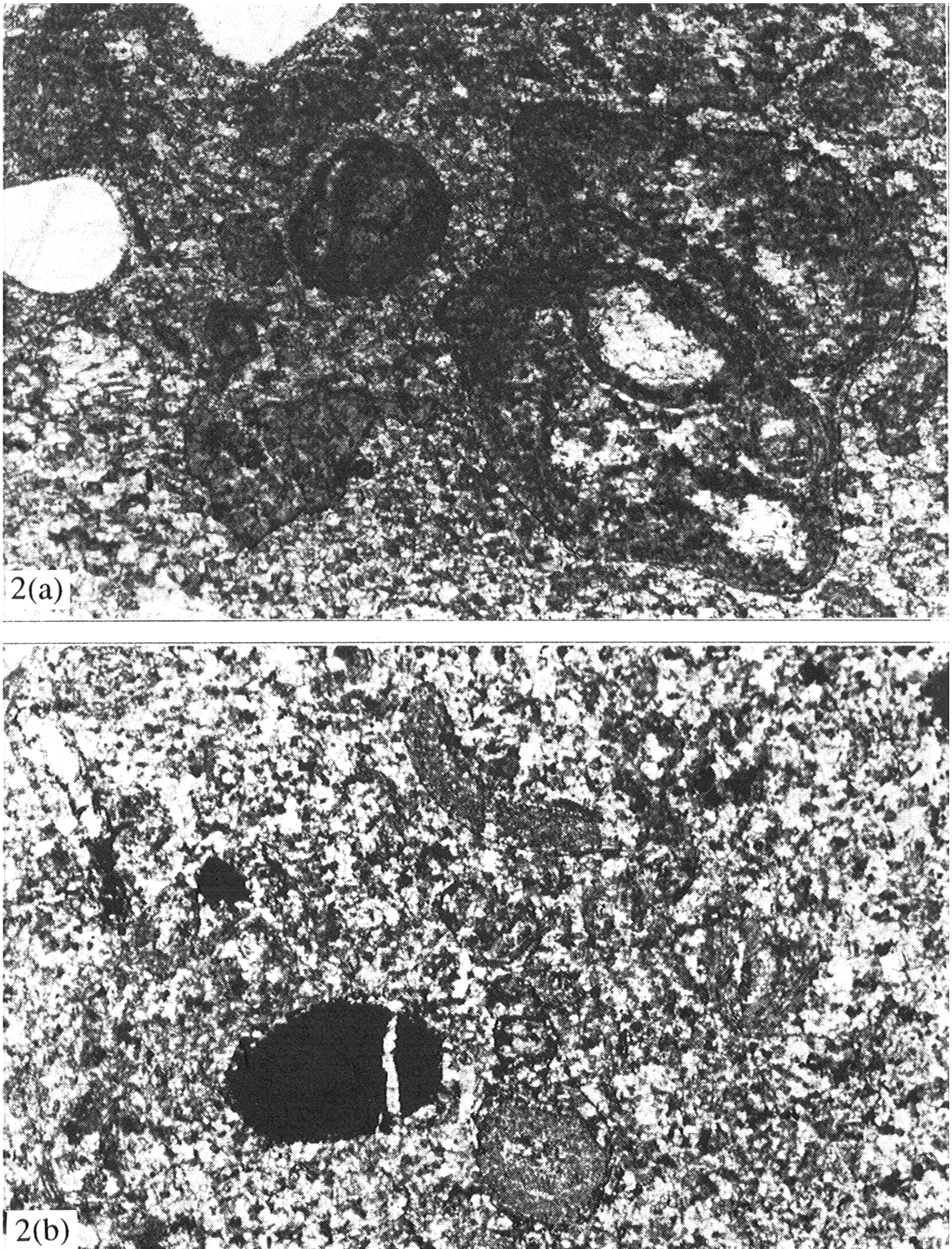


Figure 2. Thin section of Sandsuck Formation carbonate at Parksville Reservoir. Width of field is 7 mm. (a) Plane-light view of ooid (center), grapestone aggregate of superficial ooids (left), and monocrystalline quartz grains with superficial ooid coatings. Matrix is microcrystalline calcite, which probably represents nemorphosed lime mud. (b) Cross-polarized light view of possible fossil fragments (center above and below) and superficially coated quartz grain (right). These "fossils" are distinguished by overall shape and by an internal fabric that is finer than that of the surrounding microcrystalline calcite.

(1974) as Wilhite Formation carbonates, but have similar textures and compositions to those exposed at this stop. Contrary to the later interpretations of Keller (1980) and Unrug and Unrug (1990) of rocks to the northeast, Hanselman and others (1974) interpreted the Wilhite carbonates an *in situ* accumulations of sediment in subtidal to supratidal environments. Keller (1980) proposed a depositional and tectonic history for the Late Proterozoic rocks of the Tennessee Blue Ridge, and discussed several occurrences of carbonate rocks in the Walden Creek Group. All of these represent at least some degree of down-slope transport of carbonate sediment and clasts from inferred shallow marine bank or shelf environments. Keller (1980) inferred all carbonates within the Walden Creek to have been deposited as particles generally of cobble or smaller size, and suggested no evidence of downslope movement of massive carbonate blocks (e.g., "olistoliths" of Unrug and Unrug, 1990)

Petrographically, Keller (1980) characterized carbonate clasts as recrystallized to blocky calcite (including neomorphism of micrite to microspar). Nonetheless, he was able to recognize relict sedimentary structures (e.g., lamination) and discrete allochems (e.g., ooids, grapestone aggregates). His modal characterization of detrital quartzose calcarenites of the Wilhite Formation (Keller, 1980; 158) resembles the carbonate seen in the overlying Sandsuck at this stop. Particularly characteristic of this vicarious lithotype is the presence of ooids, grapestone aggregates, plagioclase, and muscovite; modal quartz in the Wilhite ranges from 5 to 75 percent, whereas quartz is present only in smaller amounts in the Sandsuck carbonate at this locality.

Sutton (1971) reported that the Sandsuck Formation in the Parksville quadrangle consists of laminated siltstone that grades upward into silty shale interbedded with feldspathic sandstone and conglomerate, and local black, quartzose limestone. He described the carbonate rocks at this stop, and nearby, as part of a lens-shaped body that passes along strike into black, sandy shale. Sutton's (1971) thin section description of a sample from this body indicates that the rock is dominated by twinned, cloudy calcite with accessory quartz, plagioclase, pyrite, and ragged (likely detrital) muscovite. Hurst and Schlee (1962) also reported the limestone contains silty layers of fine-grained subangular quartz and other clay-size minerals.

Sandsuck Formation rocks underlie the Chilhowee Group that holds up Chilhowee, Bean, Starr, and several smaller mountains in southeastern Tennessee (Hardeman, 1966). These northeast-trending mountains roughly delineate the along-strike extent of the frontal Blue Ridge allochthonous open syncline that preserves the Chilhowee Group flanked by Sandsuck Formation throughout Polk and Monroe Counties, Tennessee. West of this stop, a small, internally faulted horse of Chilhowee Group quartzite and shale (Hatcher and others, 1978) abuts the Chilhowee-Bean-Starr Mountains allochthon along the Great Smoky fault. Hanging-wall stratigraphy and physiographic position allow correlation of the slice and the allochthon with the Chilhowee Mountain block along the Great Smoky fault in Blount and Sevier Counties, Tennessee, to the north. The allochthon is bounded to the east and west by gently to moderately dipping thrust faults. The east flank of the allochthon, the Chilhowee, Bean, and Starr Mountain blocks, are cut off by the Sylco Creek-Miller Cove fault system. Following the mapping of Hayes (1895), Rackley (1951), Phillips (1952), Rodgers (1953), and Sutton (1971) no faults have been recognized to interrupt the internal Sandsuck-through-Chilhowee stratigraphy of this allochthon.

We therefore conclude that the stratigraphic sequence at this locality is uninterrupted either by olistostromal processes during deposition or later tectonic activity, and that these carbonate rocks belong to the Upper Proterozoic-Lower Cambrian succession in this area.

46.2 Ocoee No. 1 Dam. Rocks along the north side of U. S. 64 lie in an internally faulted slice of Hessee Sandstone, Murray Shale and Sandsuck Formation above the Great Smoky fault. Stop 3 on the 1978 SE GSA trip.

46.5 Intersection of U. S. 64 and Tennessee Highway 314. TURN RIGHT. Proceed north along Tennessee 314. Along this stretch of highway the skyline visible to the east is dominated by Bean Mountain. This plateau-like mountain is capped by resistant Chilhowee Group sandstone preserved in the core of an allochthonous, open syncline that extends northward along the Blue Ridge front to a point southwest of Tellico Plains. The Hiwassee River breaches this structure near its midpoint and separates Bean Mountain from Starr Mountain (reportedly named after family of the famous outlaw Belle Starr) north of the river.

51.5 Benton, Tennessee city limit. Benton is the site of Fort Marr a stockade built during the "Trail of Tears". This is the only remaining structure of the period, and its is the oldest blockhouse in the United States.

52.6 Intersection of Tennessee 314 and U. S. Highway 411. TURN RIGHT. Proceed north along U. S. 411.

56.3 Lillard Branch.

58.7 Intersection of U. S. 411 and Tennessee Highway 30.

Continue northbound along U. S. 411/Tenn. 30.

59.3 Hiwassee River.

60.7 Wetmore Community.

61.3 Polk County-McMinn County boundary.

61.6 Culpepper Branch.

62.6 Conasauga Creek.

63.8 Cane Creek.

64.8 Etowah city limit.

66.0 Intersection of U. S. 411 and Tennessee Highway 310. Continue northbound along U. S. 411.

65.7 Intersection of U. S. 411 and Tennessee Highway 30. Continue northbound along U. S. 411.

69.7 Knobs to east are upheld by Middle Ordovician Bays Formation preserved within an open syncline.

71.6 Englewood city limit.

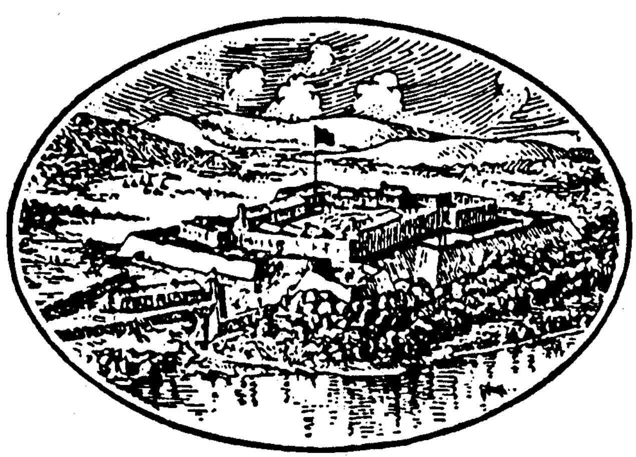
76.3 McMinn-Monroe County boundary.

80.6 Madisonville city limit.

81.7 Intersection of U. S. 411 and Tennessee Highway 68. Continue northbound along U. S. 411.

89.4 Vonore city limit. Intersection of U. S. 411 and Tennessee Highway 72. Continue northbound along U. S. 411.

91.9 Intersection of U. S. 411 and Tennessee Highway 360. TURN RIGHT. Proceed eastbound along Tennessee Highway 360 and continue southeast towards Fort Loudoun State Historic Area and Sequ9oyah Museum. As we cross regional strike, we will gradually work our way up-section through the poorly exposed Upper Cambrian and Lower Ordovician Knox Group and the succeeding Middle Ordovician rocks of the Tellico-Serview belt.



Historical sketch of Fort Loudoun. From Historic Fort Loudoun – The Fort Loudoun Association.

92.5 Cross the Tellico River valley, now inundated to form Tellico Lake.

92.8 Access road to Fort Loudoun State Historic Area. Fort Loudoun was built by the British during the winter of 1756-57 to inhibit French infiltration from the western interior of the continent. By 1760, Cherokee sympathies lay with the French and during the spring and summer the Cherokees besieged the fort which ultimately was surrendered in August. Following the evacuation of the garrison the British tried returning to South Carolina, however, a Cherokee war party attacked the garrison's camp, killing all most of the officers and many soldiers. The survivors were taken as slaves, eventually the were ransomed by South Carolina and Virginia.

The fort is being replicated on the original site just beyond the visitor center.

The trip's lunch stop is at the picnic area and visitor center located at the end of the one-mile-long access road. After lunch, return to Tennessee 360 and continue driving southeast on Tennessee 360.

93.2 Entrance to Sequoyah Birthplace Museum. The famous Cherokee, Sequoyah (ca. 1776-1843), through an early hunting accident, became crippled and thereafter engaged mostly in sedentary occupations, especially silversmithing. He himself could not speak, write, or read English, but he was fascinated with the white man's technique of "talking on paper". After many years of virtually single-handed effort, he devised a writing system for the Cherokee language. Sequoyah's syllabary, introduced in 1821, featured a separate letter-like character for each component syllable of the language. He was able to reduce the syllabary -–loosely speaking, the Cherokee alphabet – to 85 characters. Thus, at one stroke, anyone who spoke Cherokee, after simply learning to recognize the sight and sound of the 85 characters was immediately literate! Usually in only a few weeks Cherokee-speaking individuals could completely master the art of reading and writing. It has been remarked that through the invention of an illiterate, thousands of Cherokees became proficient readers, without one school being established or one teacher hired.

93.5 Approximate location (underwater) of the unconformity between the Knox Group to the northwest and the overlying Middle Ordovician succession to the southeast.

98.8 Prominent outcrop near the base of the Middle Ordovician Bays Formation, dominantly a very distinctive red to maroon mudstone. The unit is commonly slightly calcareous. At many exposures the Bays exhibits steeply dipping cleavage. This is evidently a solution cleavage and where megascopic folds and cleavage are present in the same outcrop, the cleavage is approximately axial planar. Thus, the solution cleavage is interpreted to be the same age as the folds that are undoubtedly Alleghanian structures. At this outcrop, bedding dips about 20' southeast and the cleavage, best developed in the massive, fine-grained beds, dips very steeply southeast.

99.1 Junction of Tennessee 360, which goes across the embayment, and the poorly marked road to the Citico Creek area. The field trip route goes straight ahead on the Citico Road **(DO NOT MAKE THE TURN ACROSS THE EMBAYMENT)**.

100.0 To the left are partially vegetated, dip-slope exposures of the Chattanooga Shale. In this region, the uppermost Devonian to Lower Mississippian Chattanooga unconformably overlies the Bays Formation. The unconformity, which is locally covered, was crossed a few hundred feet ago. The Mississippian Grainger Formation, dominantly a silty shale to silty sandstone sequence in this region, underlies the steep ridge to our right immediately across the valley.

101.6 Little Toqua Church is just ahead to the left; roadside exposures beneath the church are siltstone of the Grainger Formation. The trace of the Great Smoky fault is approximately 1,000 feet southeast on the west-facing slope of the ridge to our right. The fault trends northeast-southwest, virtually underneath the high-tension power lines in this area.

The fault contact is exposed in a small abandoned, heavily overgrown quarry, 0.25 miles along the secondary road to the southeast. To reach the quarry, turn right off the Citico Road, travel 50 feet, and turn left onto the secondary road. Continue 0.5 miles to the quarry located to the left (northeast) of the road. Clastic rocks of the Uppermost Proterozoic Sandsuck Formation overlie a thin slice of the Cambro-Ordovician Knox Group. Limestone of the Knox – the stone sought for in the quarrying operation – in turn overlies the Mississippian Grainger. The Jonesboro slice at the quarry is only a few hundred feet thick. The relations here, Proterozoic rocks structurally overlying a Paleozoic sequence that extends well into the Mississippian, is clear evidence that the Great Smoky fault is a late Paleozoic, or Alleghanian structure.

104.1 Junction with road to Chota-Tanasi Memorials at Tellico Lake. Continue straight ahead on the Citico Road.

104.4 **STOP 3.** Bays Formation with thick K-bentonite, Chattanooga Shale, and Grainger Formation.

Leonard S. Wiener

Park on wide gravel shoulder opposite road cut. This convenient roadside exposure is sometimes referred to as the Bacon Bend section named for a nearby prominent entrenched meander of the Little Tennessee River. The exposure reveals gently dipping beds o the Middle Ordovician Bays Formation, the disconformably overlying Mississippian-Devonian Chattanooga Shale, and succeeding beds of the Early Mississippian Grainger Formation including representatives of the Maury Formation. Minor thrust faulting has caused slight disruption of part of the sequence. Each of the stratigraphic units, as well as the structural features, is worth extended discussion of its own; however, of special interest for this year's Carolina Geological Society field meeting is the sub-Chattanooga disconformity and the detrital mineral suite of the siliceous Grainger Formation. These two aspects pertain directly to recent proposals suggesting that there were extensive depositional basins of Silurian or younger age in the Blue Ridge (Unrug and Unrug, 1990; Tull and Groszos, 1990).

As now exposed, a meter or so of typical Bays Formation is present at the west end of the road cut. These rocks are massive, grayish red (10 R 4/2), mudstone to slightly silty mudstone. Succeeding the redbeds is 4.5 to 5 meters of structureless, pale greenish yellow (10 Y 8/2) K-bentonite. At and near the base of the bentonite is rusty weathering, grayish yellow green (5 GY 7/2) chert. The chert typically is highly fractured and breaks into small, sharp-edged blocks, plates or chips. Much of the chert contains abundant ostracod fossils. Many of the fossils are a millimeter or so across, but some specimens are as much as 5 millimeters in maximum dimension. This bentonite layer is one of several in Southern Appalachian Middle Ordovician strata and likely correlates with the T-3 or T-4 bentonite found in central Tennessee. The usefulness of these bentonites for time-scale purposes is well known and radiometry on samples of zircon crystals from this outcrop and other probable correlative beds in central Tennessee and Alabama have provided an important tie point in the geologic time scale (Adams and others, 1960). Recalculation of the original data using currently accepted decay constants yields an age of approximately 457 Ma. The chert accumulation near the base of the bentonite likely resulted from precipitation of silica leached from higher in the bentonite bed. Rodgers (1953) reports only 3 to 5 centimeters of chert and 1.5 meters of bentonite; Glover (1959) also indicates a thin layer of chert followed by 1.2 meters of bentonite. Measurements made in 1991 in preparation for our field trip disclose as much as 30 or 40 centimeters of chert and 4.5 to 5 meters of bentonite. Very likely additional excavation of the embankment between the 1950's and 1991 for roadway improvements exposed a laterally equivalent, different section through the bentonite layer, thereby explaining discrepancies in measurements.

Disconformably overlying the Middle Ordovician Bays bentonite along a very distinct, sharp contact is the Mississippian-Devonian Chattanooga Shale. The Chattanooga is composed of fissile, dark-gray (N3) to medium dark-gray (N 4) shale. Upon weathering, the color lightens in value to light gray (N 7). The Chattanooga Shale measures 3.7 meters thick at this exposure; the same as the value previously determined by Glover (1959). The black shale at this locality is correlated to the Gassaway Member, the uppermost unit of the Chattanooga (Glover, 1959(. Shaly laminations of the basal 20 to 30 centimeters are crumpled and distorted, suggestive of northwest-directed bedding plane slip.

Immediately overlying the Chattanooga Shale is grayish yellow green (5 GY 7/2) to pale greenish yellow (10 Y 8/2) silty claystone. Glover (1959) assigns the silty claystone and an overlying black shale unit to the Maury Formation, 2.4 meters thick. However, as exposed in 1991, the thickness of the silty claystone ranges down to zero because of minor faulting that cuts across bedding at a low angle. The basal 15-centimeters of the unit contain abundant matrix-supported, sand-size, brownish black (5 YR 2/1) to brownish gray (5 YR 4/1) rounded grains of phosphate. Fossils are present immediately over the sandy interval. G. A. Cooper (cited in Glover, 1959) identified brachiopods, a snail, and a trilobite and concluded that the collection is of Early Mississippian age. As previously mentioned, the present exposure reveals a minor thrust fault which cuts across the silty claystone unit. This fault places a wedge of Chattanooga Shale over the silty claystone, thereby disrupting the original sequence. If the fault wedge of Chattanooga Shale is ignored, the lithologic unit stratigraphically succeeding the silty claystone is black, fissile shale. W. H. Hass (cited in Glover, 1959) identified conodonts collected from the base of the black shale as Kinderhookian or Early Mississippian in age.

The succeeding stratigraphic sequence is less well exposed but can be worked out by examining scattered outcrops along the valley walls to the north. The black shale at the top of Glover's Maury equivalent is overlain by the Grainger Formation. The Grainger's basal unit is yellowish gray (5 Y 7/2) to medium light gray (N 6), shaly to thinly layered siltstone. In this region most of the Grainger, well exposed at the road cut immediately east, is rusty weathering, thick-to medium-bedded silty sandstone. In the context of this year's Carolina Society field meeting, the Grainger Formation's detrital heavy mineral suite is noteworthy: the suite, in this area and elsewhere, includes garnet, staurolite, kyanite, and sillimanite (Wiener, 1979). About 275 meters of strata are present between the base of the Grainger and its faulted top (Biery, 1968).

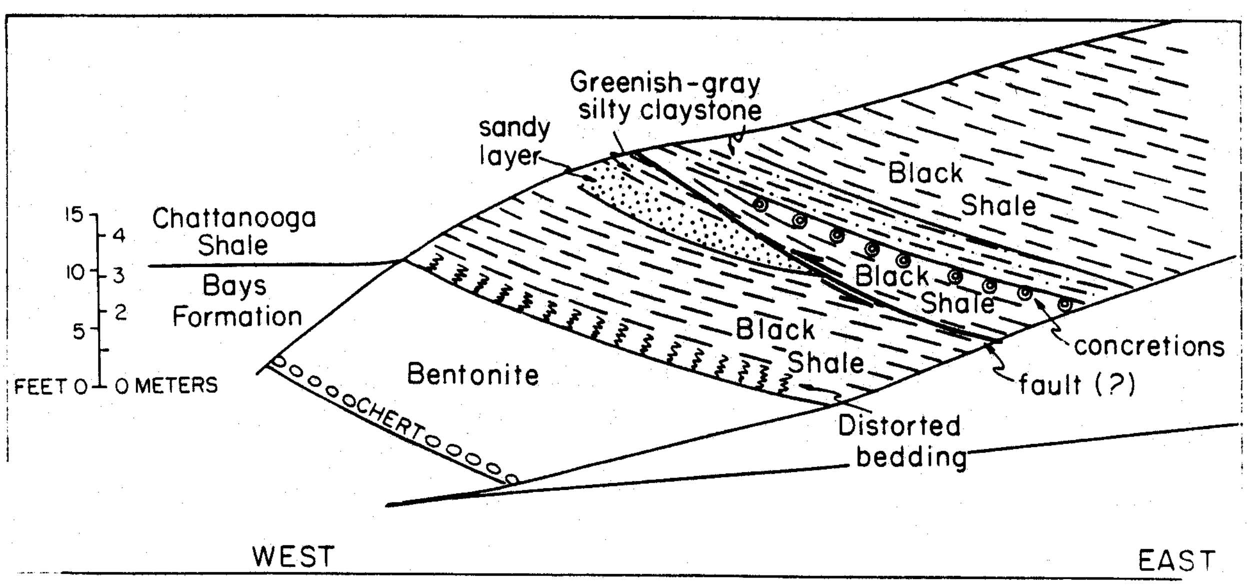


Figure 3. Field sketch of exposure at Stop 3, the Bacon Bend Section. Late Devonian Chattanooga Shale overlies Middle Ordovician Bays Formation. Vonore 7.5 minute quadrangle, Tennessee State Coordinate: 423,550 N: 2,556,500 E.

Discussion

The time span represented by the sub-Chattanooga disconformity – about 95 million years, or 30 percent of the Paleozoic era – includes part of Middle Ordovician time, Late Ordovician, the entire Silurian era, and most of Devonian time. It has long been known that this disconformity marks a major, non-depositional and erosional episode in Appalachian history. In the Blue Ridge too, uplift and erosion were certainly taking place during at least some of this time. The presence of high-grade metamorphic minerals in the Grainger Formation's detrital suite requires that a metamorphic source area – the Blue Ridge terrane – had to be exposed and undergoing subaerial erosion. To have metamorphic rocks containing high grade minerals brought to the earth's surface requires uplift and erosion of many kilometers of cover rocks. We can thus reason that the Blue Ridge was an emerging, metamorphosed hinterland, and that uplift must have begun well prior to Early Mississippian. The region-wide sub-Chattanooga unconformity represents milder consanguineous uplift and erosive beveling of the unmetamorphosed foreland.

Unrug and Unrug (1990) and Tull and Groszos (1990) hypothesize that the Walden Creek Group, several thousand feet thick and known regionally from Georgia, North Carolina, and Tennessee, is a marine deposit of Silurian or younger Paleozoic age. However, the very extensive sub-Chattanooga unconformity shows that uplift and erosion occurred in the Valley and Ridge between Middle Ordovician and Early Mississippian time, and the detrital heavy mineral suite of the Grainger Formation indicates even more severe, region-wide uplift with very deep, protracted erosion in the Blue Ridge during much, if not all of the Paleozoic time interval. Thus, the deductions and incontrovertible facts illustrated by observations at this outcrop apparently contradict the Unrug and Unrug (1990) and Tull and Groszos (1990) hypotheses.

To resume trip, turn around (a convenient place for large vehicles to turn if at the top of the hill 0.3 miles ahead) and retrace route on the Citico Road.

109.5 Junction Citico Road and Tennessee 360. Continue straight ahead on Tennessee 360 North.

116.8 Junction Tennessee 360 and U. S. 411. Turn right onto U. S. 411 northbound.

118.2 Bridge over Tellico Lake, the impounded Little Tennessee River.

119.4 Junction U. S. 411 and Tennessee 72. Turn right onto Tennessee 72 eastbound.

128.5 Junction Tennessee 72 and U. S. 129. Turn right onto U. S. 129 southbound toward Fontana. Distinctive, red-colored Bays Formation exhibiting solution cleavage is exposed at road junction.

130.0 Road makes a sharp left curve around prominent outcrop of cleaved Bays Formation. Tellico Lake (Little Tennessee River embayment) is now in sight again. Several important contacts will be crossed in the next 1.5 miles as the route continues eastward across regional strike; unfortunately, none of them are exposed along the road.

130.1 Cross Guess Creek fault.

130.2 Cross into thin slice of Jonesboro Limestone and then cross the Great Smoky fault with the Sandsuck Formation in its hanging wall. The route is now curving around the southwest end of Chilhowee Mountain. A few miles north, along strike, fossils of Early Cambrian age have been collected from the Murray Shale, a unit high in the Chilhowee Group.

131.4 Cross contact between the Sandsuck and the Cochran Conglomerate of the Chilhowee Group. This stratigraphic contact is generally taken as the Proterozoic-Cambrian boundary.

131.9 Old Tallassee store to left. A minor fault on the southeast flank of Chilhowee Mountain crosses the road in this covered area. Neuman and Nelson (1965) show this fault as simply bringing up a fault slice of the lowest Chilhowee unit, the Cochran Conglomerate. Wiener (unpublished mapping) considers the fault block to bring up an overturned sequence with the Cochran to the west, succeeded by the Sandsuck Formation to the east. The Sandsuck, according to this interpretation, continues eastward another 1.6 miles and includes siltstone to coarse, polymictic conglomerate as exposed at Chilhowee Dam, as well as minor beds of limestone.

132.8 Cross contact between the sequence dominated by coarse clastic rocks, such as seen at Chilhowee Dam, and a broad belt dominated by medium-to fine-grained metasiltstone and slate. At places, these fine-grained layers are slightly calcareous. A very minor component are scattered layers of medium-to dark-gray, white-veined limestone; a few rare conglomerate and sandy beds are also present.

This contact marks the boundary between unmetamorphosed rocks to the west, and recrystallized strata to the east. Earlier in the day, we passed this same boundary near the west end of Ocoee Gorge. In the Great Smoky Mountains National Park area the boundary is mapped as the Miller Cove fault.

132.0 **STOP 4.** Coarse clastic rocks of the Walden Creek

Group at Chilhowee Dam.

Raphael Unrug and Steven Palmes

Outcrops adjacent to the Chilhowee Dam expose channelized conglomerates and sandstones of the Wilhite Formation. The outcrops are on the north side of the road, beginning approximately 100 meters west of the dam, and continuing east for a total of about 300 meters. Ample parking is available on the south side of the road west of Chilhowee Dam.

The objective of this stop is to illustrate sedimentological relationships between channelized sandstones, conglomerates and debris-flow breccia beds within the Wilhite Formation, Walden Creek Group. In addition, the presence of carbonate clasts within polymictic conglomerates has important implications for developing age relationships and a model for the siliciclastic basin of the Walden Creek Group and the pre-Walden Creek carbonate basin (see Unrug and others, this guidebook, for discussion).

This outcrop contains abundant channelized deposits of polymict conglomerates, interbedded with debris-flow breccias and sandstone units (Figure 5, Unrug and others, this guidebook). The conglomerates contain predominantly quartz pebbles, with lesser amounts of carbonate clasts, eroded carbonate breccia clasts, and armored mud balls, particularly in the western portion of the outcrop. Metazoan fragments have been found within carbonate clasts present in these polymict conglomerates (see Unrug and others, this guidebook for description). Armored mud balls are lined with 4 – 8 cm quartz pebbles, while individual mud balls are set in 1 – 2 cm quartz pebbles. Conglomerate beds are graded in many cases, and may be up to several meters thick. Debris-flow breccia beds (up to 2 meters thick), consisting of quartz pebbles and shale clasts in a matrix of quartz sand are interbedded with and truncated by the conglomerates. In some cases these debris-flow breccia beds, occur as lenses and are cut through by channelized deposits of quartz pebble conglomerates. Channelized quartz sandstones have also been truncated by these debris-flow breccias. These sandstones are coarse-to fine-grained and consist of immature siliciclastic sediments. In the eastern portion of this outcrop, quartz sandstones and quartz pebble conglomerates commonly show well-developed and repetitive graded bedding.

The multiple truncations of different lithologies indicate an environment characterized by intense submarine erosion. The strata exposed in the road cut are interpreted as deposits within a fan delta.

13.4 **STOP 5.** Carbonate Breccia

Raphael Unrug and Steven Palmes

Park in “Lake Access Area, courtesy ofTapoco, Inc.,” parking area on right side of U. S. route 129. Section of outcrop begins approximately 50 meters west of driveway on right side of U. S. Route 129 approximately 250 meters west of the parking area.

The outcrop, exposed as a dip slope, contains a thick unit of carbonate breccia enclosed in a sequence of interbedded carbonates and shales that grades upsection into sandstone.

The objective of this stop is to show the sedimentological relationship between the carbonate breccia, the interbedded limestones and calcareous shales, and the overlying siliciclastic sediments. These relationships also play an important role in developing a basin model for the Walden Creek Group. Microfossils determining the age of the Walden Creek Group have been obtained at this outcrop.

The outcrop consists of an overturned sequence of interbedded carbonates and siliciclastic sediments, with a thick debris-flow breccia bed near the base of the measured interval (Figure 4, Unrug and others, this guidebook). Here, overturning has been determined by graded beds in the upper part of this section. These graded beds are typically calcarenites, 3 —10 cm thick, alternating with siltstones and shales. The calcarenite beds, consisting of small ooids, coated grains and microfossils set in sparry calcite cement, have been interpreted as deposits of turbidity currents. They form an integral part of the Walden Creek Group sequence and date directly the deposition of the Walden Creek Group. For a detailed description of Late Devonian (Famennian) to Early Mississippian microfossils present in the calcarenites, see Unrug and others, this guidebook. Above the calcarenite beds are shales, siltstone and graded sandstone beds 10 – 20 cm thick, representing deposition in a deep marine basin.

The breccia bed is attributed to debris flow and consists of angular carbonate clasts, 2 – 20 cm long. The breccia represents several different lithologies that are supported in a matrix of calcareous mud and quartz sand. Other clasts present in this debris-flow are shales, up to 80 cm across. This debris-flow breccia forms a planar bed 3.5 meters thick of considerable lateral extent. The breccia bed is interpreted as a debris-flow that carried carbonate clasts of shallow water origin into a deep-water basin in which predominantly siliciclastic sediments accumulated. Some of the limestone clasts in the breccia bed contain calcareous foraminifers indicating Devonian (Late Givetian to Frasnian) age. These clasts are older than the time of deposition of the breccia bed.

135.7 Junction with southeast end of the Foothills Parkway. Continue driving east on U. S. 129.

SUPPLEMENTAL TRIP (S2)

Raphael Unrug and Steven Palmes

0.0 Junction of U. S. Route 129 with Foothills Parkway. Turn left on Foothills Parkway to Supplemental Stop 2. (Optional). You are entering National Park jurisdiction, NO SAMPLE COLLECTING.

0.8 Exit bus adjacent to carbonate exposure on east side of Foothills Parkway. Busses continue on Foothills Parkway to Scenic Overlook and park here.

Excellent outcrops of carbonate olistoliths are exposed in roadcuts along the Foothills Parkway 0.8 miles north of the intersection with U. S. Route 129 (7.5 minute Tallassee quadrangle, UTM coordinates 7151E 394082N), overlook along the Foothills Parkway, 2.7 miles north of the intersection with U. S. Road 129. However, the buses leave passengers at the outcrops and return later for reboarding.

The purpose of this stop is to illustrate the occurrences of carbonate olistoliths within the Wilhite Formation. These olistoliths also play a significant role in the development of a basin model for the carbonate and siliciclastic basins of the Walden Creek Group.

Detailed geologic mapping (1:10,000 scale) of the southwest area of the Foothills Parkway (Fig. 2), Unrug and others, this guidebook) reveals the presence of blocks of carbonate, or carbonate and shale lithologies, sitting in siliciclastic sediments of the Wilhite Formation. These large blocks, some 6.75 x 10^6 cubic meters, rest on siliciclastic float and have been interpreted to be olistoliths – large blocks of rock emplaced by gravity sliding that lie within the enclosing strata. This interpretation is also based on the discordant attitude of the carbonate shale olistoliths with the enclosing siliciclastic sediments.

The carbonates in these olistoliths occur as limestones and limestone breccias interbedded with calcareous shales and siltstones. In one olistolith along the foothills Parkway, five different units have been observed (Fig. 3, Unrug and others, this guidebook). Localized soft-sediment folds formed by incipient sliding of semi-consolidated beds within olistoliths are also present in this outcrop. Individual units within this outcrop can be separated into facies assemblage B, thin-to medium-bedded dark limestones interbedded with black shales and facies assemblage C, carbonate debris-flow breccia intercalated in the bedded limestones and shale facies of assemblage B (see Unrug and others, this guidebook, for facies model description). Thus, facies assemblage C represents debris-flow breccias formed by failure of the carbonate platform margin (see Unrug and others, this guidebook, for discussion).

The carbonate clasts in the breccia boulder contain fossil calcispheres and radiospaerid calcispheres indicating a Devonian age. The clasts in the breccia bed are older than the rocks of the olistolith, and the rocks of the olistolith are older than the siliciclastic-dominated basin of the Walden Creek Group.

0.9 Travel south on Foothills Parkway to junction with US Route 129. Turn left.

END OF SUPPLEMENTAL STOP

135.8 Road northeast goes to Abrahms Creek Ranger Station and camping area. Extensive exposures for the next 2.4 miles are almost entirely slate and metasiltstone of the Wilhite Formation of the Walden Creek Group. Pervasive slaty cleavage mostly dips gently to moderately southeast; bedding is passively deformed into innumerable, similar, passive-slip folds. Many years ago several slate prospects or quarries were developed in this belt. Reportedly, most of the slate was used locally, principally for roofing shingles.

136.4 Bridge over Abrahms Creek embayment

136.8 **STOP 6.** Recumbent folds, cleavage, and overprinted faults and other brittle structures at Chilhowee Lake.

R. D. Hatcher, Jr., and J. O. Costello

Exposed here is Wilhite Formation slate (Walden Creek Group) that has been folded, cleaved, and later overprinted by brittle structures (Fig. 4). Details of the geology of the nearby area may be found in Neuman and Nelson (1965), because the highway is located immediately outside the southwestern boundary of the Great Smoky Mountains National Park. The early folds are flexural-flow modified buckle folds with a strong axial planar slaty cleavage. A limestone layer in the sequence pinches in the cut by primary sedimentary thinning and has been thickened tectonically in the hinge of the fold during folding and cleavage formation. Some pressure solution is evident in the limestone layer, but the cleavage in the slate formed by recrystallization and growth of layer silicates parallel to the XY plane of the strain ellipsoid.

Brown (1971) studied several of the folds in the Wilhite Formation along U. S. Highway 129 next to Chil-

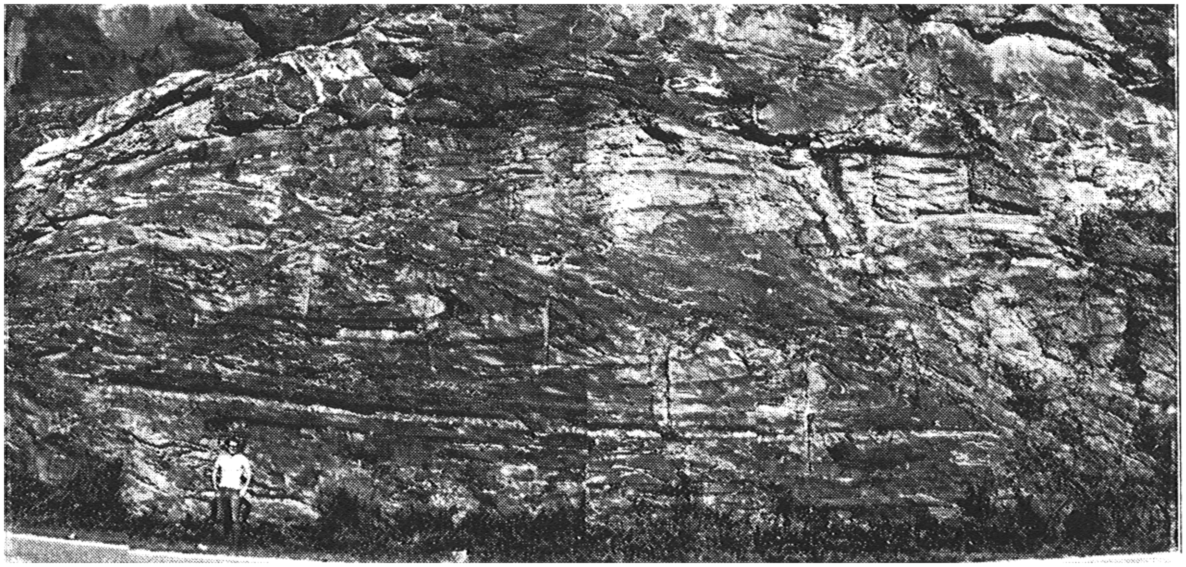


Figure 4. Folded and faulted Wilhite Formation (Walden Creek Group) slate and carbonate exposed on U. S. Highway 129 alongside Chilhowee Lake, southeastern Tennessee. Note the strong axial planar cleavage, fracture sets in the carbonate, and faults that envelop the fold. Also note that the carbonate layer is tabular and it terminates to the right side of the photograph.

howee Lake and concluded that fold geometry ranges from Ramsay's class 1C to 3 and that there may be as much as 30 percent flattening of folds perpendicular to axial surfaces. He interpreted the folding process as having taken pace by a combination of granular flow, recrystallization, and fracturing.

Several white calcite-healed extension fractures cut the limestone and probably record the folding history of this structured. One set is fanned by the fold, while others cut obliquely through the layer. Later extensional and contractional brittle faults envelop the fold and appear in an intersecting and anastomosing pattern throughout the cut. Sense of motion of these faults ranges from thrust to normal.

An important thing to note here is the tabular nature of the carbonate layer, and that it pinches in this exposure. It is unlikely that termination of the layer occurred because of tectonic extension, or that the carbonate is an olistolith (even a deformed one). Brown (1971) noted some boundinage of limestone layers in exposures of the Wilhite in this area.

ADDITION DESCRIPTION OF STOP 6.

Graded carbonate conglomerate.

Raphael Unrug and Steven Palmes

Along U. S. Route 128, 1.1 miles east of the intersection with the Foothills Parkway, is an outcrop exposing a graded carbonate conglomerate bed interbedded with shales and slates of the Wilhite Formation. This outcrop exposes an individual carbonate bed, 20 – 40 cm thick, at a height of about 2 meters above the road. This bed has been folded into a recumbent fold, with spectacular calcite filled axial plane cleavage.

The significance of this outcrop is to show the occurrence of discreet limestone beds in the Wilhite Formation that lie in conformable sedimentary contact with siliciclastic sediments.

This limestone bed has a sharp basal contact with the underlying laminated siltstone. The bottom of this limestone bed consists of pebbles, 0.5 – 4.0 cm long, that can be interpreted either as tabular clasts of detrital limestone or as pebbles flattened by tectonic processes. The axial ration of visible pebbles is 1:4. The lowermost 15 cm of this limestone bed, some 40 cm total thickness, is graded. The upper portion of this sequence consists of an upper- and lower- horizontally laminated sequence, separated by a cross laminated layer. Overlying the limestone bed are siliciclastic shales/slates. The nature of the carbonate material has been obscured by recrystallization. This bed is interpreted to be a turbidity current deposit.

RETURN ROUTE: CHILHOWEE LAKE, TENNESSEE TO MURPHY, NORTH CAROLINA, VIA U. S. 129

(Leonard S. Wiener and Carl E. Merschat)

138.2 Eastern limit of the slate and metasiltstone dominated section of the Wilhite Formation. A limestone unit, approximately 15 feet thick, crops out alongside U. S. 129 and extends northward, along strike on the west side of the small, unnamed valley at this locale. Succeeding exposures along the highway are dominated by sandstone and some conglomerate with interlayered slate sequences and very minor limestone. These units continue southwestward across Chilhowee Lake where Wiener (unpublished mapping) correlates them with the Shields Formation of the Walden Creek Group.

13.8 U. S. 129 crosses the bridge over Tabcat Creek embayment and continues southeastward leaving Chilhowee Lake.

139.9 Junction with road to Calderwood. The Great Smoky fault reaches the surface and is breached in this area thereby producing a window exposing the Jonesboro Limestone of the Knox Group. This window, called the Calderwood window, is similar to the more popular Cades Cove window, a dozen miles upstrike in the National Park. The Calderwood window has the shape of an irregular ellipse, approximately one-half mile wide and about a mile in length. The most accessible exposure of the contact between the Jonesboro within the window and the overlying Walden Creek Group rocks is 300 feet to the east of this intersection. (See description at mile 140.0).

SUPPLEMENTAL TRIP (S3) TO CALDERWOOD

0.0 Turn west (to right) onto road to Calderwood and immediately cross the covered Great Smoky fault. For the next half mile, limestone with minor dolomite of the Lower Ordovician Jonesboro Limestone crops out. Dip of bedding ranges from horizontal to vertical; but some of this variation may be attributable to large-scale slumping and rotation of limestone blocks into the area's many solution cavities.

0.5 Cross the locally covered Great Smoky fault and pass into the fault's upper plate. Most of the succeeding exposures along the road are feldspathic and pebbly sandstone of the Walden Creek Group. The authors correlate these beds with the Shields Formation (Wiener, unpublished mapping).

0.7 Junction of Calderwood Boulevard with Strawberry Drive. Turn south (left), then pass the red brick building and scattered outcrops of conglomerate and slate of the Shields.

0.85 Abundant float blocks of Walden Creek limestone are present along the road bank under the power line for approximately 200 feet.

1.0 From here southward to the powerhouse, about one-half mile away, are massive, nearly continuous exposures of coarse clastic strata. Neuman and Nelson's map (1965, plate 2) shows all these coarse strata as overlying the Rabbit Creek fault and assigns them to the Cades Formation. A slightly different interpretation offered here is that the first thousand feet of exposure are coarse clastic rocks of the Shields Formation which lie beneath the Rabbit Creek fault. The fault reaches the road at a covered area (mile 1.3), and it is only the succeeding strata to the south that are above the fault and belong to the Cades Formation.

1.3 Approximate location of Rabbit Creek fault locally covered. (This place is near the transmission tower which has one set of footings next to the road and the other footing in Chilhowee Lake).

1.45 Entrance to powerhouse. The Cades Formation here is composed mostly of medium- to coarse-grained, medium- to thick-bedded graywacke with occasional thin interbeds of dark colored slate or metasiltstone. A few graywacke layers exhibit graded bedding; scour-and-fill features are locally present. All indicate the sequence is right side up. Turn around and retrace route 0.75 miles to Calderwood Boulevard.

2.2 Junction, Strawberry Drive and Calderwood Boulevard.

2.35 Cross the Great Smoky fault, locally covered, and re-enter the window.

2.36 The Jonesboro Limestone crops out here and intermittently for the next 0.6 miles.

2.8 Gravel road to north leads to an abandoned quarry in the Jonesboro Limestone. Neuman and Nelson (1965, p. 34) report finding a small, unidentifiable species of Finkelnburgia from this locality and therefore suggest that the beds in the window belong to the lower part of the Jonesboro.

2.95 Northwesternmost exposure of the Jonesboro Limestone. The Great Smoky fault, covered in this area, crosses the road just beyond these outcrops.

3.0 Road turns sharply left onto pier. The ferry dock at the end of the pier provides access to the private Scona Lodge. Turn around and retrace route via Strawberry Drive and Calderwood Boulevard to rejoin U. S. 129. Bear right (eastward) on U. S. 129.

END OF SUPPLEMENTAL TRIP TO CALDERWOOD

140.0 Excellent exposure of the Great Smoky fault along U. S. 129, east side of the Calderwood window. At this point, slate or phyllite of the Late Proterozoic Walden Creek Group structurally overlies the Early Ordovician Jonesboro Limestone. Bedding is obscure in the slate; however, the slaty cleavage is wrinkled and folded. These small-scale weathered, structureless clay. This material may possibly represent a thin gouge zone, or may simply be residuum resulting from weathering of the limestone. The dip of the fault boundary at this exposure ranges from about 30º west to about 20º east. Some of this variation may have resulted from irregular dissolution of the underlying limestone and concomitant slumping or settling of the overlying siliceous units. Published mapping identifies the slates or phyllites here as part of the Wilhite Formation (Neuman and Nelson, 1965). However, observations in the surrounding area show that coarse clastic rocks are a major component and it may be more appropriate to correlate the sequence with the Shields. Formation.

141.1 Cross the covered Rabbit Creek fault separating Walden Creek strata to the northwest from the Cades Formation to the southeast. Locally, the Walden Creek is represented by crinkled slate to phyllite that weathers to a characteristic maroon color. Scattered small outcrops to the southeast are metagraywacke of the Cades.

141.4 Limited parking area and overlook beneath power line. To the south is a view of Calderwood Dam and lake. At full pool the lake elevation is 1,086 feet. The outcrops near the overlook are partially weathered exposures of the Cades Formation. They consist of feldspathic and pebbly metagraywacke and medium dark gray to black slate or phyllite.

142.8 Approximate location of the contact between Cades Formation (to northwest) and the Elkmont Sandstone (to southeast). This contact is mapped as a fault and, in the National Park work, is identified as the Oconaluftee fault (Neuman and Nelson, 1965). In discussing this structure Neuman and Nelson (1965, p. 63) suggest that the Oconalufte fault changes from a high-angle transcurrent, or strike-slip structure in the east, to a low-angle thrust in the southwest. They go on to remark that relations along the thrust segment of the relatively late Oconaluftee resemble those along the older, premetamorphic Greenbriar fault and tentatively conclude that the Oconaluftee in the western part of the National Park may represent a reactivation of the Greenbrier fault. Significantly, Neuman and Nelson's (1965, p. 6) sketch map shows the biotite isograd obliquely crossing this fault without offset – exactly the relation to be expected along a premetamorphic fault such as the Greenbrier.

144.0 Inferred location of the biotite isograd.

146.1 Parson Branch Road joins U. S. 129 from the east. This is a one-way road that starts in Cades Cove.

150.2 Deals Gap on the North Carolina- Tennessee State line. Elevation is about 1,950 feet. From here southeastward for the next 5.2 miles U. S. 129 crosses well-exposed Great Smoky rocks in the strike belt of the Elkmont Sandstone – Thunderhead Sandstone – Anakeesta Formation sequence defined in the National Park to the northeast. These same rocks are also in the strike belt of the Boyd Gap Formation – Buck Bald Formation – Famer Formation sequence as defined or mapped in the Ducktown region to the southwest. The route is in the lateral transition zone of these two sequences and because detailed field studies have not yet been done in this area, it is unclear how best to resolve this correlation problem.

150.9 Junction, N. C. 28 and U. S. 129. N.C. 28 leads to T. V. A.'s Fontana Dam and then follows the south side of Fontana Lake towards Bryson City, The field trip continues on U. S. 129.

151.6 View of Cheoah Lake to southeast. Lake elevation at full pool is 1,276 feet.

153.1 Bridge over Calderwood Lake and view upstream of Cheoah Dam which is owned and operated by Alcoa.

153.5 Bridge over the Cheoah River at Tapoca Lodge.

154.9 Junction with U. S. Forest Service road to Big Fat Gap and to the Slickrock Wilderness area.

155.4 Approximate location of the base of the Copperhill Formation, an extensive unit of the Great Smoky Group. The route continues southeastward in this formation for the next 11.9 miles.

156.3 Inferred location of the garnet isograd.

159.5 Route goes underneath pipeline. A 4.6 mile long combination of tunnels and pipes carries water from Santeetlah Lake (full pool evaluation 1,940 feet), formed by damming of the Cheoah River, to a powerhouse along the shores of Cheoah Lake. The hydraulic head at the power station is approximately 600 feet. Santeetlah Lake and power house are part of Alcoa's hydroelectric system.

160.4 For the next 1.3 miles the road traverses a sequence dominated by dark, fine-grained, commonly sulftic rocks. This sequence, as indicated by reconnaissance mapping, extends for approximately 60 miles along strike. A portion of its extent has been mapped and examined more closely in the nearby Joyce Kilmer area (Units 14 and 15 of Lesure and others, 1977). The North Carolina 1985 State Geological Map refers to this and other lithologically similar, but unconnected units as "Slate of Copperhill Formation".

160.6 Road to south and west leads to Joyce Kilmer Memorial Forest and Horse Cove Campground.

161.7 Approximate eastern limit of the slaty sequence of the Copperhill Formation that began at mile 24.0. Road to west leads to Cheoah Point Recreation area. In 1975, the Carolina Geological Society made a field-trip stop at Cheoah Point. The following description, including the road log from here to Red Marble Gap (mile 180.5), is adapted from the 1975 Guidebook (Kish and others, 1975, p. 33 – 37). The Cheoh Point recreation area is 0.8 miles away; to reach it, turn right, proceed 0.15 miles, turn left, and continue 0.6 miles to boat launching area. Prominent exposures at Cheoah Point are coarse-grained to pebbly metagraywacke of the Copperhill Formation with occasional finer-grained layers. Pebbles, many of which exceed 10 mm in diameter, are prominent with the bulk of the grains ranging from coarse sand to granules (1/2 to 4 mm). Many of the beds are poorly sorted, matrix-rich, homogeneous, massive units as much as 10 feet thick. Locally, graded beds are common. Pebbles are of feldspar and milky, smoky, and blue quartz; some intraformational slate fragments are also present.

Ellipsoidal masses, commonly ranging from 150 to 40 centimeters in diameter, occur is some of the beds. These are calcareous concretions, evidently formed during diagenesis. Frequently chips of slate are found in their cores.

Regional maps (Carpenter, 1970 p. 751) indicate that the Cheoah Point area is underlain by garnet grade rocks. Detailed work in the Great Smoky Group shows that recrystallization of the calcareous concretions begins to occur midway between the garnet and staurolite isograds. The recrystallized concretions from "pseudodiorite" or calcsilicate granofels, composed mainly of quartz, plagioclase, hornblende, clinozoisite or epidote, garnet, sphene, and traces of other minerals. In practice it is possible to map a "pseudodiorite isograd".

The beds in this area strike about N 25ºE and dip moderately northwest; graded bedding shows the sequence here to be right-side up. A pervasive cleavage is the most obvious planar structural element and is oriented about N 45° E, 70ºSE. Parallelism of the secondary mica minerals best defines the foliation. The primary sedimentary concretions are flattened in this plane as are some of the pebbles and granules. However, the coarse grains in other beds are not obviously deformed and still appear to retain their original detrital shapes. This may be cushioning or insulation effect caused by abundant matrix material in some beds.

Volumetric calculations indicate about 60 percent of the Great Smoky Group, as now defined and mapped from the National Park southwestward into Georgia, is composed of coarse-grained strata similar to the beds exposed here.

161.7 Coarse-grained units including some dark, fine-grained beds are well exposed in extensive road cuts along U. S. 129 for the next 0.3 miles. Dips here are toward the northwest; strata are right side up. These are typical CopperHill Formation exposures.

163.9 Scenic overlook; view of Santeetlah Lake with the Unicoi Mountains in the background. This terrain is underlain by Great Smoky Group rocks. Elevation of the lake at full pool is 1,940 feet. The peaks range up to nearly 5,500 feet.

165.9 Cross axial area of a large overturned fold. Axial plane dips steeply to the northwest. For the next mile or more, primary sedimentary features show that the northwest-dipping strata are overturned.

167.2 Bridge over Cheoah River embayment.

167.3 Approximate location of the upper contact of the Copper Hill Formation. Scattered exposures in this vicinity and for about the next 1.1 miles are mainly dark, fine-grained graphitic schist and phyllite with massive metagraywacke interlayers. This sequence is correlated with the Wehutty Formation.

168.4 Boundary between the top of the Wehutty Formation and the base of the Ammons Formation. Contact not exposed along highway.

168.5 Junction with SR 1106, main street of Robbinsville.

169.1 Well exposed rock in road cut is the Ammons Formation; it dips steeply to the northwest but is overturned as indicated by graded bedding.

170.5 Ammons Formation – Dean Formation contact, not exposed along highway.

170.6 Weathered outcrops behind blue corrugated metal building on right are coarse-grained staurolite mica schist. This rock type is characteristic of the lowermost beds of the Dean Formation near its contact with the Ammons Formation.

172.8 Exposures of cross-biotite schist of the Dean Formation.

173.5 Dean Formation – Nantahala Formation contact, not exposed along highway. This conformable contact marks the top of the Great Smoky Group and the base of the Murphy belt sequence. Several scattered exposures of typical black, sulphidic, metasiltstone of the Nantahala Formation occur along the highway for the next 1.5 miles.

175.1 Entering portion of the Nantahala Formation containing thick units of white, subarkose (Tusquitee Quartzite).

176.0 Outcrops of "Tusquitee Quartzite".

176.5 Nantahala-Brasstown Formation contact, not exposed along highway.

178.5 Prominent outcrops of the Brasstown Formation.

178.5 Brasstown Formation and view of the Nantahala Gorge. The Brasstown Formation exposed here consists of fine-grained brownish-gray schist which contains thin laminae of metasiltstone. Locally the metasiltstone exhibits a distinct gradation in grain size, possibly microturbidites.

The view from the parking area is spectacular on a clear day (see title page). The Cheoah Mountains, forming the north rim of the Nantahala Gorge, have a maximum relief of over 3,000 feet. Briertown Mountain on the south side of the gorge has a maximum relief of 1,800 feet. The Cherokee word Nanatahala means "land of the noonday sun" in allusion to the steep (up to 50º) walls of the gorge which cut out the morning and afternoon sun. At this location we are looking across an almost complete cross section of the main Murphy syncline. The north rim of the gorge is formed by dip slopes of the Nantahala and Brasstown Formations. The Murphy Marble is located on the low slopes on the north side of the gorge. The Nantahala River follows nonresistant layers in the hinge zone of the syncline. The south rim of the gorge is located on the opposite limb of the Murphy syncline, and contains overturned beds of the Nantahala Formation. The peaks visible in the distance, south of the gorge, are high peaks of the Nantahala Mountains. Wayah Bald (5,342 feet), and Wine Springs Bald (5,445 feet), east of the Hayesville fault, are approximately 10 miles away.

180.5 Red Marble Gap. Weathered rock crops out alongside the restaurant and store about 100 feet west of the bridge. Exposed here is the top of the Brasstown Formation and the base of the Murphy Marble. The Brasstown is represented by fine-grained schist or phyllite; at this outcrop the Murphy Marble is dominantly feldspathic quartzite. Van Horn (1948), in his careful, detailed investigation of the Murphy Marble in North Carolina reports that the interprets the unit in terms of three original sedimentary facies; a sandy facies, a shaly facies, and a calcareous facies which, at places, is almost completely displaced by representatives of two siliceous facies. In describing the Murphy Marble in the two-mile interval from Red Marble Gap to the southwest, Van Horn (1948, p. 11) states "Much of this marble shows encroachment of originally sandy and shaly facies, until at Red Marble Gap the entire Equivalent thinning is reflected in the Nottely Quartzite and the intervening mica schist – (Andrews Formation of present usage). Locally, the contact between the Brasstown and the Murphy is marked by a thoroughly leached or saprolitized zone about a meter thick.

The field-trip route crosses the bridge over the railroad and turns right following U. S. 129 and U. S. 19 southwestward towards Andrews and Murphy. The route remains entirely within the Murphy belt, generally following the lowland between the Snowbird Mountains to the north and west, and the Valley River Mountains to the south and east. The soluble Murphy Marble and other easily eroded units of the Murphy belt sequence underlie the valley; clastic, siliceous rocks at the base of the Murphy sequence – the Tysquitee Quartzite and Nantahala Slate, and the upper units of the Great Smoky Group – hold up the high ground.

182.9 The Brasstown Formation crops out intermittently from here on for the next 7.3 miles.

185.4 Granny Squirrel Gap.

187.5 Junction with U. S. 19 Business to Andrews. Continue straight ahead on U. S. 129 and 19.

189.7 Access to Rest Area and Andrews to left. Continue straight ahead.

190.2 Extensive road cuts to northwest are in the Brasstown Formation.

190.5 Junction with U. S. 19 Business to Andrews. Continue straight ahead.

191.7 Andrews-Murphy airport to the right. In the distance to the northwest are the Snowbird Mountains; most peaks are between 3,800 and 4,200 feet elevation. To the southeast are the Valley River Mountains with some peaks exceeding 4,500 feet elevation. Elevation at the airport is about 1,675 feet. The highway in this region is generally over the calcareous Murphy Marble or the Andrews Formation. Outcrops are virtually nonexistent for the next 9.6 miles.

195.3 Junction with access road to Marble. Continue straight ahead.

195.8 Intersection with N. C. 141; Hayesville to southeast, Marble to northwest. Continue straight ahead.

201.3 Prominent exposures of the Nottely Quartzite here and intermittently for the next 0.6 miles. In addition to the white Nottely Quartzite, deeply leached phyllite with remnant cross-biotite porphyroblasts (ottrelite of some authors) is also present. Concentrations of iron oxide are present in the residuum and commonly mark the trace of the upper and lower boundaries of the Nottely Quartzite. If the Nottely is absent, the iron oxide concentrations normally occur over the center of the Andrews Formation (Bayley, 1925, p. 19). Van Horn (1948, p. 14) points out that the best known brown iron ores occur in residuum of strata lying just southeast of the Nottely Quartzite (Van Horn's ottrelite gneiss unit; basal Mineral Bluff Formation of current terminology). The deposits were mined, principally during the late 19th and early 20th centuries.

201.6 Junction with SR 1370. Field trip Stop 3 for Sunday. The small stream, Marble Creek, has cut through the linear Nottely Quartzite ridge. A small abandoned and flooded marble quarry is present 0.2 miles to the northwest along SR 1370.

202.4 Junction with U. S. Business 19 to downtown Murphy.

204.8 Major intersection with U.S. 64. Murphy is to the right, Hayesville to the left, and the bridge over the Hiwassee River is straight ahead. Turn right onto U. S. 64.

205.0 Make a sharp right turn and then enter the Econo Lodge parking lot. End of Saturday's trip.

REFERENCES CITED:

Bayley, W. S., 1925, Deposits of brown iron ores (brown hematite) in western North Carolina: North Carolina Geological and Economic Survey Bulletin 31, 76 p.

Biery, J. N., 1968, Geology of a part of the footwall of the Great Smoky fault, Monroe County, Tennessee [M. S. thesis]: Knoxville, University of Tennessee, 53 p.

Brown, A., 1971, Deformation in the Wilhite Formation between the Capshaw Branch and Miller Cove faults: Geological Society of America Abstracts with Programs, v. 3, p. 298 – 299.

Carpenter, R. H., 1970, Metamorphic history of the Blue Ridge province of Tennessee and North Carolina: Geological Society America Bulletin, v. 81, p. 749 – 761.

Gair, J. E., and Slack, J. F., 1982, Geologic maps of the Cohutta Wilderness and the Hemp Top Roadless Area, northern Georgia and southeastern Tennessee: U. S. Geological Survey Miscellaneous Field Studies Map MF-1415-A, scale 1:48,000.

Glover, Lynn, 1959, Stratigraphy and uranium content of the Chattanooga Shale in northeastern Alabama, northwestern Georgia and eastern Tennessee: U. S. Geological Survey Bulletin 1087-E, 35 p.

Granath, J. W., 1978, Strain history of the Burra Burra anticline at Ducktown, Tennessee: Southeastern Geology, v. 19, p. 231 – 240.

Hamilton, W. B., 1961, Geology of the Richardson Cove and Jones Cove quadrangles, Tennessee: U. S. Geological Survey Professional Paper 349-A, 55 p.

Hanselman, D. H., Conolly, J. R., and Horne, J. C., 1974, Carbonate environments in the Wilhite Formation of central eastern Tennessee: Geological Society of America Bulletin, v. 85, p. 45 – 50.

Hardeman, W. D., 1966, Geologic map of Tennessee: Tennessee Division of Geology, scale 1:250,000.

Hatcher, R. D., Jr., Merschat, C. E., Milici, R. C., and Wiener, L. S., 1978, Field trip 1 – A structural transect in the southern Appalachians, Tennessee and North Carolina, in Milici, R. C., ed., Field trips in the southern Appalachians: Tennessee Division of Geology Report of Investigations 37, p. 5 – 52.

Hatcher, R. D., Jr., and Milici, R. C., 1986, Ocoee Gorge; Appalachian Valley and Ridge to Blue Ridge transition: Geological Society of America Centennial Field Guide – Southeastern Section p. 265 – 270.

Hayes, C. W., 1895, Description of the Cleveland quadrangle, Tennessee: U. S. Geological Survey Atlas Folio 20, 12 p.

Hernon, R. M., 1964, Preliminary Geologic map of the Ducktown, Isabella, and Persimmon Creek quandrangles, Tennessee and North Carolina: U. S. Geological Survey open-file report 64 – 77, 1:24,000.

Holcombe, R. J., 1973, Mesoscopic and microscopic analysis of deformation and metamorphism near Ducktown, Tennessee [PhD thesis] Palo Alto, Stanford University, 225 p.

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 – southeast Tennessee (Geological Society of America, Southeastern Section Annual Meeting: Georgia Department of Mines, Mining and Geology Guidebook, no. 3, 28 p.

Keller, F. B., 1980, Late Precambrian stratigraphy, depositional history, and structural chronology of part of Tennessee Blue Ridge [Ph. D. thesis]: New Haven, Connecticut, Yale University, 353 p.

Kish, S. A., Merschat, C. E., Mohr, D. W., and Wiener, L. S., 1975, Guide to the geology of the Blue Ridge south of Great Smoky Mountains, North Carolina: 1975 Carolina Geological Society Field Trip Guidebook, 49 p.

Lesure, F. G., Force, E. R., and Windolph, J. F., 1977, Mineral resources of the Joyce Kilmer-Slickrock Wilderness, North Carolina – Tennessee: U. S. Geological Survey Bulletin 1416, 89 p.

Neuman, R. B. and Nelson, W. H., 1965, Geology of the western Great Smoky Mountains, Tennessee: U. S. Geological Survey Professional Paper 349-D, 81 p.

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 Map GM 133-NE, scale 1:24,000.

Phillips, H. E., 1952, The geology of the Starr Mountain area, southeast Tennessee [M. S. thesis]: Knoxville, University of Tennessee, 61 p.

Power, W. R., and Forrest, J. T., 1971, Stratigraphy and structure of the Murphy belt, North Carolina: 1971 Carolina Geological Society Field Trip Guidebook, 29 p.

Rackley, R. I., 1951 The geology of the Bean Mountain area [M. S. thesis]: Knoxville, University of Tennessee, 76 p.

Rodgers, John, 1953, Geologic map of East Tennessee with explanatory text: Tennessee Division of Geology Bulletin 58, part II, 168 p.

Slack, J. F. Gazdik, G. C., and Dunn, M. L., Jr., 1982, Mineral resources of the Big Frog Wilderness Study Area and additions, Polk County, Tennessee and Fannin County, Georgia, U. S. Geological Survey Bulletin 1531, 25 p.

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.

Tull, J. F., and Groszos, M. S., 1990, Nested Paleozoic "successor" basins in the southern Appalachian Blue Ridge: Geology, v. 18, p. 1046 – 1049.

Unrug, Raphael, and Unrug, Sophia, 1990, Paleontologic evidence of Paleozoic age for the Walden Creek Group, Ocoee Supergroup, Tennessee: Geology, v. 18, p. 1041 – 1045.

Van Horn, E. C. 1948, Talc deposits of the Murphy Marble belt: North Carolina Department of Conservation and Development, Division of Mineral Resources Bulletin 56, 54 p.

Wiener, L. S., 1979, Rate of mid-Paleozoic orogenic uplift in the southern Appalachians: Southeastern Geology, v. 21, p. 91 – 102.

Wiener, L. S. and Merschat, 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 Hatcher, R. D., Jr., Merschat, C. E., Milici, R. C.,k, and Wiener, L. S., Field Trip 1 – A structural transect in the southern Appalachians, Tennessee and North Carolina, in Milici, R. D., ed., Field Trips in the southern Appalachians: Tennessee Division of Geology Report of Investigations 37, p. 23 – 29.

Wiener, L. S., and Merschat, C. E. 1981, Provisional geologic map of southwest North Carolina, southeast Tennessee and north Georgia: North Carolina Geological Survey Open File Map, scale 1:250,000.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 147-155

CAROLINA GEOLOGICAL SOCIETY

1991 FIELD TRIP ROAD LOG

SUNDAY, NOVEMBER 10, 1991

A BRIEF HISTORY OF CHEROKEE COUNTY

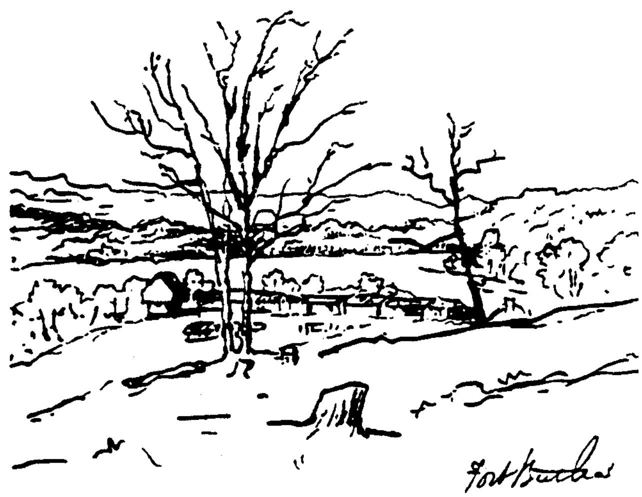
Archibald Russell Spencer Hunter moved to southwestern North Carolina in 1828 and founded Huntington where he had established a trading post on the southwestern banks of the Hiwassee River (Dockery, 1987, p. 14). Fort Butler was named after the Secretary of war at that time, B. F. Butler and was built in Huntington in1836. Fort Butler was only one of six forts built specifically for sending Cherokee Indians to Oklahoma (Sakowski, 1990, p. 36; Cashion, 1970, p. 45 – 47). Fort Montgomery was in Robbinsville, Fort Delaney was in Andrews, and Fort Hembrie was in Hayesville (Dockery, 1989, p. 15). The Indians had no intention of leaving the area voluntarily. In the spring of 1838, General Winfield Scott with 7,000 men arrived in western North Carolina, Fort Butler became Scott's headquarters, and the forced removal of the Cherokees began (Sakowski, 1990, p. 6, 36). It took six months to move them to Oklahoma along the Trail of Tears.

In 1837 the town of Murphy was named after statesman Archibald D. Murphey who helped develop public schools and was involved in road legislation (Dockery, 1987, p. 19). Cherokee County was established in 1839 and the first session of the county court met in Fort Butler. The second court house was wooden and was built on the town square. The third court house was brick and was completed by A. R. S. Hunter in 1844 (White, 1989, p. 12). Colonel Kirk, U. S. A., burned it in April, 1865 (White, 1989), p. 12). The present day court house is the seventh court house and was built in 1927. The other intervening Court Houses also burned.

The Civil War near Murphy, North Carolina

George Washington Hayes was one of the most prominent early settlers of Cherokee County and built his home at Tomotla in 1840, four miles northeast of Murphy (Dockery, 1989, p. 35; White, 1987, p. 44). He was a Captain in the Confederate army, Company A, 19th North Carolina Regiment, Second Cavalry (Freel, 1973, p. 375). The town of Hayesville was named for him because he was instrumental in forming Clay County when running for the legislature in 1860 (Sakowski, 1990, p. 47). Those people who joined the Confederacy lived as he did in the valleys, but those in the Hanging Dog area to the west were Federals.

The last armed action of the Civil War east of the Mississippi River was a skirmish at the headwaters of Hanging Dog and Hyatt Creeks on May 6, 1965 (Freel, 1973, p. 234; White, 1987, p. 35; Sakowski, 1990, p. 37). A company of



Historical sketch of Fort Butler, site on Fort Butler Street, Murphy (from National Archives).

Federal deserters mostly from Cherokee County were headed by Captain Aker who tried to find papers filed against them for desertion at the County Courthouse in Murphy. When these papers could not be found, the courthouse was burned and Lt. Jim Axley, C. S. A., was captured. Afterwards the deserters headed for Camp Valley Town but were told they were outnumbered by the Confederate garrison there and so rode to Mr. Hyatt's house near Hanging Dog Gap, near the head of Hanging Dog Creek about three miles northwest of Marble. Mr. Hyatt sent for help from Camp Valley Town, which was manned by 100 soldiers commanded by a Major Whitaker. These men arrived at the Hyatt house at dark. At dawn an attack on this house was made; but because the Confederates had little ammunition, they could not mount a sustained attack, and the Federal deserters escaped.

00.0 Start at Econo Lodge

00.1 Stop sign at CR 1552-Peachtree St.

00.3 Cherokee County House on the right was built from Regal Marble (a bluish-gray variety of the Murphy Marble). At the entrance to the Murphy museum, adjacent to the court house, is a large sculpture of a turtle carved by the Cherokee Indians. Their name for a turtle is Nuya Saligugi (stone turtle). The turtle was carved from a soft chlorite schist from a metamorphosed mafic sill exposed in the Brasstown Formation five miles southwest of Murphy in Die Bend of the

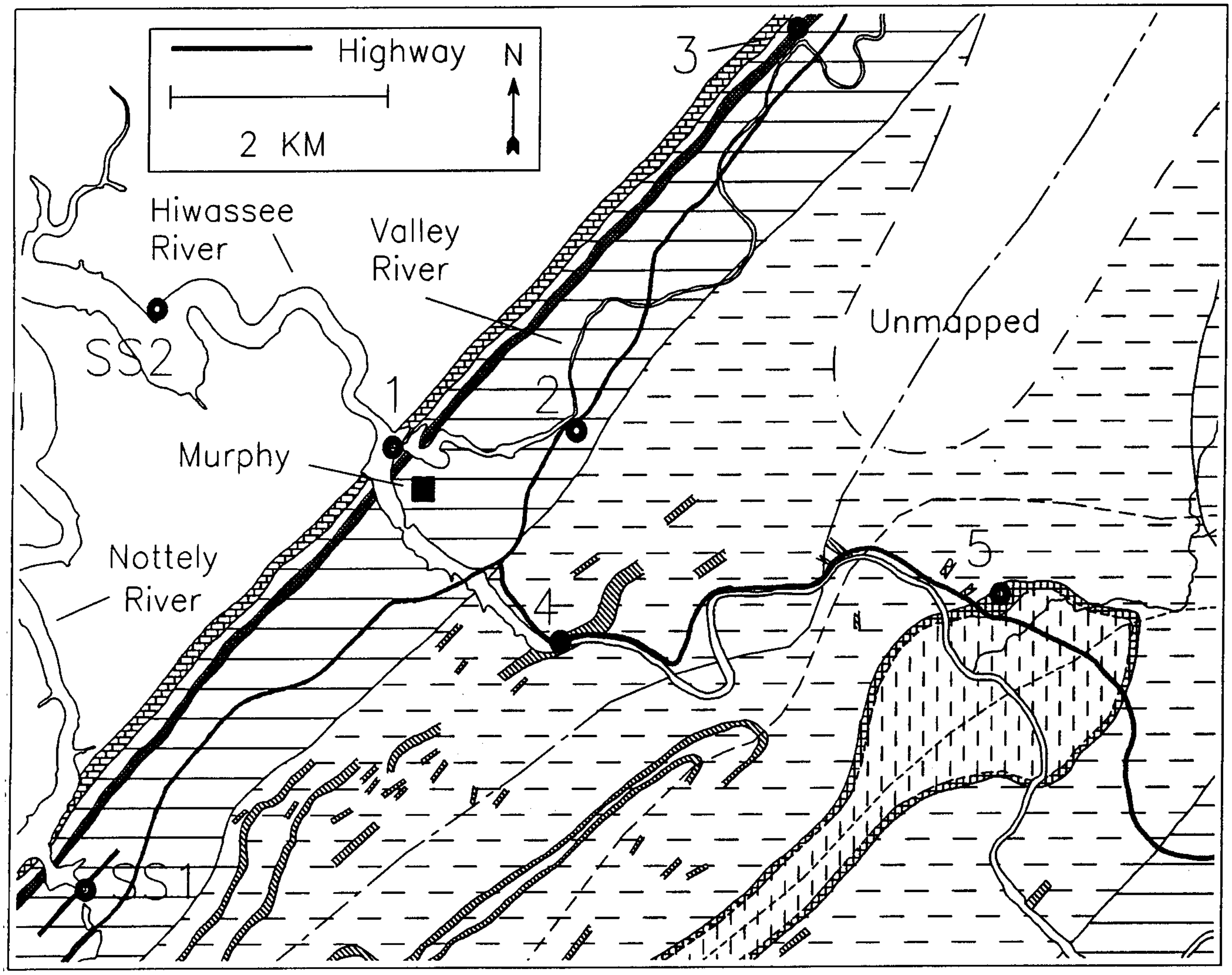


Figure 1. Location map of SUNDAY stops. See Thompson and Tull, this volume (Figure 2 and 3), for interpretation of stratigraphic symbology.

Nottely River. One block up hill to the southwest is located Harshaw Church, which is Murphy's oldest landmark. Local folklore follows the work of Cathey (1899) who thought that Abraham Enloe was possibly the father of Abraham Lincoln. Abraham Enloe's tombstone is located at Harshaw Church.

00.4 Traffic light, continue straight on Tennessee St. (northwest).

00.7 Railroad tracks

00.9 Payne St. to water treatment plant, buses will turn around.

STOP 1. BRASSTOWN FORMATION CROSS-BEDDING AT HIWASSEE-VALLEY RIVERS CONFLUENCE.

Josephy G. Aylor Jr.

Walk southwest across the highway bridge over the Valley River (Fig. 1 and 2). In the Valley River observe (if the water is clear) the Brasstown Formation from either side of the bridge and its contact with the Murphy Marble on the southeastern, upriver side. Once across the bridge, step over the guard rail and go down the rip-rap covered bridge abutment on the upriver side of the bridge. Proceed under the bridge and walk along the Valley River northwestward to the confluence with the Hiwassee River.

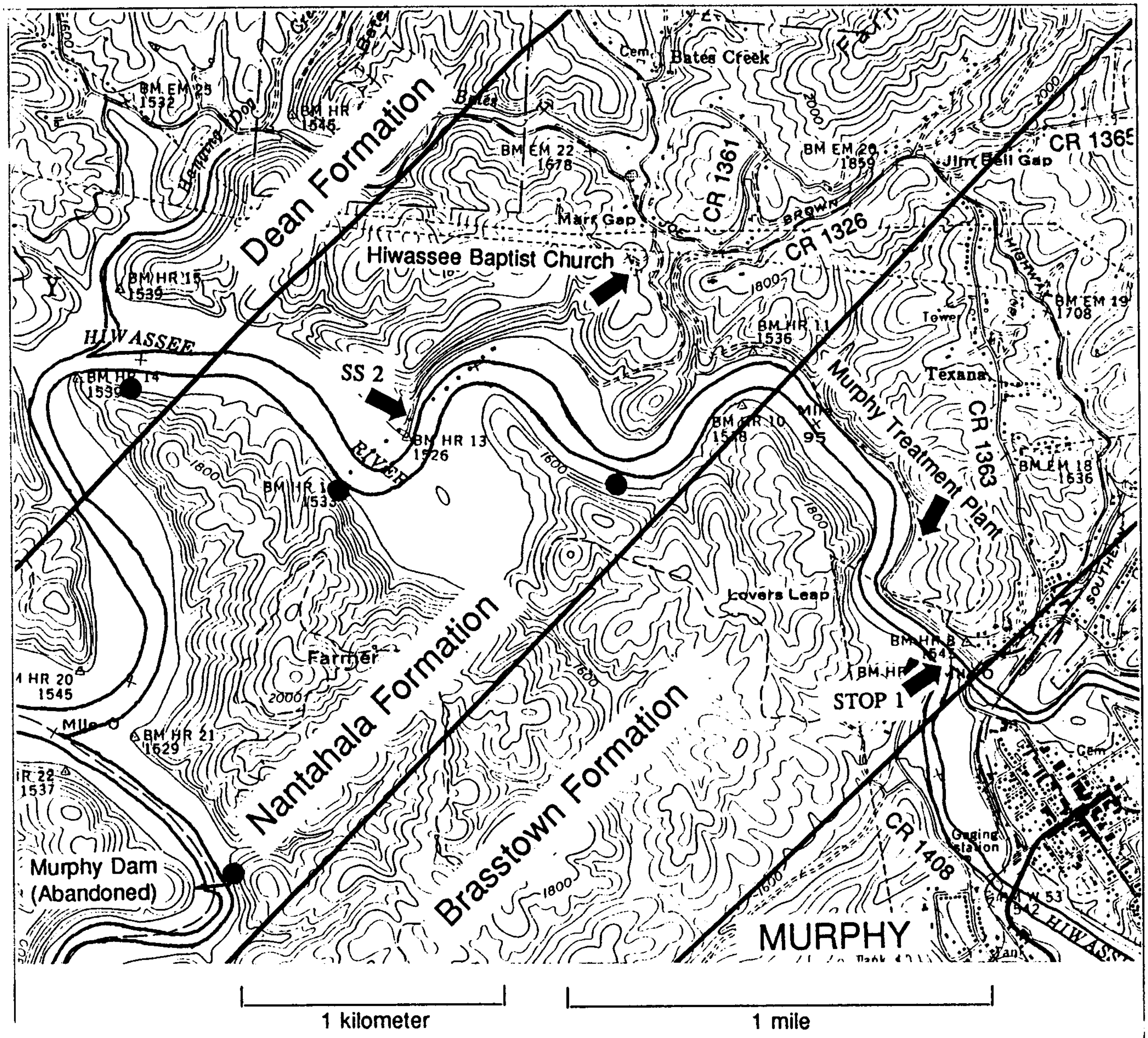


Figure 2. Location of stop 1 and supplemental stop 2 near Murphy in the Nantahala and Brasstown Formations. Filled circles in the Nantahala Formation are sill and dike locations mentioned in supplemental stop 2. The bold lines in the Hiwassee, Nottely, and Valley Rivers indicate low water.

The objective of this stop is to observe primary features in the upper part of the Brasstown Formation 86 m down section form the Murphy Marble. Exposed here is fine to medium grained sandstone containing planar tabular cross beds. Some random, detrital feldspar grains are granule in size. This stratigraphic interval within the Brasstown Formation was originally defined by Keith (1907, p. 4) as part of the Valleytown Formation. Because of problems associated with the definition of this unit, the Valleytown Formation has been abandoned, and this interval is included in the Brasstown Formation of Keith (1907, p. 4; see Tull and others, this volume). The Brasstown Formation is mostly light to dark gray metasiltstone and schist and here is at middle amphibolite facies. Alternating one centimeter thick layers of light-gray biotite quartz-rich metasandstone and dark gray metasiltstone and mica “schist” are typical (Aylor, this volume). The term “schist” is not strictly valid here because these rocks contain less than 50% mica, and schistosity is not well developed (Winkler, 1979, p. 341). In this section, biotite is more abundant in the

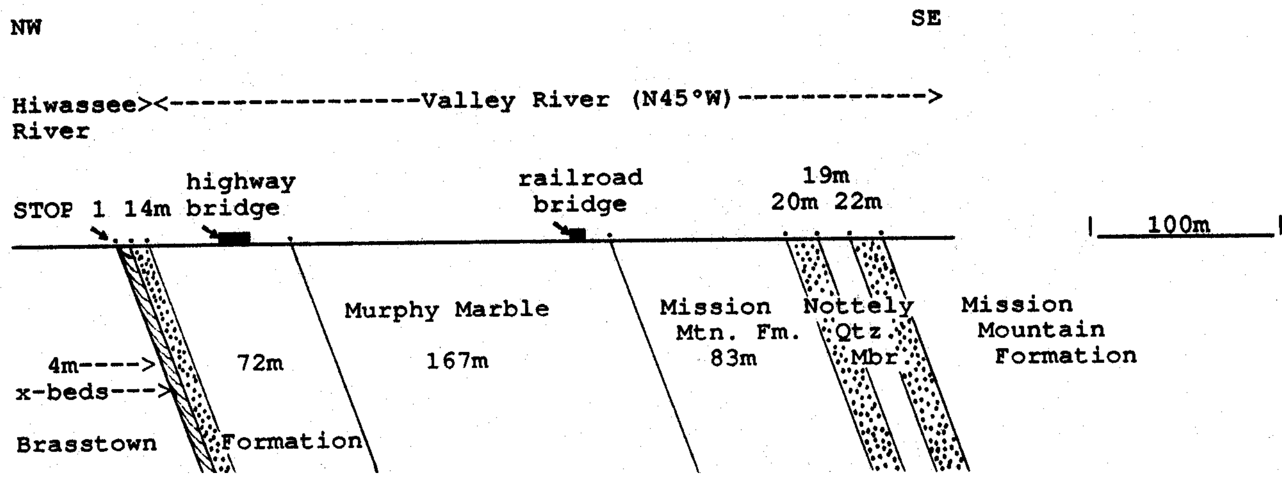


Figure 3. Generalized measured cross section perpendicular to strike of N45°E along the Valley River, Murphy, North Carolina.

darker-colored layers, whereas muscovite is more abundant in the lighter-colored layers. Graphite is abundant in the darker-colored pelitic siltstone layers. Garnet up to 1.5 mm is size is found throughout. Zoned plagioclase with inclusions of quartz and K-feldspar are detrital. The thickness of the Brasstown Formation is 1319 meters along the Hiwassee River reference section (Aylor, this volume).

The Brasstown Formation and underlying Nantahala Formation have been correlated with the Lower Cambrian Chilhowee Group (King, 1949, p. 638). Walker and Driese (1991, p. 279) place the Lower Cambrian-uppermost Precambrian boundary somewhere within the upper part of the Iapetus Ocean on the Atlantic-type Laurentian margin (Walker and others, 1988, p. 50). The transgressive sequence of the upper Chilhowee Group including units above the Cochran Formation is shallow and shelf marine deposits overlain by the Shady Dolomite which is a stable margin carbonate deposit (Schwab, 1972, p. 75; Whisonant, 1974, p. 239). The Brasstown Formation is thought to be a more distal, marine shelf deposit correlative to part of the Nichols, Nebo, Murray, and Hesse Formations (Aylor and others, 1991). In this correlation the Murphy Marble would be correlative with the Lower Cambrian Shady Dolomite.

The strike of the units is easily observed in both the Valley and Hiwassee Rivers. The dip of the units is perpendicular to and upriver of the Valley River. Figure 3 is a cross section along the Valley River to the Hiwassee River. The strike of the units is diagonal with the direction of the upriver part of the Hiwassee River to the southwest, at the location of the stop. When the lake is down in winter and when hydroelectric power is not being produced at Mission Dam, the metasandstones at this stop stand up as resistant beds. This stop is significant for depositional environment interpretation because this is a rare example of cross-bedded metasandstone beds in the Brasstown Formation. Across the Hiwassee River from this stop, trough-cross stratification is observable on strike with these units at the confluence of the rivers. At the stop, the truncated upper part of planar-tabular cross bedding demonstrates that the Brasstown Formation is upright on this limb of the Murphy syncline. Therefore, the Murphy Marble is younger than the schists in the Brasstown Formation. There are about 4.3 m (13 feet) of thickness of Brasstown Formation cross beds and about 20 m (61 feet) of total sandstone exposed, including these cross beds. Individual beds that contain the cross bedding are about 40 cm thick. Cross bedding is accentuated by heavy mineral laminations and not by sorting of grain sizes. Planar-tabular cross bedding in the sandstone units (#387, modal analysis, Aylor, this guidebook) have a paleocurrent direction of N36° and a dip from bedding of 15° (nine readings). Although most of the Chilhowee Group has a paleocurrent direction of southeast (Walker and others, 1988, p. 43), Brown (1970, p. 343) thought northeasterly directed paleocurrent data in the upper Chilhowee Group Erwin Formation (Nebo, Murray, Hesse) might suggest longshore transport. Our preliminary depositional environment interpretation of the Brasstown Formation is a bar origin on a continental shelf. Tidal features, graded bedding, channels, and symmetrical ripple marks have not been recognized.

Other models for depositional environments of the Brasstown Formation have been proposed. The regional significance of the formations within the

Murphy belt was discussed by Power and Forrest (1973), who thought these units were part of a transgressive linear shoreline. The Brasstown Formation was interpreted as being part of an open marine shelf. This interpretation of the Brasstown Formation of Power and Forrest (1973, p. 704) seems to agree with interpretations of this work. However, except for the Murphy Marble, which they interpreted as a "reef or carbonate bank", other formations within the Murphy belt do not have supporting evidence for those environments proposed by Power and Forrest (1973). The Dean Formation was thought to be an alluvial floodplain deposit by Power and Forrest (1973, p. 706). However, most workers believe the Great Smoky Group to be deposited in deeper water as turbidities (Rast and Kohles, 1986, p. 600, 610). Power and Forrest (1973, p. 706) continued their transgressive sequence seaward from the Dean Formation by assigning the Nantahala Formation by assigning the Nantahala Formation metasiltstones to a tidal flat or lagoonal origin probably because of what Forrest (1975, p. 15) thought could be flaser bedding. In this study, the apparent "flaser bedding" contains dark siltstone marking asymmetrical ripple marks, interpreted to have originated from marine currents. The bedding in the Nantahala Formation were interpreted as beach sands (Power and Forrest, 1973, p. 706). Cross bedding in the Nantahala Formation is too steep (35º) for beach deposits (Ehlers and Blatt, 1982, p. 342). The Nantahala Formation was interpreted by Aylor and others (1991) to be the inner-shelf equivalent of the fluvial Cochran Formation on Chilhowee Mountain.

Hatcher and Thomas (1988, p. 106) interpreted the Brasstown Formation to have originated from a deep water environment, such as an off-shelf turbidite. However, Mohr (1973, p. 61) found no turbidite features in the Brasstown Formation.

In conclusion this stop is important in placing the Brasstown Formation within a continental-shelf marine environment. Evidence from this study supports shelf sand bodies.

00.9 Turn around and drive east on Tennessee Street (the same road traveled to get to stop 1) toward the Econo Lodge.

01.5 Intersection of Tennessee and Peachtree Streets, continue straight on Peachtree Street (east).

02.1 Intersection with Peachtree Street and U. S. Routes 74 – 19 – 129, turn left (north).

03.1 Puff off onto right side of highway, adjacent to large vertical road cuts of Mission Mountain Formation, stop 2A.

03.2 Continue north to 2nd large exposure, near massive boulders of Mission Mountain Formation, stop 2B.

STOP 2. UPPER LITHOFACIES OF THE MISSION MOUNTAIN FORMATION

James F. Tull and Troy W. Thompson

The purpose of this composite stop is to illustrate typical lithofacies within the proposed Mission Mountain Formation, the stratigraphically lowest formation of the Mineral Bluff Group (Thompson and Tull, this volume). The Mission Mountain Formation is approximately 1000 meters thick and consists dominantly of the lithofacies seen here, but also includes metasandstone units (such as the Nottely Quartzite Member, SUNDAY Stop 3), mafic metavolcanic (?) zones (SUNDAY Supplemental Stop 1), and zones which contain carbonate olistoliths. At these exposures (Fig. 1) only approximately 30 meters of the Mission Mountain Formation are exposed along about a 150 meter strike length. At stop A, because the road cut parallels strike, only about 2 meters of section are available for inspection at ground level. Stop 2B is stratigraphically below stop 2A.

At these exposures the Mission Mountain Formation is dominated by a thinly laminated (on a scale of several millimeters to a few centimeters) fine-grained muscovite-chlorite schist interlayered with sandy "metagraywacke" intervals and distinctive layers of calc-silicate. The lithofacies and their petrography and geochemistry from this location were described in detail by La Tour and Fritz (1988) and similar exposures along strike to the southwest were described in a field trip stop by Hatcher (1978).

The Mission Mountain Formation is generally made up of layered and laminated and locally graded rocks which we have interpreted as gravitationally emplaced grain flow deposits, dominated by turbidites. This is also the conclusion of La Tour and Fritz (1988) who described the presence of plane beds, graded beds, scour and cut-and-fill structures, low angle ripple cross laminations, and possible gutter casts in these exposures to support this interpretation. The layered and laminated structure in these rocks is interpret as primary bedding (modified by recrystallization and strain) because of the presence of the primary sedimentary features geometrically related to layering which were noted by La Tour and Fritz (1988), as well as by chemical variations such as calc-silicate layers spaced at distances unlikely to result from metamorphic differentiation at this metamorphic grade.

Calc-silicate ("pseudodiorite" of earlier workers) and impure marble layers are important components of the Mission Mountain Formation. At these exposures these layers average approximately 5 cm thick and make up about 8% of the unit. They repeat approximately every 60 cm, so that about 15 layers occur in this roadcut exposure. Boundinage effects cause the thin mechanically competent calc-silicate layers to pinch out laterally, so that they are commonly discontinuous. The mineralogy, chemistry, and zoning of the calc-silicate layers were discussed by La Tour and Fritz (1988), who interpreted them to be carbonate turbidites possibly modified by metasomatism during metamorphism. We agree with this interpretation and wish to emphasize that the Mission Mountain Formation contains a very significant calcareous component that was probably dominantly detrital. This is evidenced by the calc-silicate layers seen at this exposure, by the presence of zones containing carbonate olistoliths, by the presence of impure marble layers here and elsewhere, and by the abundance of calcium-bearing mineral phases (notably calcite, epidote-group minerals, and sphene) within typical schists of the Mission Mountain Formation (see Thompson and Tull, this volume, Table 1). We interpret the protoliths of these rocks to have been carbonate turbidites, pebbly mudstones, calcarenites, and calcareous mudstones respectively. It is our interpretation that the highly calcareous nature of the Mission Mountain Formation reflects a significant carbonate source, and it has been argued (Tull and Groszos, 1988, 1990) that the immediately underlying Murphy Marble is the erosional remnant of this source and was probably originally a much more extensive carbonate bank, than is now preserved.

03.2 Continue north on U. S. Highway 74-19-129.

03.5 Murphy High School on the left.

03.9 Intersection of Valley River and U. S. Highway 74-19-129.

05.3 Turn left onto Regal Road (CR 1370).

05.4 Exposures of Nottely Quartzite Member on northwest side of U. S. Highway 74-19-129.

STOP 3. NOTTELY QUARTZITE MEMBER OF THE MISSION MOUNTAIN FORMATION

James F. Tull and Troy W. Thompson

These outcrops along the northwest shoulder of U. S. Highway 19-129 (Fig. 1) are perhaps the best and most complete exposures of the Nottely Quartzite. Tull and others (this volume) have proposed placing the Nottely Quartzite as a member within the Mission Mountain Formation, the lowest formation in the Mineral Bluff Group. The Nottely forms a prominent sharp linear ridge in this part of North Carolina, as seen here, rising 100 – 150 m above the adjacent valleys.

At this exposure (partially described as stop 3, Power and Forrest, 1971) the Nottely dips steeply (72º) southeastward and forms a composite interval 82 meters thick composed of a lower and upper quartzite separated by an interval of mica schist (Fig. 4). Cross beds exposed in the upper and lower intervals at other exposures indicate that this entire sequence is upright. At this exposure the lower quartzite is 29 meters thick, the middle mica schist is 38 meters thick and the upper quartzite is 15 meters thick. Bedding is visible both at this scale and the hand specimen scale, where it is marked by grain size differences of primary sand grains.

As one faces the road cut (looking northwestward) the lower Mission Mountain Formation (of Thompson and Tull, this volume) (formerly the Andrews Schist of Keith, 1907) is poorly exposed on the extreme left at the base of the sequence. Approximately 90 meters of this schist occurs between the underlying Murphy Marble and the lower quartzite interval of the Nottely Quartzite Member. The lower part of this schist section (not exposed here), just above the calcite. Van Horn (1948) called this interval a "transition zone" and noted that it was approximately 10 meters thick. The marble layers grade into schist layers over a distance of about 1 – 2 cm, to where the schist contains no carbonate. The schist layers contain characteristic 0.5 cm diameter porphyroblastic "cross"-biotite crystals. A petrographic mode of this schist, sampled a few 10's of meters below the Nottely at this stop contains 46.2% quartz, 19.8% plagioclase, 6.8% biotite, 7.7% opaque, 6.6% sphene, 2.3% chlorite, and a trace of tourmaline. Similar rocks occur above the Nottely Quartzite Member (see Thompson and Tull, and Tull and others, this volume).

Above the marble interbeds at the base of the Mission Mountain Formation the schist described above is rather homogeneous through an interval several 10's of meters thick (Fig. 4). About a meter from the top, 1 – 2 mm diameter quartz sand grains are visible in layers approximately 2 cm thick. Immediately above this is the massive base of the lower Nottely Quartzite interval. Thus, this contact can be interpreted as gradational and conformable.

The quartzite intervals range from subarkose to quartz arenite (Thompson and Tull, this volume, Table 1).

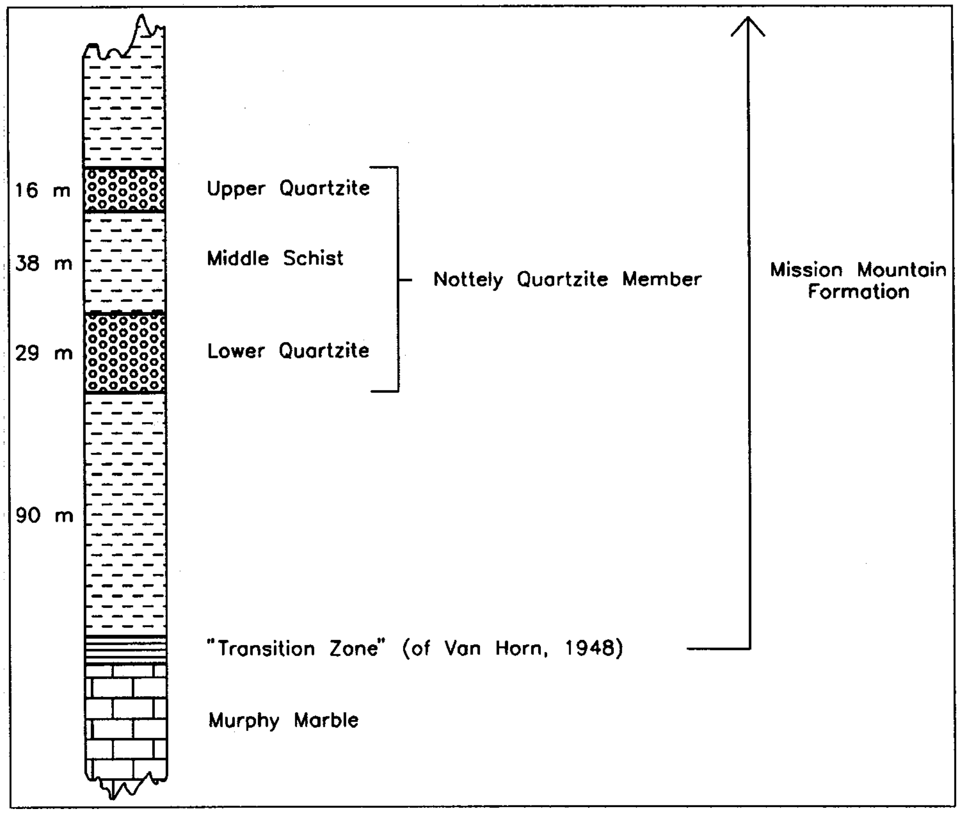


Figure 4. Stratigraphic column showing Nottely Quartzite Member of Mission Mountain Formation, SUNDAY Stop 3.

Primary sand grains are not recognizable throughout much of the interval because of recrystallization and significant grain boundary migration and suturing, but where primary grains are recognizable, the Nottely is a coarse grained metasandstone, locally containing very fine pebbles up to 3 mm long. Bedding is on a scale of several centimeters. Planar tabular crossbeds 10 – 15 cm thick with average foreset dip angles of 19° are not abundantly preserved, but have been recognized at several localities in the Murphy area. Nottely current directions (topset beds rotated to horizontal around present strike) were dominantly westward (Thompson and Tull, this volume, Fig. 4). Because the Nottely Quartzite can be mapped continuously for a least 90 km on the west limb of the Murphy syncline from near Andrews, North Carolina to White Path, Georgia, but is rarely well defined or distinguishable on the east limb of the syncline, it is probable that present structural strike is oriented near the original depositional strike of this sand body. Therefore the cross bed data indicate that current directions were highly oblique to depositional strike.

The top of the 29 m thick lower quartzite is in sharp contact with the middle schist. The interface between these two units is exposed in a sloping cliff surface facing southeastward. This interface has been deformed into asymmetric downward facing sinistral folds with wavelengths on the order of a few meters and fold axes plunging 4° S52°W. These features could conceivably be misinterpreted as primary mega-ripples, but the structures that outline the features include both bedding and metamorphic schistosity. The downward facing folds are not related to the Murphy F_1 – phase syncline, but instead are interpreted to be related to a second generation of folds oriented slightly oblique to the Murphy-phase structures. This outcrop is thus stratigraphically upright and lies on the west limb of the Murphy syncline, but the fold symmetry indicates that it also occurs on the west limb of a later antiform, probably of the generation shown in Thompson and Tull (this volume, Fig. 2 and 5).

The middle schist (Fig. 4) is a fine grained feldspathic garnet mica schist. In the upper part of the roadcut, a third generation of folds (dextral) can be seen plunging to the southwest. Secondary hematitic "iron ore" layers are common near the base of the unit and are also found at other stratigraphic levels. Exposed in the large slump debris covering most of the middle schist interval is a large boulder of sandy botryoidal "iron ore" characteristic of secondary deposits in the area. Above the middle schist is the 16 m thick upper quartzite, which is a medium to coarse grained metasandstone. Overlying this unit in sharp non gradational contact are weathered fine grained feldspathic muscovite schists typical of the Mission Mountain Formation.

0.5.5 Turn right and return south on U. S. 74-19-129, trace route back to intersection with U. S. Highway 64.

08.7 Intersection of U. S. Highways 64 and 74-19-129. Turn left (east) onto U.S. Highway 64.

09.2 Pull off onto gravel shoulder on the right side of U. S. Highway 64 and look at massive sandstone boulders on the northern bank of the Hiwassee River.

STOP 4. COARSE CLASTICS OF THE FORT BUTLER MOUNTAIN FORMATION

Troy W. Thompson and James F. Tull

WARNING:
Heavy traffic and a narrow shoulder make roadcuts on the north side of U. S. Highway 64 very dangerous. Do not attempts to cross the highway and examine these exposures.

This stop (Fig. 1) provides an easily accessible exposure to observe the coarser clastic rocks of the Fort Butler Mountain Formation of the Mineral Bluff Group. It is these resistant quartz-rich units that form the elevated topography found in the core of the Murphy belt throughout much of its length. In this area the resistant metasandstones and metaconglomerates of the formation form Fort Butler Mountain (type section to the southwest of this stop), Bell Mountain, Wildcat Mountain, Will Scott Mountain, and Mumble Head Top.

Because of the lack of a shoulder on the north side of U. S. Highway 64, we will only be able to view the exposure from the south side of the highway. However, boulders which were cleared to make this highway cut are strewn along the north banks of the Hiwassee River next to the turnout on the south side of U. S. Highway 64. We will briefly examine these boulders to get a representative idea of the nature of the coarse clastic rocks of the Fort Butler Mountain Formation.

PLEASE USE CAUTION ANDWATCH FOR BROKEN GLASS AND LOOSE BOULDERS

Individual coarse clastic intervals such as the one outcropping here range up to several 10" of meters thick and can commonly be traced continuously for several kilometers (see Thompson and Tull, this volume, Fig. 2). Similar rocks in the Mineral Bluff Group in Georgia have been described by Hurst (1955) and Tull and Groszos (1988). At this stop the rocks are medium to coarse grained feldspathic micaceous metasandstone, locally conglomeratic. Planar tabular cross beds in these units indicate that the section here is upright and that we are on the west limb of the Murphy syncline (see Thompson and Tull, this volume, Fig. 2, for stop location). Examples of these primary structures can be observed in boulders along the river bank (see flagging tape). The cross beds are about 17 cm thick and have foreset dip angles of between 20º and 30º.

Coarse clastic layers of the Fort Butler Mountain Formation are generally medium to coarse grained micaceous feldspathic metasandstones, and are locally quartz arenites (see Thompson and Tull, this volume, Table 1). We interpret the Fort Butler Mountain Formation and it's coarse clastic units to represent a coarsening and thickening upward sequence above the Mission Mountain turbidite-dominated sequence. The coarse clastics probably represent channel and more proximal debris apron components of the Mineral Bluff basin fill.

09.2 Continue east on U. S. Highway 64.

10.5 Quarry in phyllitic section of the Fort Butler Mountain Formation, on left.

12.2 Intersection with CR 1531. Pull off onto shoulder on right side of U. S. Highway 64. Be careful of oncoming traffic, cross highway and walk up to ridge top and look at massive Harshaw Bottom Quartzite.

STOP 5. TYPE SECITON OF THE HARSHAW BOTTOM QUARTZITE

Troy W. Thompson and James F. Tull

NOTE: This stop is on private land and it is only through the courtesy of and by the permission of the land owner (Mr. Bob West) that we are allowed to visit here. Please take precautions not to damage property or the recently grassed embankment leading up to the small quarry.

The unit to be examined at this stop (Fig. 1) is perhaps the most distinctive formation in the Mineral Bluff Group. The Harshaw Bottom Quartzite is named for the adjacent Hiwassee River flood plain immediately to the south of these exposures. The unit is approximately 10-0 m thick. The lower contact with the Fort Butler Mountain Formation is generally not well exposed but appears to be gradational. The upper contact is exposed in a ditch along the driveway entrance to this stop and is gradational with the stratigraphically overlying Peachtree Creek Formation (see Thompson and Tull, this volume).

The Harshaw Bottom Quartzite rims a large overturned synform cored by Peachtree Creek Formation (Thompson and Tull, this volume, Fig. 2 and 5). This synform lies to the southeast of the Murphy syncline and results from a fold generation post-dating the Murphy syncline, and in this area involves refolding of the southeast (overturned) limb of that syncline. The present structural level of map view exposure of the Murphy syncline south of the Hiwassee River is stratigraphically below the Harshaw Bottom Quartzite. Whether or not this unit is cited in the axial depression in the exposed core of the doubly plunging syncline as it extends north of the river, presently is unresolved because we have not completed detailed mapping north of the river between Murphy and Peachtree, North Carolina (Thompson and Tull, this volume, Fig. 2).

The Harshaw Bottom Quartzite is generally very pure (>97% quartz), but locally it contains significant epidote. It is also fine to very fine grained (0.1 – 0.4 mm), with a recrystallized dimensionally oriented quartz fabric defining schistosity and commonly producing a friable papery texture. Bedding can be seen in the small quarry in the woods below the crest of the ridge. Films of white mica can be seen on bedding surfaces. Quartzite benches extend along the ridge crest and can be examined above the quarry. Rare grains of coarse (1 mm diameter) blue quartz grains can be seen floating in the finely recrystallized matrix, and probably represent a detrital sand component.

The upper contact of this unit with the Peachtree Creek Formation is exposed in the driveway ditch leading up the hill from the paved road. The contact is gradational through an interval several tens of meters thick and consists of fine-grained papery quartzite interlayered with fine grained chloritic feldspathic schist. The protolith of the Harshaw Bottom Quartzite is somewhat enigmatic because few primary features are preserved. We envision the unit to have been either a very fine grained homogeneous quartz arenite or a chert. The rocks below it (Fort Butler Mountain Formation) are feldspathic and mostly compositionally immature, so rather abrupt transition into a quartz arenite would be somewhat surprising. Formation of a quartz-rich argillite or sandy chert is an alternative explanation. Other localities of this unit are locally high in epidote, so we think that parts of the protolith probably had a calcareous matrix. Lithologic similarities with the upper Talladega belt in Alabama are noted in Thompson and Tull (this volume).

12.2 Turn around and head west on U. S. Highway 64 to return to Econo Lodge.

15.7 Intersection with U. S. Highway 74-19-129 and Peachtree Street. Continue west on Peachtree Street.

15.8 Econo Lodge on right.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1991 Annual Meeting
Pages 157-161

CAROLINA GEOLOGICAL SOCIETY FIELD TRIP, SUPPLEMENTAL STOPS SUNDAY

Econo Lodge – Head south on U. S. Highway 74-19-129 to SUPPLEMENTAL STOP 1.

00.5 Intersection of Hiwassee Street (McDonald's on southwest corner) and U. S. Highway 74-19-129.

03.0 Turn right onto old U. S. Highway 64.

03.2 Turn left on 1st road seen and park or continue to next gravel road on the right (see below). Cross road and walk down the northern bank of small creek. Pass railroad trestle and outcrops are exposed just downstream on northwest bank.

03.4 Pull off of old State Road onto gravel and drive down to abandoned railroad (if there are a large number of vehicle, otherwise park on gravel road), walk to SUPPLEMENTAL STOP 1.

SUPPLEMENTAL STOP 1. METAIGNEOUS ROCKS OF THE MISSION MOUNTAIN FORMATION

Troy W. Thompson and James F. Tull

This exposure (Fig. 1, SS1) was first described by Van Horne (1948, p. 15) as a diorite or "metadiorite" which he considered to be part of a series of diorite sills occurring from 100 to 140 m both stratigraphically above and below the Murphy Marble. Van Horn (1948) mapped exposures of "sills" in four different localities on the west limb of the Murphy syncline: a) northwest of (below) the Murphy Marble 1) near Hewitt, and 2) at Kinsey, (near Ranger) North Carolina, and b) southeast of (above) the Murphy Marble 3) near the mouth of Cane Creek (this stop), and 4) in Murphy, North Carolina (see Thompson and Tull, this volume, Table 2 and 3 – sample 252 (A, B, & C)). The "sill" exposures northwest of (below) the Murphy Marble lie within the upper part of the Brasstown Formation and locally cut obliquely through bedding, and according to Van Horn (1948) these are much more continuous along strike than the "sill" exposures southeast of (above) the Murphy Marble, which lie within the lower part of the Mission Mountain Formation (Thompson and Tull, this volume). The metaigneous rocks of the Mission Mountain Formation have not been cited since Van Horn (1948) and evidence we have obtained indicate that these rocks are not intrusive in origin, but result from extrusive processes. We will discuss this evidence and describe this exposure below.

The exposure we will examine at this stop is seen on the northwest bank of Cane Creek (a tributary of the Nottely River) (Fig. 1, SS1) and is located west of CR 1304 (old U. S. Highway 64), ~30 m west of an old railroad trestle and can be observed only during low creek levels when the river is not high. The Nottely Quartzite is well exposed ~ 200 m downstream (west), near the confluence of Cane Creek and Nottely River. This outcrop is composed of 3 characteristic rock units (~ 50 m total thickness): from northwest to southeast a) metaigneous (amphibolite) unit at least 10 m thick, b) interlayered transition (?)" volcanogenic (?) and metasiltstone – metagraywacke unit ~ 30 m thick, and c) a metagraywacke interval ~ 10 m thick.

The metaigneous layer (Van Horn's diorite sill) is dominantly a green porphyroblastic amphibolite with coarse grained amphibole (0.5 – 2 cm), biotite, and opaque, surrounded by a fine grained chlorite and epidote groundmass. The geochemistry of this layer (Thompson and Tull, this volume, Table 2, 251-1E) indicates that this is probably of igneous origin (see Thompson and Tull, this volume, for a more detailed discussion of the geochemistry). Large boulders of this amphibolite are exposed on both sides of Cane Creek and interlayered with this metaigneous unit are layers and zones of pale green metagraywacke (2 – 20 cm thick) that appear to have been boudinaged. It is difficult to determine the mode of emplacement of this mafic layer based on the interlayered nature of the metasediments with the amphibolite layer. Was it intrusive or extrusive? We feel that much more compelling evidence for an extrusive origin exists when comparing the geochemistry of this layer with that of the interlayered volcanogenic (?) and metasediment material (zone 2) (see below). The lower contact of this amphibolite is not exposed and the upper contact possibly grades up into zone 2 "transition (?)".

The interlayered volcanogenic (?) and metasiltstone-metagraywacke unit (zone 2) is very distinctive and unlike any Mission Mountain exposure we have seen. Bedding is clearly displayed by the repetition of dark and light layers (N45ºE87ºNW). The following rock types can be seen throughout zone 2: volcanogenic layers (?) – dark yellowish-brown porphyroblastic biotite (0.5 – 1 cm) schist (Thompson and Tull, this volume, Table 2, 251-3F), fine grained "greenstone", and occasional porphyroblastic amphibolite (similar to amphibolite of zone 1); metasediment layers – distinctive buff to white colored epidote-rich metasiltstone-metagraywake (Thompson and Tull, this volume, Table 1, 251-3A2 and 3D), and tan phyllites. The thickness of each layer varies but in general the dark "mafic" layers are thicker (5 cm to 0.3 m thick) and more abundant than the lighter metasediment layers (2 – 8 cm thick). Geochemical analyses of the coarse biotite schist layer (Thompson and Tull, this volume, for a more complete discussion of the volcanogenic nature of this unit). The chemistry of at least part of this unit (zone 2) is comparable to other analyses along strike, and we speculate that these high Cr and Ni layers indicate an igneous origin. Thus, we further speculate that if these layers are metaigneous they must be extrusive because of their delicate interlayered relationship with the metasediments. A comparison of the metaigneous layer (zone 1 above) geochemistry with that of the interlayered volcanogenic section (zone 2) indicates they share some similar characteristics (Thompson and Tull, this volume, Table 2): high TiO_2, low SiO_2, and high transition metal values. We believe that these characteristics indicate that the metaigneous rocks of zones 1 and 2 are probably related and hence, the amphibolite of zone 1 would be extrusive.

Grading up from zone 2 lithologies are metagraywackes of zone 3 (Thompson and Tull, this volume, Table 1, 251-2A). This section is also very well exposed, exhibiting good bedding (N48ºE 64ºSE) and is massive. Possible cross-beds indicating upright facing and local medium to coarse grained detrital feldspar and blue quartz can be seen. Numerous conspicuous ellipsoidal bodies (up to 0.4 m in length) are present and may represent metasomatic zones, similar to the calc-silicates of Thompson and Tull, SUNDAY Stop 2, but less altered, or they may result from unusual weathering.

Thus, this outstanding exposure may preserve a continuum of volcanogenic and metasediment layers with zone 2 representing a transition between the metaigneous zone 1 and the metasediment zone 3.

03.4 Turn around and return to Murphy (same route taken to supplemental stop 1).

03.8 Intersection of U. S. Highway 64-74-19-129 and old U. S. Highway 64, turn left (north).

06.3 Intersection of Hiwassee Street and U. S. Highway 64-74-19-129 (McDonald's on left).

06.8 Turn left (west) on Peachtree Street, just north of Hiwassee River.

06.9 Econo Lodge on right.

07.1 Cherokee County Court House on right.

07.2 Traffic light, continue straight on Tennessee Street.

07.5 Railroad tracks.

07.7 SUNDAY Stop 1. Turn left (northwest) on Payne Street and continue toward the Murphy treatment plant. The dike is along old "Route 3" that follows the north bank of the Hiwassee River, only driveable when the lake level is down, usually only in winter.

08.3 Murphy treatment plant.

08.4 Quarry in Brasstown Formation (Power and Forrest's (1971, p. 16) stop 1).

08.5 Second quartz vein photographed byVan Horn (1948, p. 7).

08.8 Brasstown-Nantahala contact (Fig. 1) at road to CR 1361 (Power and Forrest's (1971, p. 18) stop 3). This road goes to the Joe Brown Highway below the Amoco station. This Nantahala-Brasstown Formations contact on the north side of the Hiwassee River is laminated sandstones in gradational contact with the schists of the Brasstown Formation. On the south side of the river a gradational contact is found between the schists of the Brasstown Formation and cross-bedded conglomeratic sandstones of the Nantahala Formation.

09.0 Concrete bridge across creek.

09.2 Old "Route 3" goes into the woods.

09.3 Road from Hiwassee Church comes down the hill in these woods.

09.4 "Route 3" leaves woods.

Continue for another half mile the dike is intersected 100 meters before an abrupt right turn formed by a migrating down river cut bank forming a Nantahala Formation cliff.

An alternate route is to go via the Hiwassee Baptist Church at Hanging Dog Community and walk to the dike. Drive along Joe Brown Highway past the before mentioned Amoco station on the right, two miles from the Valley River bridge. Drive another 0.4 mile and turn left into the church graveled driveway and park. A dirt road beneath a power line is cut down hill toward Lake Hiwassee. When old "Route 3" is found about a half mile down hill in the woods, turn right. When coming out of the woods look across the river at the sandstones of the Nantahala Formation which contains cross bedding as described in Aylor (this guidebook). The easiest way to get to this exposure other than going across the river is to go southwest from the traffic light in Murphy and proceed along Hiwassee St. Hardee's is 0.1 mile from this intersection. In 0.3 mile from this intersection turn right on CR 1408 after driving over W. Frank Forsyth bridge. Drive to the end of this road at the MGM brakes building at one mile from the Murphy town square location. Walk down river from this parking lot.

SUPPLEMENTAL STOP 2. MAFIC DIKE CROSS CUTTING THE NANTAHALA FORMATION

Joseph G. Aylor Jr. and Stephen A. Kish

The objective of this supplemental stop is to note the relationship of the metamorphosed mafic dike (Fig. 1 and 2, SS2) to the Nantahala Formation and to note formational contact along the river. It is easy to spot the dike from a distance because it cuts bedding at a high angle. The bedding attitude of the Nantahala Formation is N50ºE, 68ºNW, its trend represented by a dotted line of Figure 2 (SS2). This 1.2 m thick dike has the most clear cut contact relationships of all the mafic rock bodies along the Hiwassee River and its tributaries. Mafic float on trend with this dike was found across the Hiwassee River to the southwest, represented as a large filled circle. Sills found in place when measuring sections along the Nottely River include those near the old Murphy dam within the Nantahala Formation. Also, float was found along the old Whiting Railroad bed on the south side of the Hiwassee River in the Nantahala Formation in the metasiltstone but near the uppermost metasandstone. An area of sills and dikes about 20 cm thick is in the Dean Formation across the Hiwassee River from the mouth of Hanging Dog Creek.

Other igneous rocks are found as metamorphosed mafic sills, called "metadiorite" by Van Horn (1948, p. 15) in the Brasstown Formation in Die Bend of the Nottely River, five miles southwest of Murphy. The Cherokee Indians carved several turtle sculptures out of this rock type and one is in front of the Cherokee County Museum, beside the Court House in Murphy. This rock is actually a high Mg-chlorite schist.

Chemistry suggest that this dike has a nepheline normative composition (Table 1). These rocks have no original igneous texture. The texture is completely metamorphic with coarse grained biotite and light-green pleochroic amphibole, and calcite replacing plagioclase. The important chemical characteristics of these mafic rocks in the Murphy belt are elevated concentrations of TiO_2, high field strength elements such as Nb and Zr, and light rare earth elements. The apparent silica undersaturation of this sample may be due in part to metamorphic hydration and alteration,. The overall chemistry of these igneous bodies is similar to other mafic igneous rocks that were deposited in late Proterozoic to early Paleozoic times (i.e. Unicoi and Catoctin basalts) along the margin of eastern North America (Kish and others, 1991). None of the mafic rocks studied in the Murphy belt have chemical signatures that are similar to MORB-type or island arc-type tholeiitic basalts. There are no true ultramafic-type igneous bodies (i.e. ophiolites) present in the area of this study.

Contacts of Dean-Nantahala Formations and Nantahala-Brasstown Formations can be found on both sides of the Hiwassee River in this area (Fig. 2). On the north side of the Hiwassee River the Nantahala-Dean Formations contact is covered, but siltstone of the Nantahala Formation is on the eastern side and

Table 1. Hiwassee River dike.

Chemistry		CIPW Norm		Mode	
SiO_2	43.1	Orthoclase	15.66	Plagioclase	21.1
TiO_2	1.91	Albite	9.16	Orthoclase	0.5
$A1_2O_3$	14.3	Anorthite	26.13	Biotite	28.6
Fe_2O_3	3.41	Diopside	22.4	Hornblende	35.8
FeO	9.54	Olivine	14.15	Magnetite	4.6
MnO	0.3	Forsterite	(7.80)	Ilmenite	
MgO	6.57	Fayalite	(6.36)	Calcite	9.4
CaO	10.4	Magnetite	5.26		
Na_2O	1.59	Ilmenite	3.87		
K_2O	2.49	Apatite	0.55		
P_2O_5	0.22	Nepheline	2.83		
LOI	4.7				
Total	98.88				
Calculation of Fe^{++}/Fe^{+++} by the method of Irvine and Baragar (1971))					

coarse-grained quartz-muscovite schist of the Dean Formation is on the western side. On the south side of the river the Nantahala Formation is in gradational contact for less than a meter with a foliated schist of the Dean Formation. A thin section study of a crenulated siltstone from the Dean Formation along the Joe Brown Highway near the Nantahala Formation contact at the quarry (stop 5 of Power and Forrest (1971, p. 19)) contained quartz, garnet, chloritoid (?), muscovite, and biotite. The Nantahala Formation is a laminated quartz biotite-muscovite siltstone and fine-grained sandstone.

REFERENCES CITED

Aylor, J. G., Jr., Tull, J. F., and Walker, Dan, 1991, Comparison of the Lower Murphy Group, North Carolina with the Lower Chilhowee Group, eastern Tennessee: Geological Society of America Abstracts with Programs, v. 23, p. 4.

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 Paleozoic Stratigraphy in the western Blue Ridge: Carolina Geological Society Field Trip Guidebook.

Brown, W. R., 1970, Investigations of the sedimentary record in the Piedmont and Blue Ridge of Virginia, 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. 335-349.

Cathey, J. H., 1899, The Genesis of Lincoln, 307p.

Cashion, J. C., 1970, Fort Bulter and the Cherokee Indian removal from North Carolina (a draft report prepared for the state division of Archives History), 2, p. 45 – 47.

Dockery, Carl, ed., 1989, Marble and Log, The History and Architecture of Cherokee County, North Carolina: Murphy, Cherokee County Historical Museum, 141 p.

Ehlers, E. G., and Blatt, Harvey, 1982, petrology: Igneous, Sedimentary, and Metamorphic: New York, W. H. Freeman and Company, 732 p.

Forrest, J. T., Jr., 1975, Geologic evolution of a portion of the Murphy Marble belt in southwestern North Carolina [Ph.D. dissertation]: Houston, Rice University, 76 p.

Hatcher, R. D., Jr., 1978, Structure in the Mineral Bluff Formation at Murphy, North Carolina, in Milici, R. C., ed., Field trips in the southern Appalachians: Tennessee Division of Geology Report of Investigation No. 37, p. 42 – 45.

Hurst, V. J., 1955, Stratigraphy, structure, and mineral resources of the Mineral Bluff quadrangle, Georgia: Georgia Geological Survey Bulletin 63, 137 p.

Irvine, T. N., and Baragar, W. R. A., 1971, A guide to the chemical classification of the common volcanic rocks: Canadian Journal of Earth Science, V. 8, p. 523 – 548.

Keith, A., 1907, Description of the Nantahala quadrangle, North Carolina and Tennessee: U. S. Geological Survey Geologic Atlas, Folio no. 143, 11p.

Keith, Arthur, and Hayes, C. W., compiled by King, P. B., 1950, Geologic of the Murphy quadrangle, Tennessee-North Carolina: U. S. Geological Survey open-file report 50 – 02.

King, P. B., 1949, The base of the Cambrian in the southern Appalachians: American Journal of Science, v. 247, p. 622 – 645.

Kish, S. A. Campbell, S. K., Groszos, M. S., and Tull, J. F., 1991, Geochemistry and petrology of metaigneous rocks in Murphy syncline, Tate, Georgia: Geological Society of America Abstracts with Programs, v. 23, #1, p. 53.

LaTour, T. E., and Fritz, W. J., 1988, Volcanogenic character of parts of the Mineral Bluff Formation: Evidence from field and geochemical studies, in Fritz, W.J., and LaTour, T. E., eds., Geology of the Murphy belt and related rocks Georgia and North Carolina: Georgia Geological Society Guidebook, v. 8, no. 1, p. 75 – 93.

Mohr, D. W., 1973, Stratigraphy and Structure of part of the Great Smoky and Murphy belt Groups, western North Carolina: American Journal of Science, Cooper v. 273-A, p. 41-71.

Power, W. R., and Forrest, J. T., 1971, Stratigraphy and structure of the Murphy belt, North Carolina: Carolina Geological Society, Annual Field Trip Guidebook, 29 p.

Power, W. R., and Forrest, J. T., 1973, Stratigraphy and Paleogeography in the Murphy Marble belt: American Journal of Science, v. 273, p. 698 – 711.

Rast, Nicholas, and Kohles, K. M., 1986, The origin of the Ocoee Supergroup: American Journal of Science, v. 286 p. 593 – 616.

Sakowski, Carolyn, 1990, Touring the western North Carolina backroads: Winston-Salem, John F. Blair Publisher, 305 p.

Schwab, F. F., 1972, The Chilhowee Group and the late Precambrian-early Paleozoic sedimentary framework in the central and southern Appalachians, in Lessing, Peter, Hayhurst, R. I., Barlow, J. A., and Woodfork, L.D., eds., Appalachian structures: Origin, evolution, and possible potential for new exploration frontiers: West Virginia University and West Virginia Geological and Economic Survey, Seminar, P. 59 – 86.

Thomas, W. T., and Hatcher, R. D., Jr., 1988, Deep-water off-shelf passive-margin setting of deposition of the rocks in the Murphy belt: Another outrageous hypothesis, in Fritz, W. J., and LaTour, T. E., Geology of the Murphy belt and related rocks, Georgia and North Carolina: Georgia Geological Society Field Trip Guidebook, v. 8, #1, p. 103 – 109.

Thompson, T. W., and Tull, J. F., 1991, Stratigraphy and of the Mineral Bluff Group, southwestern North Carolina, in Kish, S. A., ed., Studies of Precambrain Paleozoic Stratigraphy in the western Blue Ridge. Carolina Geological Society Field Trip Guidebook.

Tull, J. F., Thompson, T. W., Groszos, M. S., Aylor, J. G., Jr., and Kish, S. A., 1991, Murphy belt lithostratigraphic nomenclature, in Kish, S. A., ed., Studies of Precambrian and Paleozoic Stratigraphy in the Western Blue Ridge: Carolina Geological Society Field Trip Guidebook.

Tull, J. F., and Groszos, M. S., 1988, Murphy belt: stratigraphic complexities and regional correlations, in Fritz, W. J., and LaTour, T. E., eds., Geology of the Murphy Belt and related rocks Georgia and North Carolina: Georgia Geological Society Guidebook,. 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., Thompson, T. W., Groszos, M. S Aylor, J. G., and Kish, S. A., 1991, Murphy belt lithostratigraphic nomenclature, in Kish, S. A., ed., Studies of Precambrian Paleozoic Stratigraphy in the western Blue Ridge: Carolina Geological Society Field Trip Guidebook.

Van Horn, E. C., 1948, Talc deposits of the Murphy Marble belt: North Carolina Department of Conservation, Div. Mineral Resources Bulletin 56, 54 p.

Walker, Dan, Skelly, R. L., Cudzil, M. R., and Driese, S, G., 1988, The Chilhowee Group of east Tennessee: Sedimentology of the Lower Cambrian fluvial-to-marine transition, in Driese, S. G., and Walker, Dan, eds., Depositional history of Paleozoic sequences, southern Appalachians: Knoxville, Tennessee, University of Tennessee, Department of Geological Sciences, Studies in Geology 19, p. 30 – 61.

Walker, Dan, 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.

White, A.D., ed., 1987, The Heritage of Cherokee County, North Carolina, v. 1: Cherokee County Historical Museum, Winston-Salem, Hunter Publishing Co., 599p.

Whisonant, R.C., 1974, Petrology of the Chilhowee Group (Cambrian and Cambrian(?)) in central-eastern and southern Tennessee: Journal of Sedimentary Petrology, v. 44, p. 288 – 241.

Winkler, H. G. F., 1979, Petrogenesis of metamorphic rocks: New York, Springer-Verlag, 348 p.