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## THE ORIGIN OF THE OCOEE SUPERGROUP

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**ABSTRACT.** The Ocoee Supergroup consists of Late Precambrian sediments at the Appalachian edge of the Laurentian Shield (Kentucky-Tennessee Platform). These deposits are unconformably or disconformably overlain by the Early Cambrian or the latest Precambrian Chillhowee Group. In the Tennessee-North Carolina area the Ocoee Supergroup is divided into three major groups which occur in thrust slices but are not present in the well-borings of the platform. The earlier sediments are shallow-water high energy (marine?) clastics (Snowbird Group) passing up into turbidites (Great Smoky Group). These are overlain by another shallow-water clastic sequence (Walden Creek Group). The cycle in the Great Smoky Group is repeated twice, and the second cycle ends with euxinic shales. The earliest sediments (Snowbird Group) had provenance to the southeast, and the later sediments (Great Smoky-Walden Creek Groups) to the northwest. Two models can explain this. Model 1 envisions the deposition of the Snowbird derived from an easterly gneissic terrain (a Precambrian welt) and the Great Smoky-Walden Creek sediments derived from the northwest (Laurentian terrain). Model 2 involves the deposition of the Snowbird on the one hand and the Great Smoky on the other, on either side of the ridge with apparent provenance being away from this ridge (to the southeast and northwest). The Walden Creek sediments overstep these deposits. The present day relationships of the Snowbird, Great Smoky, and Walden Creek groups are explained by later overthrusting arising from the depositional basins. Sedimentary facies relations of the Great Smoky Group and Walden Creek Group are more consistent with Model 2. Thus the Ocoee Supergroup represents the deposition in extensional basins that have been compressed and overthrust during Lower Paleozoic orogenic events.

### INTRODUCTION

The Late Precambrian Ocoee Supergroup, a large body of mainly terrigenous clastic sedimentary rocks, composes much of the western Blue Ridge Province in the central and southern border area of Tennessee and North Carolina, in northern Georgia, including the Great Smoky Mountains (fig. 1), and probably in Alabama (John Rodgers, personal commun.). The Ocoee Supergroup is unfossiliferous, and no volcanic units have been reported from it. It lies unconformably upon Grenville basement of gneissose and granitic rocks and is capped locally by the Cambrian-Pre-

GEOLOGY OF THE SOUTHERN  
BLUE RIDGE

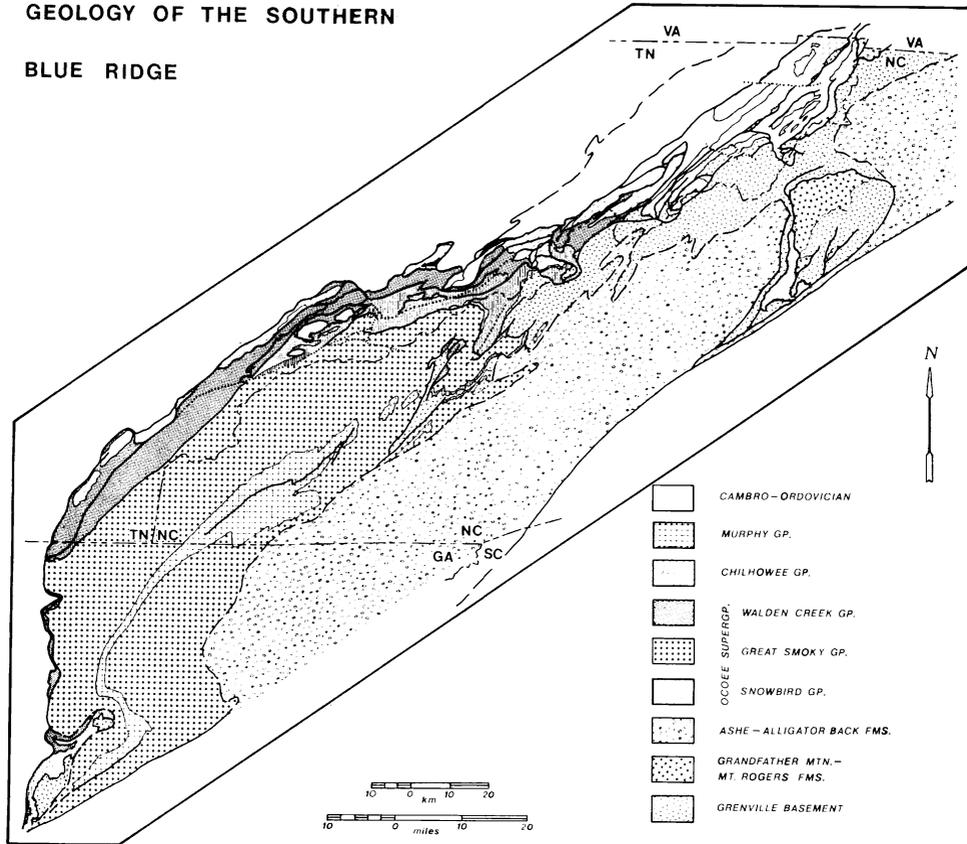


Fig. 1. Geographical distribution of the Ocoee Supergroup in the Southern Appalachians (modified from Hadley, 1970).

Cambrian(?) clastic Chilhowee Group to the northwest and the carbonates and shales of the Murphy syncline in the southeast.

The entire sequence, in varying degrees, has been affected by three major compressional episodes of deformation (table 1). An Ordovician event (Taconian) generated folding and later thrust movements principally along the Greenbrier fault (fig. 2), and also subsequent regional metamorphism varying from greenschist facies in the northwest to amphibolite facies or even possibly granulite facies (Absher and McSween, 1985) in the southeast. A Late Devonian event (Acadian) resulted in a ductile shear zone, the Fries fault (fig. 2) (Bartholomew, 1983; Bartholomew and Lewis, 1984), and a Permo-Carboniferous event (Alleghanian) transported the entire body northwestward along the Great Smoky fault (fig. 2). These deformational events have complicated the stratigraphic relationships within the Ocoee Supergroup and have made interpretations

TABLE 1  
Tectonic history of compressional events in the Southern Appalachians

Age	Orogenic event	Areas affected	Major structures	Volcanism and plutonism	Metamorphism
About 330-240 Ma	Alleghanian	Valley and Ridge, Blue Ridge, and Piedmont	Valley and Ridge thrusts; Blue Ridge thrusts (Great Smoky and associated thrusts); some movement along the Brevard zone; open to tight folds; cleavage	Granitic and gabbroic plutons (330-260 Ma)* Volcanism-bentonite layers found in Pennsylvanian sequences	Anchimetamorphism; greenschist to lower amphibolite facies?; metamorphic peak 250 Ma‡; retrograde metamorphism along fault zones
About 390-350 Ma	Acadian	Blue Ridge and Piedmont	Fries thrust system** reactivation of Brevard zone; open to tight folds	Pegmatites, granitic plutons	Low to high grade (biotite to sillimanite-kyanite); metamorphic peak 390 Ma‡
About 480-440 Ma	Taconian	Blue Ridge and Piedmont	Greenbrier and Hayesville thrusts; Brevard zone; isoclinal recumbent folds; open folds; two? cleavages	Pegmatites, granitic and gabbroic plutons	Very low grade to high grade (sillimanite-kyanite); metamorphic peak, 470 Ma; retrograde metamorphism of Grenville basement
About 620-570 Ma	Virgilina-Avalonian	Piedmont	Open buckle folds	Granitic plutons (pre- and post-orogenic); volcanism-felsic, intermediate, and mafic***	
About 1,100-900 Ma	Grenville	Exposed in Blue Ridge and Piedmont		Migmatites	High grade (including amphibolite, shallow granulite, and deep granulite facies)**

\* Sinha and Zietz, 1982.

\*\* Bartholomew and Lewis, 1984.

\*\*\* Glover and Sinha, 1973.

‡ Sutter, 1982.

**MAJOR FAULTS OF THE SOUTHERN  
BLUE RIDGE**

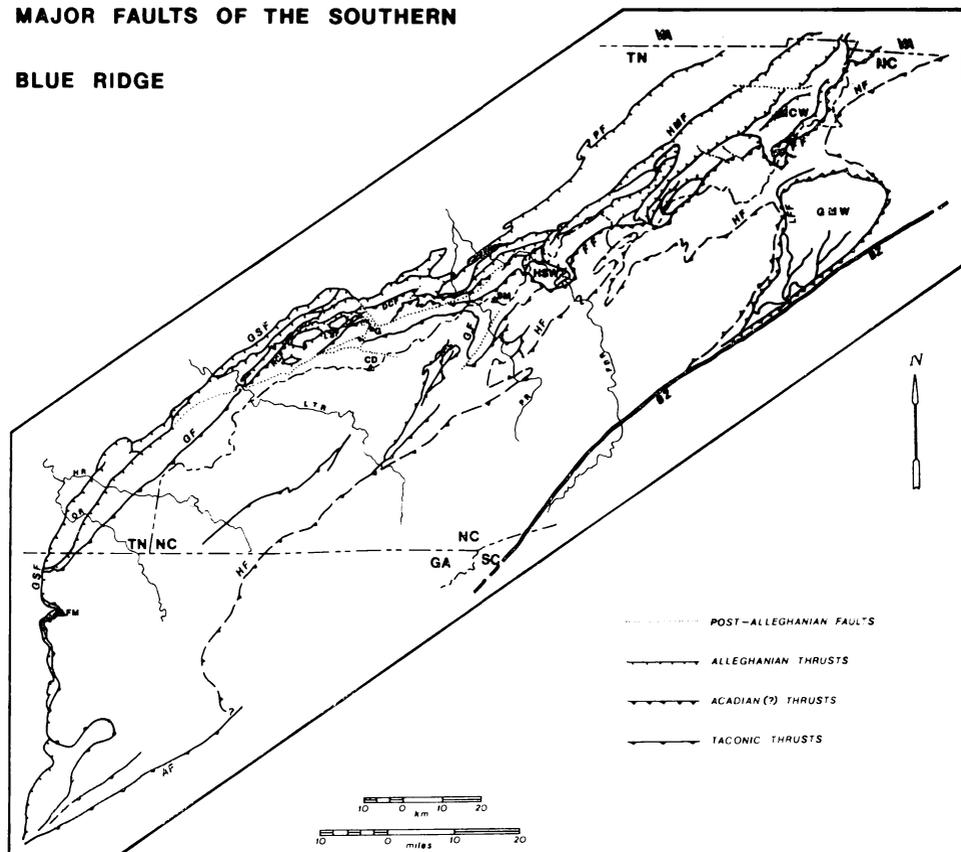


Fig. 2. Important geographic localities and positions of major fault structures. Localities: CD—Clingman's Dome, FM—Fort Mountain area, G—Gatlinburg, GMW—Grandfather Mountain window, HSW—Hot Springs window, MCW—Mountain City window, SM—Snowbird Mountain. Rivers: FBR—French Broad, HR—Hiwassee, LTR—Little Tennessee River, OR—Ocoee, PR—Pigeon. Thrust faults: AF—Allatoona fault, BZ—Brevard Zone, DCF—Dunn Creek fault, FF—Fries fault, GF—Greenbrier fault, GSF—Great Smoky fault, HF—Hayesville fault, HMF—Hoston Mountain fault, LLF—Linville Falls fault, LSF—Line Springs fault, PF—Pulaski fault, RCF—Rabbit Creek fault.

of its origin problematic, since large sections of the supergroup are now in mechanical rather than stratigraphic contact. These sections, arranged in thrust sheets of various ages, were affected by later folding that produced domes and depressions, the erosion of which resulted in a large number of tectonic windows. To the southwest of the Great Smoky Mountains the Hayesville thrust (fig. 2), identified by Hatcher (1978), truncates the outcrop of the Ocoee Supergroup *sensu stricto*. Despite these complications there have been tentative attempts to correlate it to other assemblages (Hadley, 1970; Rankin, 1975; Schwab, 1984; Wehr and Glover, 1985), both along and across the Appalachian trend.

## STRATIGRAPHIC CLASSIFICATION AND PREVIOUS INVESTIGATIONS

Rocks of the Ocoee Supergroup (henceforth abbreviated as the Ocoee) were first recognized by Safford (1856, 1869) as the Ocoee conglomerate and slate, occurring along the gorge of the Ocoee River in southeast Tennessee (fig. 2). Keith, at the turn of the century, mapped the Ocoee in a number of geologic folios. His early interpretations of the stratigraphic order (1895, 1896) are by today's standards chaotic, since he was not aware of large thrust faults that disrupt the stratigraphic sequence. Later he proposed a new classification and took thrusting into account (1904, 1907). This classification consisted of Precambrian "Archean" Carolina and Roan gneisses and Max Patch and Cranberry granites, overlain by the "Cambrian" Snowbird Formation, Hiwassee slate, Great Smoky conglomerate, and Nantahala slate. A radically different succession of the Ocoee in the Great Smoky Mountains was proposed by Stose and Stose (1944, 1949). In their work they proposed the term Ocoee series, which was divided into the Hurricane graywacke, the Great Smoky quartzite, and the Nantahala slate.

The presently accepted stratigraphic classification of the Ocoee Supergroup was developed by the officers of the U.S. Geological Survey, P. B. King, J. B. Hadley, W. H. Nelson, R. B. Neuman, W. H. Hamilton, R. Goldsmith, and others. King and others (1958) observed the Ocoee Supergroup (Ocoee series at that time) as an estimated 12 km succession of strata, composed of a number of monotonous sequences of terrigenous clastics, predominately coarse-grained and texturally and mineralogically poorly sorted. Carbonates are uncommon but have been recorded, especially from the upper parts of the Ocoee sequence (Safford, 1869; Hamilton, 1961). It was also noted that the sequences, both vertically and laterally, were commonly gradational. Nevertheless, they divided the Ocoee into three broad major lithologic units, referred to as the Snowbird Group, the Great Smoky Group, and the Walden Creek Group. Each of these groups contains several constituent formations (table 2), while a few unclassified units are not fitted into any particular group.

As shown in table 2, the stratigraphic subdivisions by King and others (1958) actually contain two sequences, one lying north of and below the Greenbrier fault and another lying south of and above it. This structural division was most important to the classification, as it allowed for the stratigraphic ordering of Ocoee units within each of the two sequences to be made with relative certainty (Keller, ms).

## SEDIMENTOLOGY AND PALEOGEOGRAPHY

The recognition of the succession of the Ocoee Supergroup has led to a number of analogous interpretations of its origin. Hadley and Goldsmith (1963) and King (1964) proposed, on the basis of paleocurrents and heavy minerals, the provenance of the Ocoee sediments as follows: the source area for the Snowbird Group was to the east or southeast, for the Great Smoky Group to the northeast, and for the Walden Creek Group to the northwest. King (1964) also suggested that the Great Smoky sedi-

TABLE 2

Age	Succession A: Northwest of and below the Greenbrier fault	Succession B: Southeast of and above the Greenbrier fault									
Middle Cambrian through Middle Ordovician	Knox Group Conasauga Group Rome Formation	Murphy Group									
Early Cambrian	Chilhowee Group										
Late Precambrian	<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small; margin-right: 5px;">Ocoee Supergroup</div> <table border="1" style="border-collapse: collapse;"> <tr> <td style="text-align: center; width: 150px;">Walden Creek Group</td> <td>Sandsuck Formation Wilhite Formation Shields Formation Licklog Formation</td> </tr> <tr> <td style="text-align: center;">Unclassified Formations</td> <td>Sandstones of Webb Mountain and Big Ridge Cades Sandstone Rich Butt Sandstone</td> </tr> <tr> <td style="text-align: center;">Snowbird Group</td> <td>Metcalf Phyllite Pigeon Siltstone Roaring Fork Sandstone Longarm Quartzite Wading Branch Formation</td> </tr> </table> </div>	Walden Creek Group	Sandsuck Formation Wilhite Formation Shields Formation Licklog Formation	Unclassified Formations	Sandstones of Webb Mountain and Big Ridge Cades Sandstone Rich Butt Sandstone	Snowbird Group	Metcalf Phyllite Pigeon Siltstone Roaring Fork Sandstone Longarm Quartzite Wading Branch Formation	<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small; margin-right: 5px;">Ocoee Supergroup</div> <table border="1" style="border-collapse: collapse;"> <tr> <td rowspan="2" style="text-align: center; width: 100px;">Great Smoky Group</td> <td>Anakeesta Formation Thunderhead Sandstone Elkmont Sandstone</td> </tr> <tr> <td>Roaring Fork Sandstone Longarm Quartzite Wading Branch Formation</td> </tr> </table> </div>	Great Smoky Group	Anakeesta Formation Thunderhead Sandstone Elkmont Sandstone	Roaring Fork Sandstone Longarm Quartzite Wading Branch Formation
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Great Smoky Group	Anakeesta Formation Thunderhead Sandstone Elkmont Sandstone										
	Roaring Fork Sandstone Longarm Quartzite Wading Branch Formation										
Earlier Precambrian	Grenville basement										

\* Successions A and B can be cross-correlated only at the level of the Snowbird Group.  
(modified from King and others, 1958)

ments were "deep-water" turbidites, while the Walden Creek Group was composed of unstable shelf deposits. He was uncertain of the Snowbird Group's origin; in particular, he was concerned for the lack of obvious explanation of the great thickness of fine-grained Metcalf Phyllite in the Snowbird Group.

Because of the Ocoee's great thickness, suggesting rapid deposition and poor sorting of the strata, Rodgers (1972) expressed an opinion that sedimentation was contemporaneous with and caused by local uplifts and downwarps. Rankin (1975) agreed and suggested a mechanism of Late Precambrian block faulting to cause the uplifts and downwarps. He envisioned the Ocoee sediments as occupying "a large and deep basin" formed as a result of extension of the continental crust by rifting during the initiation of the proto-Atlantic Ocean. Rankin (1975) also pointed out that the lack of volcanics and the position on the western flank of the Blue Ridge anticlinorium suggest that the Ocoee strata were deposited well west of the main spreading center of the proto-Atlantic Ocean. De Windt (1975) also recognized that rifting and graben formation played a part in the origin of the Ocoee. His more detailed examination of the sedimentological and stratigraphic aspects led to inferences of paleogeography and paleoenvironments for each of the major Ocoee units.

*The Snowbird Group* rocks are present both above and below the Greenbrier fault, although above the fault only the basal three of the five named formations occur (table 2), and the sequence is only one tenth as thick as that found below the Greenbrier thrust (King and others, 1958; King, 1964). King and others (1958) described the Snowbird as a conformable and intertonguing sequence of feldspathic sandstones, siltstones, and argillaceous rocks, generally fining laterally to the northwest. De Windt (1975) considered the partly pebbly, feldspathic quartzites and slates of the Wading Branch Formation (table 2), the thin basal unit of the Snowbird Group, as reworked alluvial deposits of the deeply weathered Grenville basement. The moderately well-sorted feldspathic quartzites and arkoses of the Longarm Quartzite with characteristic middle-size cross-bedding and ripple marks, he considered to be a transgressive fluvio-deltaic sequence with littoral sands. The indication of a westward to northwestward paleocurrent direction by cross-bedding and the presence of heavy detrital minerals (magnetite, epidote, and sphene) led him to the suggestion that the Longarm Quartzite was derived from Grenville basement to the southeast and deposited in a transgressive sea.

The units overlying the Longarm Quartzite are the Roaring Fork Sandstone and the Pigeon Siltstone. The Roaring Fork Sandstone is a massive medium- to fine-grained feldspathic quartzite, with ripple marks and horizons of shales, while the Pigeon Siltstone is composed of thinly laminated to massively bedded siltstone, with minor interbeds of argillite and feldspathic sandstone showing current bedding and slump structures (King and others, 1958; De Windt, 1975; our observations). De Windt (1975) noted the same heavy detrital minerals in the Roaring Fork Sandstone and Pigeon Siltstone that were found in the Longarm Quartzite

and, as current-ripple bedding indicates a continued westward to north-westward transport, supported a continued eastern to southeastern source. He suggested that "the Roaring Fork and Pigeon succession may represent delta-front, interdeltic, and prodeltic deposits laterally transitional between the shallow-water Longarm and deeper-water Metcalf phases" (De Windt, 1975, p. 90).

For the substantial thickness of argillaceous siltite composing the Metcalf Phyllite, De Windt (1975) suggested deposition possibly through the action of turbidity currents in a rapidly subsiding deep basin with possible source areas to the west, northwest, and southwest as well as the east. Considerable search by us did not reveal any secure indications of turbidite activity such as well-developed grading, unsorted sediments, or flute casts, et cetera. Therefore, we consider it as an offshore basinal deposit of shales and thin sandstones related to a prodelta.

The Cades and Rich Butt sandstones and the sandstones of Webb Mountain and Big Ridge, considered as unclassified (table 2) (King and others, 1958), are isolated lenticular units restricted to the sequence below the Greenbrier fault and laterally related to the Metcalf Phyllite and Pigeon Siltstone of the Snowbird Group. However, they resemble more closely the sandstones of the Great Smoky Group, being massively bedded but unsorted, commonly graded, and with interbeds of dark argillites. An eastern source for these units was proposed by Neuman and Nelson (1965). De Windt (1975) viewed the Cades and Rich Butt as "localized deep-water turbidite fans" deposited on the eastern margin of the "Metcalf basin." We agree with this observation with regard to the Rich Butt Sandstone and sandstones of Webb Mountain and Big Ridge, but we disagree for the Cades Sandstone (compare paragraph below and p. 603).

*The Great Smoky Group* is a very thick mass of clastic rock containing conglomerates, coarse- to fine-grained sandstones, and silty or argillaceous units and has been divided into the Elkmont Sandstone, the Thunderhead Sandstone, and the Anakeesta Formation (table 2) (King and others, 1958). It is restricted to the sequence above the Greenbrier fault. In the Great Smoky Mountains the Thunderhead Sandstone forms the thickest part of the succession of the Great Smoky Group. The Thunderhead is characterized by thick clastic beds often graded and unsorted. Abundant pebbles of vein and blue quartz and angular fragments of feldspar are suspended in a coarse sandy matrix. Most graded sequences contain pebbly conglomerates at the base and are capped by thin dark argillites. De Windt (1975) and King (1964), among others, have interpreted the Thunderhead strata as turbidites deposited in a deep elongated basin or basins. The laterally variable stratigraphy indicates extensive submarine facies. Hadley and Goldsmith (1963) suggested a distant north-eastern source for these strata because of the abundance of leucogranitic rock fragments. De Windt (1975) supported this suggestion by pointing out the lack of sphene and epidote grains, which were common in the Snowbird strata, and the thickening and coarsening of the Thunderhead conglomerates to the northeast.

The Elkmont Sandstone is the basal unit of the Great Smoky Group and, according to King and others (1958), intertongues laterally with the overlying Thunderhead Sandstone and is lithologically somewhat similar to it. It consists of feldspathic sandstones which are finer-grained and thinner and contains silty and argillaceous units which are thicker and more abundant than those in the Thunderhead. Graded bedding is present but often is not very prominent (King and others, 1958). De Windt (1975) suggested that the Elkmont Sandstone is transitional between the delta front and prodeltaic deposits of the Snowbird Group and overlying basinal Thunderhead turbidites.

The upper unit of the Great Smoky Group, the Anakeesta Formation, intertongues with the Thunderhead Sandstone and is composed of dark silty and argillaceous strata rich in carbon and sulfides. They also contain lenses of coarse sandstone similar to the Thunderhead Sandstone (King and others, 1958). De Windt (1975) proposed that the Anakeesta argillites were deposited in "deep, euxinic pockets of the basin(s)" (p. 93), which was presumably filling up.

*The Walden Creek Group* is described by King and others (1958) as a lithologically heterogeneous succession of siltstones and shales with conglomerates and sandstones in discontinuous masses. Minor units of limestone and dolomite are also present, often as sedimentary breccias of Cow Head type (compare McIlreath and James, 1979). The group is variable and has been divided into several distinct formations (table 2). De Windt (1975), following King (1964), considered the Walden Creek Group as deposits of an unstable, shallow marine shelf with a nearby northwest provenance. He cited the lenticular distribution and brecciated texture of carbonate units and the poorly sorted conglomerates with angular rock fragments as evidence for reworking of shallow-water deposits under unstable conditions. The northwest provenance was indicated by cross-bedding, pebble imbrication, and asymmetrical load casting. Keller (ms) demonstrated that the Walden Creek is conformable on the Snowbird Group.

#### BASIN ANALYSIS

The broad sedimentological analysis of the Ocoee Supergroup by De Windt (1975) and his predecessors (King and others, 1958) is based on sound data. The rocks they examined are sufficiently low grade to permit the preservation of many sedimentary structures, especially in the western and northwestern parts of the area. To the east and southeast the higher grade of metamorphism and complicated tectonics, including the involvement of the Hayesville fault (Hatcher, 1978) and pronounced polyphase deformation, obscure many sedimentary structures and distort the primary sedimentary directional indicators, so that it is difficult to restore them to their original orientation. De Windt (1975) does not state how structural corrections were done to obtain original paleocurrent directions. An important difficulty in deducing the true direction of paleocurrents from cross-bedding is the heterogeneous distortion the rocks have suffered. King

(1964, p. 36) compares the very different (undeformed and strained) shapes of concretions in the Thunderhead Sandstone with different intensities of foliation. Thus most reported paleocurrent measurements, at present, must be considered unreliable. Therefore, directions of derivation are most dependable if deduced from the types of lithological materials. Thus, indications of source are provided by lateral coarse to fine variations, heavy mineral grains, and rock and mineral fragments.

Laterally, the Ocoee succession, which is 12 to 16 km in the Great Smoky Mountains, thins and apparently dies out north of Asheville (North Carolina) and thins to a maximum of 5 km in northwest Georgia (McConnell and Costello, 1984). In Alabama a thick sequence of clastic sediments, originally mapped as Talladega by Butts (1926, 1940), underlies the equivalents of the Chilhowee Group, and therefore Ocoee sediments are present and have been so indicated by McConnell and Costello (1982).

The Snowbird Group is the most extensive and stretches from the Unaka Mountains of northeastern Tennessee to the Cartersville (McConnell and Costello, 1982) area of northwestern Georgia (fig. 1). At the former locality it is mapped as an undifferentiated sequence of psammitic rocks probably equivalent to Longarm and Roaring Fork quartzites, and it thus continues to the Great Smoky Mountains where its lower part also contains the Wading Branch Formation, which appears unconformable on basement crystallines. In Georgia (McConnell and Costello, 1982) the only lithology recorded that is similar to Longarm Quartzite is unconformable on the basement. In the Great Smoky Mountains the Snowbird sequence thins rapidly to the southeast (King and others, 1958, p. 956) suggesting its derivation from a southeasterly source. Where the Walden Creek Group overlies the Snowbird sequence, it also shows facies variations which are accentuated below the alleged unconformity (King, 1964) overlain by the Chilhowee succession. The group is highly lenticular. Based on the differences in its facies in the Great Smoky sheet (fig. 1) where it outcrops as a thick sequence, the Del Rio and Hot Springs thrust sheets where it is thicker (Keller, 1980), and the Hot Spring window (Oriol, 1950) where it is very thin and consists entirely of the Sandsuck Formation, its derivation can be either from the northwest or southeast, although King (1964) and De Windt's (1975) sedimentary structures inferred a northwesterly source. The relationship of the Walden Creek sequence within the various thrust sheets are diagrammatically shown in figure 3. It indicates that if the thrust sheets shown in figure 3A are pulled back, the thinnest and the least complete sequence (fig. 3B) lies to the northwest. At first it thickens to the southeast, but then starts thinning again. We suggest that this represents a two-sided (symmetric) basin during Walden Creek deposition in contrast to the earlier asymmetric basin suggested for the Snowbird Group (fig. 3C).

Lastly, the Great Smoky Group, although it underlies a large part of the area considered, including much of the Great Smoky Mountains (fig. 1), is effectively limited in its distribution by structural contacts (Greenbrier and Hayesville faults). These structures along with local variations

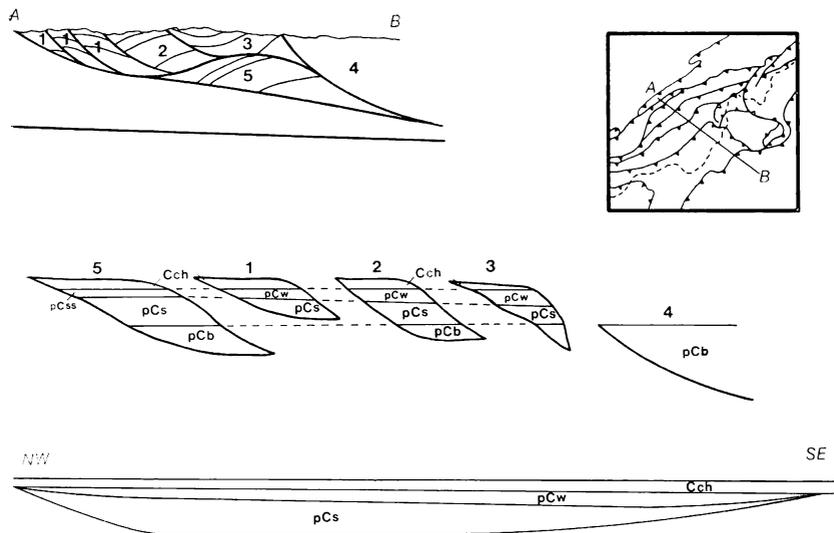


Fig. 3. Relationships among successions in separate thrust sheets in northeast Tennessee and North Carolina.

A. Schematic relationships of thrust sheets (1—Great Smoky, 2—Del Rio, 3—Hot Springs, 4—Fries, Rector Branch, 5—Inner Hot Springs). After Keller (ms) and Oriel (1950).

B. Stratigraphic sequences within each thrust sheet. pCb—plutonic Grenville basement, pCs—Snowbird Group, pCw—Walden Creek Group, pCs—only Sandsuck Formation of the Walden Creek Group, Cch—Chilhowee Group.

C. Schematic representation of basal setting for the Snowbird and Walden Creek groups.

obscure the overall facies relations of the group. King and others (1958, p. 959) and De Windt (1975, p. 91) have indicated, however, a general thickening and development of finer grained sequences in strata to the southwest and southeast suggesting derivation from the northeast or northwest.

The distribution of detrital heavy minerals and rock and mineral fragments in the strata of the Ocoee Supergroup has been investigated by Hamilton (1961), Hadley and Goldsmith (1963), King (1964), and Neuman and Nelson (1965). A review of their data, presented in table 3, has revealed several important features which are emphasized below:

A. A significant component of the sandstones and conglomerates of the Great Smoky Group is rutiliferous blue quartz, which has presumably been derived from a charnockitic (granulite) terrain. Problematic sandstones such as the Rich Butt and those of Webb Mountain and Big Ridge likewise contain such quartz and probably were derived from a similar source, but the Cades Sandstone, unlike these, has no blue quartz and therefore must have been derived from a different source and may belong to the Snowbird Group.

B. Zircon and tourmaline among detrital heavy minerals are normally absent in the Snowbird Group, though traces appear in the upper

TABLE 3  
Composition and distribution of detrital heavy mineral grains and rock and mineral fragments  
in the Ocoee Supergroup. Compiled from Hamilton (1961), Hadley and Goldsmith (1963),  
King (1964), and Neuman and Nelson (1965)

		Rip-up clasts	Conglomeratic pebbles					Large rock fragments				Heavy minerals						
		Pelite Carbonate	Quartzite Vein quartz Blue quartz Feldspar Chert Granite/gneiss				Quartzite/Ss. Carbonate Granite Gneiss				Magnetite Ilmenite Apatite Epidote Sphene Leucocoxene Zircon Tourmaline Rutile							
Walden Creek Group	Sandsuck Formation	+	*	+	+	+								o	o	o	x	o
	Wilhite Formation (Upper member)	+	*		+		*				o		o	o		o	o	o
	Wilhite Formation (Lower member)	*	*	*		+	+	+		o	o	o	o	x	x	o	o	
	Shields Formation	*	*	*	*	+	+	+						o	o	o		
	Licklog Formation			*														
Great Smoky Group	Anakeesta Formation	*		+	+	+				o	o		o	o	o	o	o	o
	Thunderhead Sandstone Elkmont Sandstone	+		*	*	*	+	+	+	x	o	o	o	o	o	x	x	
Unclassified Formations	Cades Sandstone	*		*	*	*	+	+	+	o	x	o		o	o	x	o	
	Webb Mountain and Big Ridge Sandstone			*	+	*	+				o	o				x	x	
	Rich Butt Sandstone	+		*	*	*				o	o				x	x		
Snowbird Group	Metcalf Phyllite									o	o	o	x	o	o	o	o	o
	Pigeon Siltstone									o	o	o	o	o	o	o	o	
	Roaring Fork Sandstone			+	+							o	x	o	o			
	Longarm Quartzite Wading Branch Formation	*		*	*	*				o	o	x	x					

\* relatively common.  
+ relatively rare.  
\* greater than 1 percent.  
° less than 1 percent.  
blank — not present,

Pigeon and Metcalf sequences. In the Great Smoky Group and unclassified sandstones (Rich Butt, Cades, et cetera), however, they are relatively abundant. The presence of these minerals suggests granitic plutons as a source of derivation.

C. Detrital epidote and sphene are effectively restricted to the Snowbird Group. Their presence suggests derivation from amphibolites.

D. Granitic pebbles and larger rock fragments are rare but have been found in the Thunderhead Sandstone of the Great Smoky Group and in the unclassified sandstones.

E. Most of the conglomeratic units of the Snowbird and Great Smoky groups and unclassified sandstones contain angular feldspar pebbles. This indicates a nearby source for much of the strata.

F. The Walden Creek Group contains, though in relatively small amounts, most of the detrital heavy minerals, granitic rock fragments, and possibly blue quartz. This suggests a less restricted source for most of the Walden Creek succession. One noteworthy exception is the Wilhite Formation which contains carbonate breccias. These breccias, particularly when they are thick and of slide facies (Cow Head type), suggest derivation from a carbonate bank or reef structure on the edge of a slope.

Upon examination of the sedimentological data and review of previous interpretations, it is evident that the origin of the Ocoee Supergroup cannot be explained by a simple, single basin model such as that illustrated by De Windt (1975, p. 81). As pointed out by King and others (1958), the Ocoee Supergroup actually consists of two sequences (table 2) effectively separated by the Greenbrier fault. We envision these sequences as formerly occupying two distinct basins, most likely grabens, separated by an area of uplift, probably a horst. These basins we shall call the Gatlinburg basin, for the sequence below the Greenbrier fault, and the Clingman basin, for the sequence above the Greenbrier fault. The area of uplift we have named the Unaka horst.

The Gatlinburg basin must have formed first and originally extended over a large area, part of which (eastern half) would later become the site of the Clingman basin as the Unaka horst developed and isolated the two separate basins. We suggest that the Gatlinburg basin was a slowly forming half-graben (fig. 4A) because of the pronounced thinning to the southeast where the Snowbird clastics were derived from amphibolites. Precambrian amphibolites are common to the southeast in amphibolite-facies Grenville gneisses of the Globe, Elk River, and Sauras massifs (Bartholomew and Lewis, 1984). The paleoenvironmental interpretation set forth by De Windt (1975) (p. 601) agrees with this model which connects the sequence of the earliest alluvial (Wading Branch Formation), later fluvio-deltaic (Longarm, Roaring Fork, Pigeon units), and latest offshore (Metcalf Phyllite) environments which reflect the development of the basin.

The Clingman basin formed in consequence of a horst developing and splitting the Gatlinburg half-graben (fig. 4B). The three thin basal units of the Snowbird Group (Wading Branch, Longarm, and Roaring Fork formations), which previously existed at the southeastern edge of

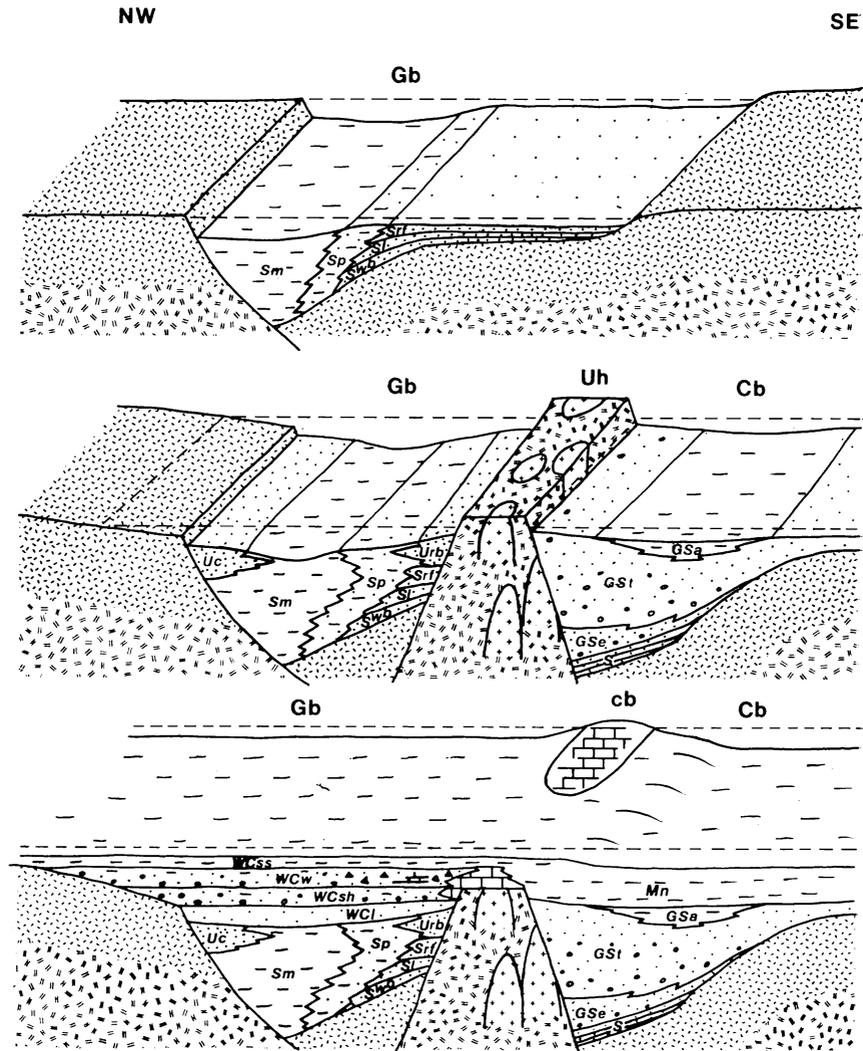


Fig. 4. Schematic representation of the depositional history and paleogeography of the Ocoee Supergroup. Geographic features: cb—carbonate bank, Cb—Clingman basin, Gb—Gatlinburg basin, Uh—Unaka horst. Stratigraphic units: GSa—Anakeesta Formation (shales and minor sandstones), GSe—Elkmont Sandstone, GSt—Thunderhead Sandstone, Mn—Nantahala Slate (of Murphy Group), S—Snowbird Group (Wading Branch, Longarm, and Roaring Fork), Sl—Longarm Quartzite, Sm—Metcalf Phyllite, Sp—Pigeon Siltstone, Srf—Roaring Fork Sandstone, Swb—Wading Branch Formation (sandstones and conglomerates), Ucb—Cades Sandstone, Urb—Rich Butt Sandstone, WcL—Licklog Formation (sandstones), Wcsh—Shields Formation (conglomerates and sandstones), WcSs—Sandsuck Formation (shales), WcW—Wilhite Formation (shales and sandstones with conglomerates and carbonate breccias). Patterns: bricks—limestone, crosses—granitoids, single cross-hatched—amphibolite-facies Grenville basement, double cross-hatched—granulite-facies Grenville basement.

the Gatlinburg half-graben, were now incorporated into the Clingman basin and overlain by the clastics of the Great Smoky Group. The strata of the Great Smoky Group were derived from the uplifted horst which consisted of granulites penetrated by granitic intrusions. Granulite-facies Grenville gneisses (Watauga and Lovingston massifs) (Bartholomew and Lewis, 1984) are exposed northeast of the area and contain granites known as the Crossnore Plutonic Series (about 710-650 Ma) (Rankin, 1975; Bartholomew and Lewis, 1984). Equivalents extended southwestward but are now concealed below the Greenbrier thrust fault or were eroded after displacement by the Greenbrier fault.

The clastics of the Rich Butt Sandstone and sandstones of Webb Mountain and Big Ridge also originated from this horst but were deposited on the southeastern edge of the Gatlinburg basin (fig. 4B). Presumably, the Cades Sandstone, because it lacks blue quartz, was deposited on the northwestern edge of the Gatlinburg basin at some distance from the granulites of the horst.

The strata of the Walden Creek Group, which were deposited in and eventually filled the Gatlinburg basin (fig. 4C), had a more diverse source than that of the Snowbird and Great Smoky groups. Although much of the sequence had provenance to the northwest, some sediments were apparently derived from the eroding horst. We suggest that the horst was also a site at which a nascent carbonate bank originated (fig. 4C) to give rise to carbonate breccias (Wilhite Formation), since there is no evidence for a Precambrian carbonate bank northwest of the area.

The model we use here agrees with the configurations of recent rifted continental margins, particularly the horst and graben form of profiles of the Biscay continental margin (fig. 5A and B) presented by Montadert and others (1979). Laterally along this margin, however, over a distance of 150 km the situation is shown to change somewhat (Montadert and others, 1979) with listric faults becoming dominant and creating mainly half-horsts and half-grabens (fig. 5C). Thus, both models may be applicable to the Ocoee and account for the significant lateral (along the trend) facies changes within the area. The latter model (fig. 5C) is analogous to that employed by Wehr and Glover (1985) for the Late Precambrian strata of the Virginia Blue Ridge.

#### STRUCTURAL RELATIONSHIPS

King and others (1958) identified and placed in sequence the strata of the Ocoee Supergroup. They also recognized two types of major thrusts, the premetamorphic Greenbrier and the postmetamorphic Great Smoky. The latter comes close to involving Mississippian strata (Hatcher, 1978) and is therefore considered to have occurred during the Alleghanian orogeny, while the former is both premetamorphic and prefoliation, although later than the earliest folds (Hadley and Goldsmith, 1963, p. 80-81). The Great Smoky thrust cuts across metamorphic zones (Carpenter, 1970; Butler, 1972; McConnell and Costello, 1984). King (1964) and Hadley and Goldsmith (1963) have associated the Greenbrier thrust with

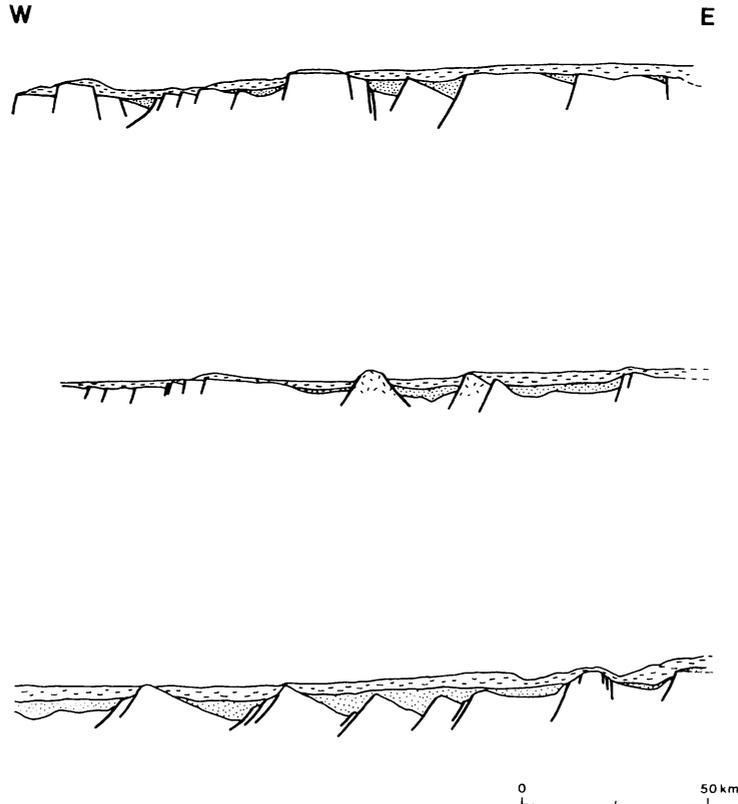


Fig. 5. Models of present-day continental margins from the Bay of Biscay region based on interpretations of seismic reflection data. Heavy lines indicate interpreted normal fault patterns: dashed and stippled — recent clastic sediments, unornamented — acoustic basement composed of Late Jurassic and Early Cretaceous carbonates, Late Paleozoic clastics, and granitic rocks (cross-hatched). Vertical scale exaggerated 2.5 times. Modified from Montadert and others, 1979.

the Taconic orogeny that gave rise to the clastic wedge represented by the Sevier and Tellico formations in the Valley and Ridge Province. Dallmeyer (1975) has estimated the date of the acme of Taconic metamorphism in the Southern Appalachians as about 480 Ma.

Since the pioneer work of King and co-workers other important fault systems have been recognized. Hatcher (1978) and Hatcher and others (1985) suggested another premetamorphic thrust, the Hayesville thrust, southeast of the Great Smoky Mountains. He connected it, however, to the previously known Fries fault near the Grandfather Mountain window and to the Allatoona fault near Cartersville, Georgia (Hatcher, 1978). While the subsequent mapping confirms all three faults, the Hayesville fault is premetamorphic while the Fries fault (Bartholomew, 1983) and the Allatoona fault (McConnell and Costello, 1984) are in part postmeta-

morphic producing retrogression (Stose and Stose, 1957). To the northeast the Fries fault has been connected by Bartholomew and Lewis (1984) to the so-called Rockfish Valley fault of Virginia, which Herz and Force (1984) considered a Precambrian structure, reactivated in Paleozoic times. Bartholomew and Lewis (1984) separated the Hayesville and the Fries faults entirely and suggested that the Fries is the equivalent of the Fork Ridge fault of the Tennessee-North Carolina Blue Ridge. They contended that the Linville Falls fault forms a closed window but is connected underground to the Fries system; the Linville Falls fault has yielded a date of 302 Ma (Van Camp and Fullagar, 1982), however, and is therefore Carboniferous. The Fries system they considered Late Devonian from the date supplied by Dietrich, Fullagar, and Bottiono (1969) and postulated that it cuts both the Hayesville and Greenbrier faults. The Hayesville thrust does not show mylonites along its trace, while the Allatoona structure does, and therefore we suggest that the Allatoona fault is a continuation of the Fries rather than Hayesville system. Mylonitized faults such as those in the Fort Mountain area (fig. 2), which have been dated by Russell (1976) as  $368 \pm 9$  Ma, are, we suggest, of the same generation and attributable to the Acadian orogeny. If the Fries fault continues southward from the Hot Springs window between the Greenbrier and Great Smoky faults, as Bartholomew and Lewis (1984) have suggested, it may be that the Dunn Creek fault, Line Springs fault, and Rabbit Creek fault (fig. 2) (Hamilton, 1961; King, 1964; Neuman and Nelson, 1965) are parts of the Fries thrust system.

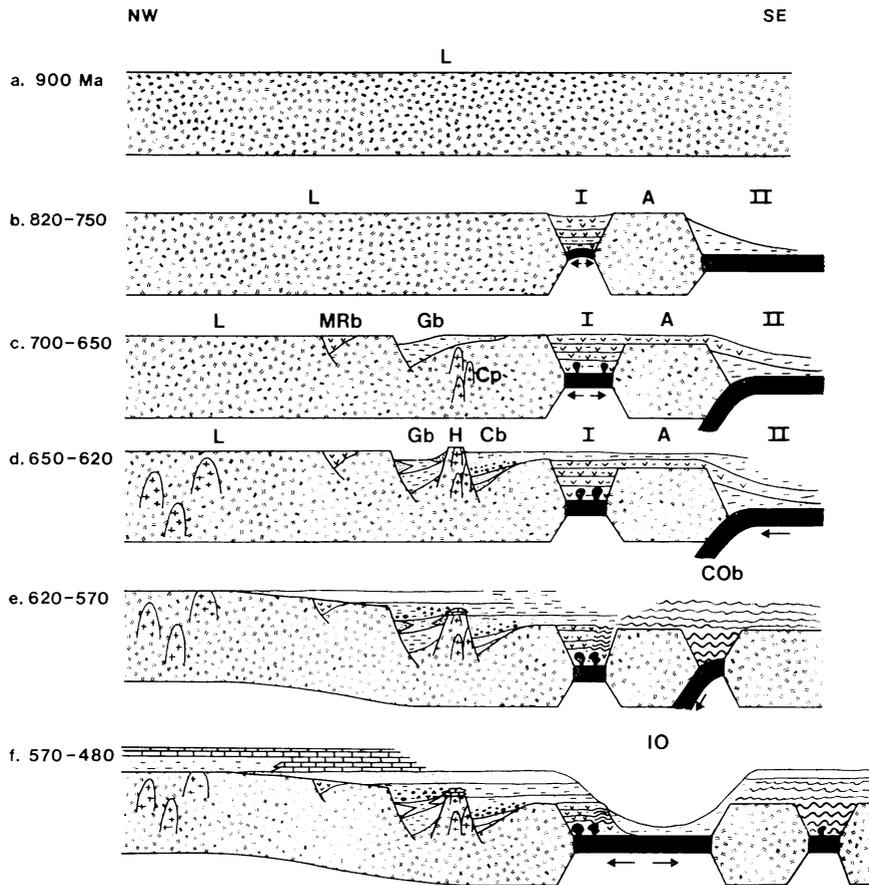
In summary, we suggest that the Greenbrier and Hayesville thrusts were Taconic, the Fries thrust system Acadian, and the Great Smoky-Holston Mountain thrust Alleghanian. With the successive formation of each major thrust the previously generated, overlying thrust sheet is carried forward. Thus, the Fries, which carried the Hayesville and Greenbrier sheets, is subsequently carried by the Great Smoky fault.

The Hayesville fault brings forward the Ashe and Alligator Back formations, clastic sediments that contain sheets and slices of amphibolites, ultramafic rocks, et cetera, which have been interpreted by Hatcher (1978) as sediments resting on and presumably mixed up with a thin continental or entirely oceanic crust. These types of rocks appearing as a mega-mélange are continuous north and northeast of the Grandfather Mountain window (Abbott and Raymond, 1984). In fact in the Hayesville area itself (Lacazette, 1984) similar mélanges are present.

The Fries fault brings forward Grenville gneisses and later granites of the Elk River massif (Bartholomew, 1983) with the overlying Hayesville and Greenbrier sheets over the Watauga massif in the Mountain City window and Precambrian and Cambrian rocks of the Great Smoky Mountain foothills (figs. 1 and 2).

The Great Smoky Fault brings forward all the above thrust sheets and in places cuts across them. The fact that the Great Smoky Group of sediments exists only above the Greenbrier sheet suggests that these formed an infilling of a basin that was separated by a barrier from the basin with

Fig. 6



the Walden Creek Group and the thicker part of the Snowbird Group. Thus the present juxtaposition occurred only after the formation of the Greenbrier fault which presumably nucleated in the basin of sedimentation containing Great Smoky Group sediments.

#### PLATE-TECTONIC INTERPRETATION (A MODEL)

Stratigraphic and structural relationships lead us to a plate-tectonic model (fig. 6). The Ocoee sediments were deposited in deep basins on Grenville crust which was attenuated and thinned. We interpret these basins as grabens at the former edge platform of the North American (Laurentian) continent. The platform originally must have been wide, since even in the Piedmont Grenville inliers of sialic basement are abundant (Hatcher, 1984; Farrar, 1984, 1985). In this paper we are concerned essentially with the development of the Blue Ridge but extend general inferences into the Piedmont. To the north of the area considered here

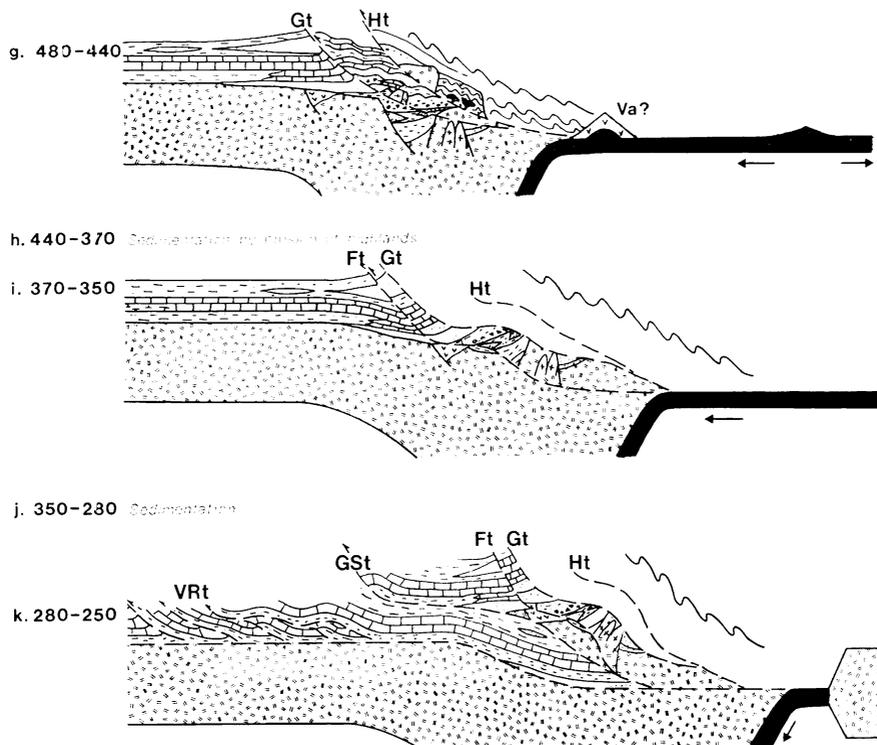


Fig. 6. Diagrammatic representation of the Precambrian (Grenvillian) through Paleozoic evolution of the Southern Appalachians of Tennessee, North Carolina, and Georgia. A — Avalon microcontinent or platform, Cb — Clingman basin, COB — Cadomian orogenic belt, Cp — Crossnore plutons, Ft — Fries thrust, Gb — Gatlinburg basin, Gt — Greenbrier thrust; GSt — Great Smoky thrust, H — horst, Ht — Hayesville thrust, IO — Iapetus Ocean, L — Laurentian craton, MRb — Mount Rogers basin, Va — volcanic arc, Vrt — Valley and Ridge thrusts, I — rift basin, I, II — rift basin II.

Wehr and Glover (1985) have independently arrived at conclusions similar to ours.

Diagrammatically the following stages of development of the continental edge are suggested:

- A. (about 900 Ma) The continent L (Laurentian) was complete and may have been continuous for a long distance.
- B. (about 820-750 Ma) The continent was split along one or possibly two rifts, like the present-day east Africa. The rifts may have converged along the strike. The large fragment of continental crust in between the two rifts formed a microcontinent (A). The distension of rift I eventually gave rise to an inland sea and of rift II to an open ocean. The sediments and associated volcanics deposited in rift I gave rise to the Alligator Back-Ashe formations.
- C. (about 700-650 Ma) Another distensional phase is envisioned in which half-grabens MRb (Mount Rogers basin) and Gb (Gatlinburg basin) are formed. The Mount Rogers basin was filled main-

ly with volcanics while the Gatlinburg basin was filled with clastic sediments. Microcontinent A became an island arc, which suggests the initiation of subduction. This island arc may be the Avalon platform with continental basement and bimodal volcanics, dominantly of felsic type (Rast and Skehan, 1983). Although the junction between the Avalonian Carolina slates and the probably Grenville rocks is mechanical, Farrar (1985) suggests that the fault is of Taconic age. It thus seems possible that since the dislocation involves younger on older rocks, it is merely a slipped unconformity. We speculatively consider it as such. Also granites (Crossnore plutons and others) were generated and intruded into the Grenville basement northwest of rift I, presumably caused by a mantle-based convective overturn below the back-arc basin, which arose on the site of former rift I.

- D. (about 650-620 Ma) The intrusion of abundant granites of Crossnore type (Cp) (Bartholomew, 1983) led to the formation of an uplift or horst, since light granites were intruded into heavier granulitic crust and a new basin Cb (Clingman basin), filled with Great Smoky Group sediments, originated on the side of the horst distal to continent L. Sandstones (Rich Butt, Webb Mountain, and Big Ridge) were deposited on the distal side of the Gatlinburg basin, while the Cades Sandstone arose on the proximal side of the Gatlinburg. The early sediments of the Walden Creek Group were laid down in the Gatlinburg basin, but the latest Walden Creek sediments (Sandsuck) possibly extended onto the eroded platform to the west. Temporarily, the horst was the site of carbonate deposition.
- E. (about 620-570 Ma) A relatively mild period of orogenic activity (Virgilian-Avalonian orogeny) produced deformation and possibly metamorphism and even minor ophiolites on the side of back-arc basin I distal to the continent. This situation is similar to that of Anglesey, Wales, and Newport, Rhode Island (Rast and Skehan, 1981). Also basin II, which by this time was a shrinking ocean, closed giving rise to the Cadomian orogenic belt of northern France and the Iberian Peninsula (Cogné and Wright, 1980). The resultant compressive episode led to the cessation of distension and initiation of mild compressive conditions throughout the faulted continental platform. Thus the horst or horsts were eroded away and unconformably overlain by Chilhowee sediments (around 570 Ma).
- F. (about 570-480 Ma) Predominately fine clastic sedimentation (Rome Formation) continued on the platformal edge of the continent. The source as with the Chilhowee Group clastics lay to the west. Replacing the "Rome" clastics to the east a carbonate bank (Shady Dolomite) came into existence. Clastics in the west and carbonates in the east (Conasauga Group) were deposited above the Rome and subsequently overlain by a carbonate bank (Knox

Group and possibly Murphy Marble) which extended across the entire platform.

- G. (about 480-440 Ma) The edge of the continent was affected by a compressional event (Taconian orogeny). This event generated two major thrusts, the Hayesville (Ht) and the Greenbrier (Gt). The Hayesville thrust translates volcanics and clastic sediments along with fragments of oceanic crust from rift basin I to a position overlying the Clingman basin (Cb). The Greenbrier thrust, which lies forward of the Hayesville, in turn translates the sediments of the Clingman basin and overriding Hayesville sheet to a position above the Gatlinburg basin (Gb). After the emplacement of these thrust sheets the area was regionally folded and metamorphosed. The resultant uplift in this area is also thought to be the source for the thick clastic wedge of Middle Ordovician Sevier Shale. These sediments lie disconformably upon the Knox Group and mark a reversal of provenance from the earlier Paleozoic sediments, since the Sevier Shale coarsens and thickens eastward.
- H. (about 440-370 Ma) A period of orogenic quiescence during which confined Taconian uplift to the northeast continued to provide clastic material (Juniata Formation and Clinch Sandstone) deposited to the west.
- I. (about 370-350 Ma) Compressional deformation was again introduced (Acadian orogeny), the main consequence of which was the generation and emplacement of the Fries thrust (Ft). The Fries translated sediments of the Gatlinburg basin (Gb) and overriding assemblages of the Greenbrier and Hayesville sheets along with intervening basement massifs westward. The Fries sheet overrode platformal sediments, particularly those of the Walden Creek Group and Chilhowee Group.
- J. (about 350-280 Ma) An easterly uplift during the Acadian (Ettensohn and Barron, 1981) gave rise to Late Devonian (Chattanooga Shale) and Early Mississippian (Grainger Formation) clastics.
- K. (about 280-250 Ma) The Alleghanian orogeny, the last major compressional episode to affect the area, generated the Great Smoky and associated thrusts in the Blue Ridge, the imbricate thrust system of the Valley and Ridge, as well as deformation in the eastern Piedmont. The Great Smoky thrust translated the Early Paleozoic platformal sequence and overlying assemblages of the Fries, Greenbrier, and Hayesville sheets westward, presumably along a decollement at the base of the platformal succession. A subsequent episode of folding distorted the entire Blue Ridge package and is an indirect cause of the present outcrop pattern in the area.

Since the Alleghanian deformation gave rise to the sole thrust (fig. 3) indicated in COCORP and other crustal sections (discussed in Cook and others, 1983), the Late Paleozoic Alleghanian orogeny in the Valley and

Ridge and Blue Ridge provinces generates a predominantly thin-skinned deformation but, by way of the sole thrust, carried forward remnants of the former thick-skinned deformations which were active in Lower and Middle Paleozoic times.

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