

GEOLOGIC MAP OF THE GREENVILLE 1°×2° QUADRANGLE, SOUTH CAROLINA, GEORGIA, AND NORTH CAROLINA

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INTRODUCTION

Regional geologic investigations show that all the metamorphosed crystalline rocks underlying the Greenville 1°×2° quadrangle are allochthonous. Seismic-reflection studies, the COCORP line (Cook and others, 1979), and the U.S. Geological Survey (USGS) seismic lines (Harris and Bayer, 1979; Harris and others, 1981) present seismic profiles across different parts of the southern Appalachians. Recent geophysical studies for the now discontinued Appalachian Ultradeep Core Hole (ADCOH) project were concentrated in the Greenville quadrangle (Hatcher and others, 1988). The ADCOH seismic-reflection profiles tie in with the COCORP profile of Cook and others (1979), providing a three-dimensional view of the Earth's crust (Coruh and others, 1987; Hatcher and others, 1987, 1988). The seismic studies clearly corroborate the allochthonous nature of the crystalline rocks as suggested by geologic mapping. They also suggest that Paleozoic sedimentary rocks in several thrust sheets continue from the Valley and Ridge beneath the crystalline rocks of the Blue Ridge and under a part of the western Inner Piedmont. Harris and Bayer (1979) suggest 179 km of westward transport for the crystalline rocks of the Blue Ridge.

PREVIOUS WORK

Many geologic studies have been made within the Greenville quadrangle over a considerable time span. Yeates and others (1896) and Park (1953) described some of the gold deposits and mining properties of Georgia. One of the major gold-producing zones, the Dahlonega gold belt, extends northeast from Dahlonega, Ga., and forms part of the Helen thrust sheet, defined later in this report. Hopkins (1914) described soapstone, and Furcron and Teague (1943) reported on mica-bearing pegmatites within the Greenville quadrangle. Crickmay (1952) and Hurst (1973) discussed rocks in this area as part of their general description of Blue Ridge crystalline rocks. Hartley (1973) reported on the ultramafic rocks present in the north part of the area, and Hatcher (1971) described the geology of Rabun and Habersham Counties, Ga. Hatcher also reported on various aspects of the tectonic history of northern Georgia (1974, 1976, 1978a,b). Dupuis (1975) and Wooten (1980) mapped adjoining areas to the west and north, respectively, of the Greenville quadrangle, and Shellebarger (1980) and Gilon (1982) mapped areas in the northwest part of the quadrangle. German (1985) mapped the Dahlonega gold belt. Nelson (1982, 1983a,b, 1985) and Nelson and Koeppe (1986) and later Peper and others (1991) mapped different areas in the northwest part of the Greenville quadrangle.

In the Inner Piedmont and southeast of the Brevard zone, Griffin (1967, 1973, 1974b, 1975, 1977, 1978, 1979, 1981) mapped a large part of the Greenville quadrangle in South Carolina, Grant (1958) mapped Hart County, Ga., and Hatcher (1969) mapped southeast of the Brevard zone. Nelson and others (1987) compiled a tectonic map of the Greenville quadrangle.

GENERAL GEOLOGY

Parts of three major allochthonous terranes underlie the Greenville quadrangle. From northwest to southeast, they are the eastern part of the Blue Ridge Mountains, the Inner Piedmont, and the Charlotte terrane. Each of the terranes consists of a series of westward-transported stacked thrust sheets. The Brevard zone forms the tectonic boundary between the Blue Ridge and the Inner Piedmont, and the Lowndesville shear zone forms the boundary between the Inner Piedmont and the Charlotte terrane. A stack of five crystalline thrust sheets underlies the Blue Ridge terrane; a stack of four (possibly five) thrust sheets forms the Inner Piedmont. Two additional thrust sheets are included in the Charlotte terrane in the Greenville quadrangle southeast of the Lowndesville shear zone. In ascending order the thrust sheets forming the Blue Ridge thrust stack are the Great Smoky thrust sheet, the Helen thrust sheet, the Young Harris thrust sheet, the Richard Russell thrust sheet, and the Tallulah Falls thrust sheet. The ascending stacking order for the Inner Piedmont thrust sheets are the Chauga-Walhalla thrust complex, the Six Mile thrust sheet, the Paris Mountain thrust sheet, and the Laurens thrust sheet. A mafic-ultramafic complex and the Charlotte volcanic-arc assemblage are included in the Charlotte terrane.

The metamorphosed stratified rocks of the Great Smoky thrust sheet include rock assemblages of the Late Proterozoic Ocoee Supergroup together with some minor Cambrian rocks of the Murphy syncline. The ages of metasedimentary rock units in other thrust sheets, however, are uncertain, but their ages are thought to range from Late Proterozoic(?) to Ordovician(?). Three bodies of Middle Proterozoic (Fullagar and others, 1979; T.W. Stern, USGS, oral commun., 1986) basement rocks are present in the Greenville quadrangle; one occurs in the Richard Russell thrust sheet and two are present in the Tallulah Falls thrust sheet. Middle Proterozoic basement has not been observed elsewhere in the Greenville quadrangle. In the adjoining Knoxville 1°×2° quadrangle to the north, Middle Proterozoic plutonic rocks and variably layered paragneisses are exposed in the eastern part of the Great Smoky thrust sheet (Hadley and Nelson, 1971; Nelson and Zietz, 1983). Basement rocks in the Blue Ridge province the ages range in age from 1.3 to 1.0 Ga, ages typical of the Grenville province of eastern Canada and

elsewhere in the Appalachian orogen (Rankin, 1975, p. 304). It is uncertain whether the Middle Proterozoic rocks represent detached fragments of the Grenvillian North American craton, or possibly parts of an accreted terrane (Hatcher, 1978a; Zen, 1981; Nelson and Zietz, 1983).

Griffin (1970, 1971, 1974a, 1977, 1978) divided the Inner Piedmont, which extends from the Chauga belt (Hatcher, 1969) southeast of the Brevard zone to the Lowndesville shear zone, into a central core of sillimanite schist and gneiss that is flanked on either side by zones rich in amphibolite and granitoid gneiss. These zones are separated from each other by faults and tectonic slides. Griffin (1975) named the Walhalla, Six Mile, and Antreville nappes as parts of his core-and-flank complex and proposed a tectonic stockwork model for the Inner Piedmont. While many of the geologic interpretations here are similar to those presented by Griffin, we integrate the more recent COCORP seismic data into our model and interpret the stacking order of the thrust sheets differently than shown in the stockwork model. The Inner Piedmont has been divided into four (possibly five) thrust sheets (Nelson and others, 1987).

Exclusive of the Great Smoky thrust sheet and the Young Harris thrust sheet where granitic intrusive rocks are rare, all other thrust sheets in the Greenville quadrangle contain significant amounts of intrusive rocks. These rocks range in age from Middle Proterozoic to Jurassic and all, except those of Mississippian or younger age, have been regionally metamorphosed and deformed. The rocks range in composition from granite to gabbro, with granite gneiss and granodiorite gneiss bodies the most widespread and constituting the largest plutons. Although mafic intrusions are present in the Inner Piedmont, most of the large undeformed mafic intrusions occur in the Charlotte terrane southeast of the Lowndesville shear zone.

THRUST SHEETS OF THE BLUE RIDGE TERRANE

(Described in ascending structural position)

In the following discussion of thrust sheets, only the general characteristics and main tectonic features of each thrust sheet are given. Descriptions of lithologic units for each thrust sheet are given in the map explanation.

GREAT SMOKY THRUST SHEET

Greenville basement rocks and rock assemblages of the Ocoee Supergroup, the Nantahala Slate, and Cambrian rocks of the Murphy Syncline (as used by Dallmeyer and others, 1978) constitute the Great Smoky thrust sheet. Metamorphosed Late Proterozoic rocks of the Ocoee Supergroup make up most of the Great Smoky thrust sheet in the northwest corner of the quadrangle. Rocks of the Ocoee Supergroup in northeast Georgia represent sequences that were deposited in shallow water in a fluvial coastal-plain environment (Dupuis, 1975; Price, 1977; Shellebarger, 1980), probably along the west side of a rift basin along the eastern margin of the North American craton. Ocoee rocks in the Greenville and nearby Knoxville 1°×2° quadrangles do not contain volcanic deposits, and are believed to have formed from sediments derived from the North American craton.

The Great Smoky thrust fault defines the base of the Great Smoky thrust sheet, but this fault is not exposed in the Greenville

quadrangle. However, farther west in Georgia and to the north in Tennessee, the Great Smoky thrust sheet rests on Paleozoic sedimentary rocks of the Valley and Ridge along the Great Smoky fault (Hadley and Goldsmith, 1963). The Hayesville thrust fault marks the upper boundary of the Great Smoky thrust sheet in the northwestern part of the Greenville quadrangle. Several areas of Great Smoky thrust sheet rocks are exposed below the Hayesville fault in the Brasstown Bald and Shooting Creek windows through the Richard Russell thrust sheet, southeast of the principal outcrop area of the Great Smoky thrust sheet.

HELEN THRUST SHEET

The Helen thrust sheet that is exposed in the northwest part of the Greenville quadrangle consists of a variety of metasedimentary and metavolcanic rocks, including the Helen Group (Nelson and Gillon, 1985) and some chemical metasediments (Stanton, 1976). Gillon (1982) believed these rocks were derived from sediment deposited in a moderate- to low-energy rift basin, with associated marine-pelitic and volcanic deposits. The metavolcanic rocks are believed to be the results of volcanism on the ocean floor.

Rocks of the Helen thrust sheet form part of an accretionary wedge, the Talking Rock complex (Higgins, Crawford, and others, 1988), and they rest on the Great Smoky thrust sheet along an unnamed fault zone southwest of the Greenville quadrangle. The Richard Russell thrust sheet rests on the Helen thrust sheet along the Hayesville thrust fault which, along with the unnamed fault zone to the southwest, defines the northwestern border of the Helen thrust sheet. The Dahlenega thrust fault establishes the southeastern border of the Helen sheet and places the Tallulah Falls thrust sheet on top of the Helen sheet.

YOUNG HARRIS THRUST SHEET

All of the thrust sheets overlying the Great Smoky thrust sheet contain a wide variety of ultramafic and mafic rocks which occur as small discontinuous pods as well as some large mappable units (Hadley and Nelson, 1971; Nelson, 1982, 1983a,b; Nelson and Zietz, 1983). A separate thrust slice of ultramafic and mafic rocks, the Young Harris thrust sheet, lies between the Great Smoky and the Richard Russell thrust sheets around the Brasstown Bald and Shooting Creek windows in the northwestern part of the quadrangle. At least parts of the Young Harris thrust sheet are a mélange. The ultramafic rocks of the Young Harris sheet have chemical affinities with mantle rocks (Hartley, 1973, p. 59); additional geochemical studies suggest a mid-ocean ridge or island-arc origin for them (Long and Miller, 1983). Shaw and Wasserburg (1984) made strontium and neodymium isotopic analyses of a sample from the Young Harris thrust sheet that suggest it represents oceanic crust. The Young Harris thrust sheet and other smaller mafic-ultramafic bodies may represent fragments of oceanic crust emplaced within the various thrust sheets during or before their westward transport.

RICHARD RUSSELL THRUST SHEET

The Richard Russell Formation, the informally named schist of Crooked Creek, and some granitic and dioritic gneisses and associated pegmatites are included in the Richard Russell thrust sheet exposed in the northwestern part of the quadrangle. This thrust sheet was formerly called the western part of the Hayesville

thrust sheet (Nelson and Zietz, 1983). The Richard Russell Formation is predominantly a mixture of quartzofeldspathic gneiss, metagraywacke, biotite gneiss, some minor schist, and lesser amounts of amphibolite. The schist of Crooked Creek is a more heterogeneous mixture of reddish-weathering schists and various metasedimentary rock units that commonly contains amphibolite layers. Certain lithologic differences between the Crooked Creek and the Richard Russell suggest that they may have formed in different environments, or in different parts of a large depositional basin, or in a basin that had a large influx of volcanic material during deposition of the Crooked Creek. Interlayered, thin psammitic and pelitic horizons with thicker and locally graded metagraywacke of the Richard Russell suggests that these rocks most likely originated as deep-water turbidite deposits (Gillon, 1982). Bedding is rarely preserved within the Crooked Creek and the Richard Russell; instead, a discontinuous compositional layering is the most prevalent structure. This results from the metamorphic differentiation and transposition of bedding into the regional foliation (Nelson, 1983b). In the northern part of the quadrangle, a fault separates the Richard Russell from the Crooked Creek, but elsewhere the nature of the contact between the two rock units is obscure and it is difficult to determine if it is tectonic or depositional. The Richard Russell thrust sheet rests on parts of the Helen and Great Smoky thrust sheets along the Hayesville thrust fault.

TALLULAH FALLS THRUST SHEET

Metamorphosed assemblages of sedimentary, volcanic, and intrusive rocks make up the Tallulah Falls thrust sheet. The Tallulah Falls Formation of Galpin (1915), as used by Hatcher (1971), occupies a large part of the thrust sheet and consists of four members: (1) a lower metagraywacke-schist-amphibolite, (2) an aluminous schist, (3) a metagraywacke-schist, and (4) an upper quartzite-schist (Hatcher, 1976). Unnamed biotite gneiss, mica schist, and amphibolite units are also present. Gillon (1982) considered the metasedimentary rock assemblages in the western part of the Tallulah Falls thrust sheet, which correlate with the Tallulah Falls Formation, to represent sediments deposited in a fluvial-delta to distal-turbidite environment. The Tallulah Falls thrust sheet overlies the Helen thrust sheet along the Dahlonega fault, and to the southeast is bounded by the Brevard zone.

THRUST SHEETS OF THE INNER PIEDMONT

(Described in ascending structural position)

CHAUGA-WALHALLA THRUST COMPLEX

The Chauga-Walhalla thrust complex of Nelson and others (1987) lies just southeast of the Brevard fault zone. It includes rock assemblages assigned by Hatcher (1972) to the Chauga belt and by Griffin (1969) to the Walhalla nappe. The Chauga belt of Hatcher (1972) contains metamorphosed sedimentary and volcanic rocks of the Chauga River and Poor Mountain Formations of Hatcher (1969) and the Henderson Gneiss, which is thought to be plutonic in origin. The Walhalla metamorphic suite (informal name of Horton and McConnell, 1991) consists of hornblende-plagioclase gneiss, amphibolite, and associated units previously described by Griffin (1969, 1971, 1973, 1974b, 1975) as components of the Walhalla nappe. Hatcher (1974) suggested that

amphibolite here assigned to the Walhalla metamorphic suite may be a higher grade equivalent of finer grained amphibolite in the Poor Mountain Formation. Rocks of the Walhalla metamorphic suite are variably migmatitic and commonly injected by granitoids. The Chauga River Formation, Poor Mountain Formation, and Walhalla metamorphic suite probably originated from sediments deposited in a setting where a variety of pelitic, clastic, and carbonate units were interlayered with submarine volcanic materials, possibly on a shelf and (or) in an associated rift basin.

Griffin (1974a) interpreted the contact between the rocks of the Chauga belt and his Walhalla nappe to be a tectonic slide; elsewhere, Hatcher and Acker (1984) interpreted this contact as a metamorphic gradient. Our work suggests that there is a structural discontinuity locally between these lithotectonic units, but that in other places the contact appears to be a metamorphic gradient. The Chauga-Walhalla thrust complex structurally overlies the Tallulah Falls thrust sheet along the Brevard zone.

SIX MILE THRUST SHEET

A variety of unnamed rock units that consist of varying assemblages of many rock types are included in the Six Mile thrust sheet. The rock units include mica schist and sillimanite-mica schist, mixed gneiss and schist, felsic and quartzofeldspathic biotite gneiss, and smaller amounts of interlayered calc-silicate rock, amphibolite, quartzite, and gondite. These rocks developed from sediments deposited in an environment that also received some volcanic material.

The Six Mile thrust sheet structurally overlies the Chauga-Walhalla thrust complex along a major thrust fault. This fault, named and described by Horton and McConnell (1991) as the Seneca fault, was first recognized and described by Griffin (1969, 1971, 1973) as a tectonic slide. The Seneca fault is the best mapped and best documented member of the thrust system by which the Inner Piedmont thrust stack was assembled. This thrust is characterized by lithologic and structural discontinuities and by contrasts in metamorphic grade, notably where sillimanite-grade rocks of the Six Mile thrust sheet overlie kyanite-grade rocks of the Chauga-Walhalla thrust complex. The Seneca fault is difficult to map in some areas because of interlayered rock types, granitoid injections, and poor exposure. Numerous outlying klippen of the Six Mile thrust sheet overlie the Chauga-Walhalla thrust complex. One of these klippen is the Alto allochthon (Hatcher, 1978b; Hopson and Hatcher, 1988). The basal thrust of the Alto allochthon is well exposed at Toccoa Falls near Toccoa, Ga., where it has been described by Nelson and Horton (1989).

PARIS MOUNTAIN THRUST SHEET

The principal rock type in the Paris Mountain thrust sheet is sillimanite-mica schist. Interlayered rocks include amphibolite, quartzite, and garnet-quartz rock. These rocks probably formed from sediments deposited in a setting that received minor volcanic material. Intrusive granite gneiss is common. The Paris Mountain thrust sheet structurally overlies the Six Mile thrust sheet along an unnamed thrust fault as discussed by Nelson and others (1987). Construction of cross sections for this map suggests that the Paris Mountain thrust sheet lies beneath and was overridden by the Laurens thrust sheet. Thrust faults at the base and roof of the Paris Mountain thrust sheet are largely inferred.

LAURENS THRUST SHEET

The Laurens thrust sheet consists primarily of biotite gneiss that is variably layered and locally porphyroblastic. Biotite-sillimanite schist, amphibolite, and small, local bodies of marble are interlayered with the gneiss. The rocks probably developed from a combination of sedimentary and volcanic material. The granite gneiss of Gray Court and the Reedy River complex (informal name) of Wagener (1977) are the largest of many granitoid gneiss bodies. The interpretation here, which differs from our earlier interpretation (Nelson and others, 1987), is that the Laurens thrust sheet structurally overlies and straddles both the Paris Mountain and Six Mile thrust sheets along an unnamed thrust fault. This basal thrust is largely obscured by intrusive granitoid gneisses and becomes lost in the granitoid gneiss near Antreville, S.C. Stratigraphic relationships among metamorphic suites in the Laurens, Paris Mountain, and Six Mile thrust sheets are undetermined.

THRUST SHEETS IN THE CHARLOTTE TERRANE SOUTHEAST OF THE LOWNDESVILLE SHEAR ZONE

MAFIC-ULTRAMAFIC COMPLEX

An assemblage of ultramafic, mafic, and fragmental mafic rocks, together with some variably sized granitic bodies, lies on the southeast side of the Lowndesville shear zone near the southern border of the Greenville quadrangle. This heterogeneous assemblage includes gabbro, diorite, amphibolite, ultramafic rocks, mafic dikes, and granitic bodies in a gabbroic(?) matrix. The rocks are deeply weathered to saprolite and fresh exposures are sparse. An intimate intermixing of rock types led Nelson and others (1987), Higgins, Atkins, and others (1988), and Higgins and others (1989) to interpret this mafic-ultramafic assemblage as part of a *mélange* complex. A problem for this interpretation is the igneous composition of the matrix that surrounds isolated pods of mafic and ultramafic rock. Such pods can form by ductile deformation of synplutonic dikes in an igneous complex, and the transition from tabular mafic dikes to isolated pods by shearing, stretching, and necking is well documented in other parts of the Charlotte belt (Butler and Secor, 1991, p. 76). Griffin (1978, 1979) described this mafic-ultramafic assemblage as the Latimer complex (informal name) and interpreted it to be a metamorphosed igneous complex disrupted by migmatization. In the Greenville quadrangle, migmatization and granitoid intrusions characterize the mafic-ultramafic assemblage but are lacking in other parts of the Charlotte terrane. Griffin (1978, p. 30) cited this contrast as evidence that the Latimer complex was affected by processes at a deeper crustal level. The boundary between the mafic-ultramafic assemblage and other rocks of the Charlotte terrane has not been observed but is here inferred to be a thrust fault.

CHARLOTTE VOLCANIC-ARC ASSEMBLAGE

Metamorphosed volcanic and related sedimentary rocks together with plutonic rocks make up the Charlotte volcanic-arc assemblage, which may or may not represent a distinct thrust sheet or thrust complex. Rock units include metatuffs, phyllite, quartzite, and quartz-muscovite schist commonly assigned to the

Carolina slate belt; gneisses, schists, amphibolite, and intrusive rocks commonly assigned to the Charlotte belt; and rocks assigned by Griffin (1979) to the Lowndesville belt, mainly phyllonite and other deformed rocks of the Lowndesville shear zone. The Charlotte volcanic-arc assemblage and the mafic-ultramafic complex overlie rocks of the Six Mile and Laurens thrust sheets along the Lowndesville shear zone.

DEFORMATION

All the thrust sheets and some rocks within fault zones have experienced several episodes of deformation. Detailed studies in the northwestern part of the Greenville 1°×2° quadrangle showed that the rocks were deformed by folding at least four and possibly six times (Nelson, 1985). Small interference folds are commonly seen at rock exposures, and the present outcrop patterns of large structural features, such as the Chattahoochee basin (Nelson, 1985) and the Tallulah Falls dome (Hatcher, 1971) resulted from superposed folding (Dallmeyer and others, 1978; Hatcher, 1974; Nelson, 1985). The first-generation folds (F_1) are represented by intrafolial, rootless, recumbent isoclinal folds in transposed layers. Second-generation folds (F_2), which form the major folds, are steeply inclined to recumbent. The limbs of F_2 folds were folded into two sets of tight to open, upright to overturned flexure folds. These later folds form conjugate fold pairs. All the above-mentioned folds have axial-planar cleavages. A later folding event gently folded the flanks of some late flexure folds but axial-plane cleavage was not identified in these later folds.

Most of the major folds (F_2) trend northeast and their axes plunge gently northeast or southwest. These folds range from upright to inclined to recumbent, and although some of them verge southeast, most verge northwest. Regional F_2 folds in the Great Smoky thrust sheet are mostly overturned to the northwest and their axial surfaces are steeply inclined. In the Richard Russell sheet, most of the F_2 folds are reclined to recumbent and, depending on their location with reference to the Chattahoochee basin (Nelson, 1985), have variable orientations reflecting considerable F_3 (northwesterly and northeasterly) strain. In contrast, in both the Helen and Tallulah Falls thrust sheets west of the Tallulah Falls dome, the F_2 folds generally have steeply dipping axial surfaces overturned to the southeast and their axes generally plunge northeast or southwest. These fold attitudes resulted from later superposed folding associated with development of basins and domes in this part of the Greenville quadrangle (Nelson, 1985). Table 1 summarizes the types of folds characteristic of each fold phase.

Except for diabase dikes, some small granitic plutons, and pegmatite and quartz veins, all rocks in the quadrangle have a pervasive foliation, and in many places the rocks display multiple sets of planar surfaces, which include foliation, cleavage, metamorphic layering, and bedding. Bedding can be identified in most rock units of the Great Smoky thrust sheet. Farther to the southeast, however, most of the bedding in the various rock units in the quadrangle appears to be transposed into the regional foliation. The first foliation (S_1) formed during a regional metamorphic event and was later deformed during regional folding (F_2) that probably occurred after the high temperature peak of metamorphism (Nelson, 1985). The second-generation folds appear to have a poorly developed axial-planar schistosity (S_2). Moderate temperatures may have continued through a third episode of

Table 1.—Summary of fold phases observed in the northwest part of the Greenville quadrangle northwest of the Tallulah Falls thrust sheet

F ₁	Rootless, recumbent to reclined, isoclinal folds that trend northeast. They may be coplanar with F ₂ folds, and lie in the transposed S ₁ foliation
F ₂	Steep to recumbent, isoclinal folds. Form major folds and fold S ₁ foliation. Probably are post-peak metamorphism. Rarely have well-developed axial-plane S ₂ foliation.
F ₃	Upright to slightly inclined, conjugate fold pairs that have axial-planar crenulation cleavage in pelitic units. Probably late metamorphic. Conjugate fold sets trend northeast and northwest
F ₄	Sparsely developed, gentle, upright folds and warps that have east- and north-northeast-trending axes; axial-plane cleavage has not been observed with these later folds

folding (F₃). This is indicated by biotite that has grown along the axial-plane cleavage (crenulation cleavage) of third-generation folds. This later folding event may also represent a separate thermal pulse as well.

The crenulation cleavage, although common throughout the quadrangle, is not uniformly well developed except locally, where it masks the earlier regional foliation. It is the latest planar structure that is associated with folding. This cleavage is present in many pelitic units, and northwest of the Brevard zone it is axial planar to either northwest- or northeast-trending F₃ folds. Where the cleavage is well developed, F₃ folds deform the layering and the regional foliation. In some places northwest of the Brevard zone two principal crenulation cleavage sets are present; one set is associated with the northeast-trending F₃ folds, whereas the other set is related to the northwest-trending F₃ folds. The northeast-striking crenulation cleavage set is much more common and widespread than is the northwest set.

Locally small crenulations associated with the two cleavage sets form a conjugate fold pair. These conjugate folds are rare, but they and their related crenulation cleavages suggest that the northwest-striking folds and the northeast-striking folds probably formed together as a conjugate F₃ fold pair. As such, the F₃ folds probably represent one of the later sets of compressive structures to form during the waning stages of regional metamorphism and deformation that affected the southern Appalachians.

In the Inner Piedmont, four fold generations have been recognized in most areas, although their numerical designations vary (Griffin, 1969, 1971, 1974a; Hatcher, 1978a), and five have been described in some places (Hatcher and Acker, 1984; Horton and McConnell, 1991). The earliest schistosity (S₁) is parallel to compositional layering, except in the hinges of first-generation (F₁) isoclinal intrafolial folds where it appears to be axial planar. Second-generation folds (F₂) are isoclinal to tight, reclined to recumbent, generally verge west or northwest, and have a strong axial-planar schistosity (S₂). S₂ is the predominant foliation in the Inner Piedmont, but S₂ and S₁ are generally subparallel except in the hinge areas of F₂ folds. F₂ fold limbs are commonly sheared off along tectonic slides, and granitoid dikes have been locally emplaced along these slides. Upright, open F₃ folds and crenulations in the Inner Piedmont have axes that plunge gently northeast and southwest. Their axial surfaces and locally developed crenulation cleavage (S₃) dip vertically to steeply southeast. These and late open folds (locally designated F₄ and F₅) associ-

ated with kink folds and crenulations superimpose broad synforms, antiforms, and basin-and-dome interference patterns on the earlier Inner Piedmont structural pattern dominated by F₂.

Numerous thrust faults characterize the southern Appalachian Mountains (Rodgers, 1953; King, 1964; Hadley and Goldsmith, 1963; Hadley and Nelson, 1971; Hatcher, 1971, 1972). The Hayesville fault, which carries the Richard Russell thrust sheet over the Great Smoky thrust sheet, is probably pre- to synmetamorphic, but developed before the regional metamorphic peak (Shellebarger, 1980; Wooten, 1980). North of the Greenville quadrangle, Wooten reported that the fault is folded by F₂ folds; it does not appear to offset the sillimanite isograd or to juxtapose rocks of different metamorphic grade. Apparently, the first-generation foliation attitudes are not deflected in rocks on either side of the fault in either the Greenville quadrangle or in the adjoining area to the north (Wooten, 1980). At a few places along the fault, however, some rocks of the Richard Russell thrust sheet have small zones where blastomylonite and mylonite textures are preserved (Shellebarger, 1980).

The northwest side of the Helen thrust sheet is bounded by the Hayesville fault (Nelson, 1991). Foliation attitudes appear to be parallel in rocks on both sides of the fault; however, local discordances of foliation attitudes between the Helen and the Richard Russell thrust sheets suggest some post-S₁ foliation movement along at least part of the fault. From the Georgia-North Carolina boundary, the Hayesville fault extends southwestward toward Dahlonega (Gillon, 1982), and then just west of the Greenville quadrangle it turns and has a northwest trend (Nelson, 1991). That part of the Hayesville fault separating the Helen and the Richard Russell thrust sheets was previously called the Shope Fork fault by Hatcher (1976) and by Nelson (1985). Later, Hatcher and others (1988) called it the Soque River fault. Nelson (1991) renamed it the Hayesville fault. The Hayesville fault does not continue southwestward through Georgia as depicted by Williams (1978). Southwest of the Greenville quadrangle, McConnell and Costello (1980) correlated the Allatoona fault with the Hayesville fault, but Higgins and others (1989) mapped the Allatoona fault as the northwesternmost boundary of the Ropes Creek thrust sheet, which corresponds with the northwestern part of the Helen thrust sheet.

The Dahlonega fault (Crickmay, 1952) thrusts migmatitic rocks of the Tallulah Falls thrust sheet over lower-grade nonmigmatitic rocks of the Helen thrust sheet. Early ductile deformation along the fault produced mylonites and blastomylonites, but later brittle deformation caused button schists to develop and intensely fractured the rocks (Bowen, 1961; McConnell and Costello, 1980; Gillon, 1982). Ductile deformation along the Dahlonega fault probably began near the metamorphic peak, and later brittle deformation probably occurred after temperatures had cooled to near the lower temperature boundary of greenschist facies conditions (Sibson, 1977).

The Seneca fault is the best mapped and best documented major thrust in the Inner Piedmont. Our work reaffirms Griffin's (1974a) interpretation of this contact as a metamorphic break. Thus, the age of movement must be younger than the thermal peak of regional metamorphism, but older than the Early Silurian (435 Ma) Caesars Head Granite pluton which cuts the fault.

The northeast-striking Brevard fault zone separates thrust sheets of the Blue Ridge and Inner Piedmont and is one of the most conspicuous features on the geologic map. The Brevard zone is also one of the most intensely studied features in the

southern Appalachians and a thorough discussion is beyond the scope of this text. Bobyarchick and others (1988) and Horton and McConnell (1991, p. 53–55) review the evidence which supports a lengthy history of ductile and brittle deformation, including episodes of Paleozoic thrusting and dextral strike-slip motion.

The north-northeast-striking Lowndesville shear zone separates contrasting rocks of the Inner Piedmont and Charlotte terranes. Mylonitic and cataclastic fabrics and multiple cleavages in this zone are described by Nelson (1981). Shear bands indicate a component of sinistral shear, at least locally, but further study is needed to determine the overall history and sense(s) of movement. Gravity maps (for example, Wynn and others, 1988) show a sharp Bouguer gravity gradient across the Lowndesville shear zone and strikingly different gravity fields on opposite sides. This gradient is part of the regional Appalachian gravity gradient, which has been interpreted and modeled in a variety of ways to mark a major change in the overall composition or thickness of the Earth's crust (Hatcher and Zietz, 1980; Nelson, 1981; Hutchinson and others, 1983; Cook, 1984; Dainty and Frazier, 1984).

Steep, tabular zones of silicified fault breccia (sb) are widespread in the Greenville quadrangle and typically strike northeast or east-northeast. Discontinuous bodies occur in the Marietta-Tryon fault system in the Inner Piedmont (Garihan and others, 1990), in the Warwoman shear zone in the Blue Ridge (Hatcher, 1974), and in the Cold Spring shear zone in the Charlotte terrane (Griffin, 1979). Extensional fabrics and abundant evidence of oblique-normal slip postdating diabase dikes suggest that the silicified breccia zones are early Mesozoic extensional features (Garihan and others, 1990).

Jointing is ubiquitous throughout the study area but joint patterns have not been studied in detail. Most joints are steeply inclined and do not seem to have well-defined preferred strike orientations. Less commonly, joints are shallow dipping or are horizontal. Some thin pegmatite and quartz veins occupy early joint sets.

METAMORPHISM

An inset map (sheet 2) shows zones of Paleozoic regional metamorphism in the Greenville quadrangle. Metamorphic gradients exist within some thrust sheets and some thrust faults juxtapose terranes of differing metamorphic grade. Northwest of the Brevard zone in the Blue Ridge, the Great Smoky thrust sheet has regional metamorphic zones ranging from chlorite (in the northwest) to sillimanite (in the southeast) (Hadley and Nelson, 1971). In the Greenville quadrangle, however, the rocks of the Great Smoky thrust sheet range from garnet to sillimanite-muscovite zones (Shellebarger, 1980; Gillon, 1982). In the overlying Richard Russell thrust sheet, the rocks appear to be mostly in the sillimanite-muscovite zone (Gillon, 1982; Nelson and Zietz, 1983) with a small part in the kyanite zone, although to the northeast, beyond the quadrangle boundary, some of the rocks are in the granulite facies of regional metamorphism (Eckert and Mohr, 1985). The Helen thrust sheet is exposed in a relatively narrow zone and generally contains lower grade rocks than does the adjoining Richard Russell thrust sheet to the northwest or the Tallulah Falls thrust sheet to the southeast. Rocks in the Helen thrust sheet range from the garnet to staurolite and kyanite zones (Gillon, 1982; Nelson, 1982, 1983b). To the southeast, the Tallulah Falls thrust sheet includes rocks ranging from the kyanite to

sillimanite-muscovite zones (Hatcher, 1976; Roper and Dunn, 1970).

Southeast of the Brevard zone, the Chauga-Walhalla thrust complex of the Inner Piedmont contains prograde metamorphic rocks ranging from the greenschist facies in the eastern part to the kyanite zone of the amphibolite facies in the western part of the complex. Most of the rocks in the Chauga part of the complex are in the greenschist facies. To the southeast, the metamorphic grade generally increases to kyanite in the Walhalla part of the thrust complex (Griffin, 1967, 1975; Hatcher, 1969). To the southeast, the Six Mile thrust sheet is mostly in the sillimanite-muscovite zone, but locally is in the kyanite zone (Griffin, 1975); the Laurens and Paris Mountain thrust sheets farther to the east are in the sillimanite-muscovite zone.

Southeast of the Lowndesville shear zone, highly weathered and altered rocks of the mafic-ultramafic assemblage are poorly exposed and, although metamorphic data are sparse, the rocks appear to be at medium grade. Adjoining the mafic-ultramafic assemblage to the northeast is the Charlotte volcanic-arc assemblage which includes rocks of the Carolina slate belt that are in the biotite-chlorite zone of the greenschist facies. Also included are rocks of the Kings Mountain belt and the Charlotte belt that contain rocks of the amphibolite facies.

Retrograded metamorphic rocks are exposed in and near the Brevard zone and the Lowndesville shear zone. Retrograded metamorphic rocks are also associated with some smaller shear zones elsewhere in the quadrangle.

Much radiometric whole-rock and mineral age dating has been done on samples from the southern Appalachian Mountains (Long and others, 1959; Kulp and Eckelmann, 1961; Medlin, 1968; Butler, 1972; Odom and Fullagar, 1973; Dallmeyer, 1975, 1978; Odom and others, 1976; Whitney and others, 1976; Fullagar and Butler, 1979; Fullagar and Kish, 1981; Harper and Fullagar, 1981). This radiometric dating includes the U-Pb zircon, K-Ar, $^{40}\text{Ar}/^{39}\text{Ar}$, and Rb-Sr methods. The oldest period of regional metamorphism recorded in the southern Appalachian Mountains occurred at about 1,200 to 1,000 Ma (Hadley and Goldsmith, 1963; Rankin and others, 1969), but there was also a thermal peak at about 900 to 800 Ma. In the Blue Ridge thrust sheet (mostly Great Smoky thrust sheet of this report), Butler (1972) indicates that a Paleozoic Barrovian-type prograde metamorphism occurred between 470 and 430 Ma, probably during the Taconic orogeny; there was also a possible period of metamorphism at about 380 Ma (Acadian orogeny) when the Spruce Pine pegmatites originated. In addition, he indicated an episode of retrograde metamorphism that was particularly intense along the Brevard zone and along other faults, but sporadically developed elsewhere. This retrograde metamorphism appears to be associated with late Paleozoic deformation and thrust faulting, but could also be the result of uplift and cooling and not necessarily a separate thermal event (Shellebarger, 1980). Dallmeyer (1975) also concluded the Blue Ridge was regionally metamorphosed at about 480 Ma. Butler (1972) considered the Inner Piedmont to have been metamorphosed at about 430 to 410 Ma, and that belts to the southeast were metamorphosed at about 420 to 380 Ma.

Odom and others (1976) indicated that a part of the southern Appalachians in Alabama and Georgia that corresponds to the Tallulah Falls thrust sheet was regionally metamorphosed at about 370 Ma. Dallmeyer (1978) gave evidence to support a regional metamorphic event in the Inner Piedmont of Georgia at

about 365 Ma. Most recently, Dallmeyer (1988) found that hornblendes from the Helen and Tallulah Falls thrust sheets of the eastern Blue Ridge, and those from higher grade parts of the Chauga-Walhalla thrust complex and eastern parts of the Six Mile thrust sheet in the Inner Piedmont, have $^{40}\text{Ar}/^{39}\text{Ar}$ plateau ages of 333 to 322 Ma. Hornblende from lower-grade parts of the Chauga-Walhalla thrust complex and from the Alto allochthon, a western klippe of the Six Mile thrust sheet, have older plateau ages of 362 to 322 Ma. Dallmeyer (1988) interpreted the hornblende ages to date regionally diachronous cooling following Late Devonian or earlier regional metamorphism. His muscovites, which have a lower argon closure temperature, yielded plateau ages of 318 to 302 Ma throughout the eastern Blue Ridge and Inner Piedmont.

The latest retrograde metamorphic assemblage in mylonite of the Brevard fault zone has a rubidium-strontium isochron age of 273 Ma (Sinha and others, 1988). Late Paleozoic (Alleghanian) deformation is well documented in the Brevard zone (Bobyarchick and others, 1988; Horton and McConnell, 1991). The minimum age for mylonite formation in the Lowndesville shear zone was earlier interpreted as about 350 Ma (Davis, 1980; Horton, 1981), but unpublished U-Pb zircon ages of deformed and undeformed granites (T.W. Stern, USGS, written commun., 1986) suggest that these mylonites formed between 344 and 312 Ma. The Brevard zone and the Lowndesville shear zone are tectonic boundaries for three major allochthonous terranes in the Greenville quadrangle and both have been subject to late Paleozoic tectonism.

DISCUSSION

Rocks in all thrust sheets are polymetamorphic and polydeformed. Some rocks contain two relatively late metamorphic schistosity or cleavage surfaces, and some rocks have been folded at least four times (Nelson, 1985). Small patches of retrograded rocks are irregularly dispersed in all thrust sheets, but the most intensely retrograded rocks are in or close to the Brevard fault zone and the Lowndesville shear zone. Locally, a small diamictite in the western part of the Richard Russell thrust sheet contains some medium-grade boulders and rock fragments whose foliation-schistosity trends are discordant to the regional schistosity of the enclosing matrix. This suggests the boulders and their source rock unit within the same thrust sheet had a previous prograde metamorphic history. Other evidence to support earlier metamorphic events, however, is rare. Most probably, if there were early prograde events, much of the evidence was destroyed as each thrust sheet was regionally metamorphosed under relatively high-grade conditions.

Even though considerable isotopic dating has been done in the southern Appalachians, the orogenic evolution and age of metamorphism of some allochthonous terranes in the orogen remain enigmatic. The Greenville quadrangle is underlain by a series of stacked thrust sheets extending from the Blue Ridge province through the Inner Piedmont and into the Charlotte terrane of the Piedmont province. Some of these thrust sheets correlate with terranes where the regional metamorphism has been dated. For example, the Great Smoky, the Richard Russell, and possibly the Helen thrust sheets form a large part of the terrane that was metamorphosed between 470 and 430 Ma (Butler, 1972). There appear to be conflicting isotopic dates, however, for rocks within the Tallulah Falls thrust sheet. Rock units of the Tallulah

Falls thrust sheet were previously thought to correlate with rocks to the northeast that were regionally metamorphosed between 470 and 430 Ma (Butler, 1972); however, these rocks to the northeast are now believed to be from the Great Smoky and the Richard Russell thrust sheets. To the southeast, some rocks in the Tallulah Falls thrust sheet probably correlate with units of the Ashland-Wedowee belt (Hurst, 1973). Odom and others (1976) presented Rb-Sr data that suggests some metasedimentary units of the Ashland-Wedowee belt were regionally metamorphosed at about 370 Ma. Preliminary unpublished U-Pb zircon ages suggest that the latest regional metamorphism in the Tallulah Falls thrust sheet is probably no older than 373 to 351 Ma (T.W. Stern, USGS, written commun., 1986) and thus may represent the same metamorphic event reported by Odom and others (1976).

The age of regional metamorphism for the Inner Piedmont, which includes the Chauga-Walhalla thrust complex and the Six Mile and Laurens thrust sheets in the Greenville quadrangle, is also incompletely understood. Butler (1972) interpreted the age of metamorphism in the Inner Piedmont northeast of the Greenville quadrangle to be about 430 to 410 Ma. Dallmeyer (1988) subsequently obtained $^{40}\text{Ar}/^{39}\text{Ar}$ mineral ages from the Chauga-Walhalla thrust complex and Six Mile thrust sheet within the Greenville quadrangle. He interpreted the results to date regionally diachronous cooling following a Late Devonian or earlier high-grade metamorphism.

Preliminary radiometric dating suggests that the latest regional metamorphism in the Chauga-Walhalla thrust complex was no earlier than about 385 Ma (T.W. Stern, USGS, written commun., 1987). Preliminary U-Pb zircon ages suggest that the latest regional metamorphism for the eastern part of the Six Mile thrust sheet occurred no earlier than about 391 to 365 Ma (T.W. Stern, USGS, oral commun., 1986). These limits are compatible with Dallmeyer's (1988) interpretation of Inner Piedmont metamorphism as Late Devonian or earlier. Preliminary U-Pb zircon ages for rocks in the Laurens thrust sheet suggest that the latest regional metamorphism occurred no earlier than about 359 to 344 Ma (T.W. Stern, USGS, oral commun., 1986). This may be a latest age of the same event.

Within the Greenville quadrangle, the Inner Piedmont is bounded on the northwest by the Brevard zone, which separates the Tallulah Falls thrust sheet on the northwest from the Chauga-Walhalla thrust complex in the southeast. Farther to the southwest in Georgia and Alabama, the Brevard zone does not form a major terrane boundary as some rock units from the Ashland-Wedowee belt extend from the west across the Brevard zone and into the Inner Piedmont (Medlin and Crawford, 1973). Because of this, Dallmeyer (1978) has pointed out that the Ashland-Wedowee belt and some rocks of the Inner Piedmont were probably regionally metamorphosed around 370 to 356 Ma.

Butler (1972) suggests that belts southeast of the Inner Piedmont and east and northeast of the Greenville quadrangle were regionally metamorphosed between 420 and 380 Ma. In the Greenville quadrangle, the Charlotte terrane lies immediately southeast of the Inner Piedmont along the Lowndesville shear zone. Preliminary U-Pb zircon studies suggest the Charlotte terrane was regionally metamorphosed at approximately 338 to 312 Ma (T.W. Stern, USGS, oral commun., 1986), and here the age of regional metamorphism does not correspond with the 420 to 380 Ma event farther to the northeast. Medlin (1968) reported postmetamorphic plutons in the Charlotte terrane that

have K-Ar age dates of 387, 386, and 380 Ma. These dates do not correspond with recent U-Pb zircon dates, but they do correspond with the 420 to 380 Ma event of Butler (1972).

Fullagar and Kish (1981) presented Rb-Sr mineral age data for a part of the Inner Piedmont represented by the Laurens thrust sheet, the Paris Mountain thrust sheet, and the Charlotte thrust sheet. These Rb-Sr mineral ages, within the report area, range from 280 to 254 Ma (Permian). The Fullagar and Kish study shows that the youngest mineral ages are in the western part of the quadrangle and suggests this results from more recent uplift and erosion of the rocks underlying the western Piedmont. The 280 to 254 Ma mineral ages (Permian) for parts of the Laurens, Paris Mountain, and Charlotte thrust sheets are probably the results of rapid cooling of an earlier thermal event. Throughout the Greenville quadrangle, there are several postpeak regional metamorphic stages of cleavage development and mica crystallization in these cleavage planes. The Permian mineral ages are considered to be minimum ages for these cleavages.

MINERAL RESOURCES

The following summary of mineral resources in the Greenville quadrangle is adapted from an overview by Nelson and others (1990), which readers may consult for additional information and primary references.

Industrial and other nonmetallic mineral resources account for most of the recent mineral production in the Greenville quadrangle. Quarries in the Elberton Granite annually produce about one-fourth of the monumental granite in the United States. Crushed stone has been produced from all the thrust sheets and potential sources of granitoid stone are abundant in the Six Mile, Walhalla, and Charlotte thrust sheets. Mica is produced in Hart County, Georgia, from coarse granite saprolite in the Six Mile thrust sheet. Pegmatites are former sources of mica in the Richard Russell, Helen, Tallulah Falls, Chauga-Walhalla, and Six Mile thrust sheets (Lesure and Shirley, 1968). Vermiculite is presently mined, mainly east of the quadrangle, from deeply weathered, metamorphosed ultramafic bodies in the Laurens thrust sheet. Small amounts of asbestos, mainly anthophyllite, have been produced from ultramafic bodies in the Tallulah Falls, Helen, Chauga-Walhalla, and Six Mile thrust sheets. Corundum has been mined from small deposits in altered ultramafic rocks of the Tallulah Falls and Young Harris thrust sheets, and it is known to occur in the Laurens and Six Mile thrust sheets. Sillimanite is widespread in schists of the Six Mile and Paris Mountain thrust sheets where it has been prospected but not mined. Kyanite in schist of the Tallulah Falls thrust sheet has been mined on a small scale from saprolite and placer concentrations. Marble has been quarried on a small scale from lenses in the Chauga-Walhalla thrust complex near the Brevard fault zone and in the Laurens thrust sheet. Skarn is locally associated with marble in the Laurens thrust sheet, suggesting the possibility of exploration targets for base metals.

Sand has been produced from alluvial deposits along rivers and streams throughout the quadrangle. However, dams constructed on the Savannah River and other rivers have flooded large areas of alluvium, reducing the availability of sand.

Metal production in the Greenville quadrangle has included gold, silver, copper, lead, manganese, and thorium. Most of the gold has been mined from low-sulfide gold-quartz veins and placer deposits in the Dahlonega gold belt of the Helen thrust

sheet (Nelson and others, 1990). Massive sulfide deposits include the Chestatee mine (Lumpkin County, Ga.) in the Helen thrust sheet (which produced pyrite for sulfuric acid), the Tom Coward prospect (Rabun County, Ga.) in the Richard Russell thrust sheet, and the Saluda copper mine (Abbeville County, S.C.) in the Laurens thrust sheet. Interlayered metavolcanic and metasedimentary rocks of the Charlotte volcanic-arc assemblage are potential hosts for disseminated gold deposits similar to those mined east of the quadrangle.

The "southeastern monazite" belt constitutes a large resource of thorium and rare-earth elements (Mertie, 1979). In this area, the monazite belt coincides closely with the Six Mile, Paris Mountain, and Laurens thrust sheets. Thorium has been produced from monazite in Greenville County, S.C.

CONCLUSIONS

While the timing of regional metamorphic events in specific thrust sheets within the Greenville 1°x2° quadrangle is imperfectly known, the following pattern seems to be present. The oldest regional metamorphic event, exclusive of the Middle Proterozoic event in the basement rocks, occurs in the rocks of thrust sheets northwest of the Tallulah Falls thrust sheet. The youngest prograde metamorphic event appears to be in the rocks of the Charlotte thrust sheet in the southeast part of the quadrangle. Generally, the Chauga-Walhalla thrust complex, the Six Mile thrust sheet, the Laurens thrust sheet, and the Charlotte thrust sheet appear to have been regionally metamorphosed at successively younger intervals from west to east.

At the present time there is only a sketchy understanding of the metamorphic and deformational history of the thrust sheets underlying the Greenville quadrangle. The distribution and position, as well as the present metamorphic grade and age, of the thrust sheets underlying the Greenville quadrangle show they have evolved through a complex deformation and metamorphic history. Thrust sheets with varying ages and grades of metamorphism are juxtaposed and some thrust sheets have poorly constrained ages of metamorphism. Deformation along some of the major thrust faults covers a long time interval; some faults are pre- to synmetamorphic, and parts of some earlier faults appear to have been reactivated later under a brittle regime. We suggest the present distribution of the thrust sheets results from telescoping of the previously metamorphosed thrust-sheet stack during a long interval of intermittent westward transport of much of the thrust stack onto the North American craton during the Paleozoic, and that selected assemblages of thrust sheets were metamorphosed during one of several metamorphic events and assembled into their present position as outlined below.

The Helen thrust sheet was emplaced upon the Great Smoky thrust sheet before the regional metamorphic peak at 470 to 430 Ma. Later, during an interval that began before, but extended into, the period of regional metamorphism, the Richard Russell thrust sheet and the Young Harris thrust sheet were thrust over both the Helen and the Great Smoky thrust sheets along the Hayesville fault. The Hayesville fault is a pre- to synmetamorphic fault, but some postmetamorphic movement along the fault between the Richard Russell and Helen thrust sheets has occurred (Nelson, 1985). The Great Smoky, Helen, and Richard Russell thrust sheets, along with the Young Harris thrust sheet, constitute a northwest thrust sheet assemblage that was metamorphosed at 470 to 430 Ma (Taconic).

In places, lower grade rocks (garnet zone) of the Helen thrust sheet are juxtaposed with migmatite and sillimanite grade rocks of the Tallulah Falls thrust sheet, suggesting the two thrust sheets were separated during metamorphism of the Tallulah Falls thrust sheet that occurred at about 365 Ma (Acadian). Therefore, the metamorphosed Tallulah Falls thrust sheet was probably emplaced upon the Helen thrust sheet along the Dahlonga fault after the metamorphic event at 365 Ma.

Thrust sheets of the Inner Piedmont exposed between the Brevard zone and the Lowndesville shear zone comprise a distinct thrust sheet assemblage considered to have been metamorphosed during the same Late Devonian or earlier Paleozoic event. The Six Mile thrust sheet was thrust onto the Chauga-Walhalla thrust complex along the Seneca fault, and all of these were subsequently cut by the Caesars Head Granite. When the Paris Mountain thrust sheet was emplaced onto the Six Mile thrust sheet is unknown, but the Laurens thrust sheet was emplaced after the Paris Mountain and Six Mile thrust sheets were joined.

The Inner Piedmont thrust stack probably was thrust onto the Tallulah Falls thrust sheet, forming mylonites along the Brevard fault zone, although the history of the Brevard zone is complicated by episodes of strike-slip and late brittle deformation (Bobyarchick and others, 1988). The metamorphosed and deformed Charlotte thrust sheet was juxtaposed against parts of the Six Mile and Laurens thrust sheets along the Lowndesville shear zone between 344 and 312 Ma.

If the present interpretation is correct, the various thrust sheet assemblages were metamorphosed during one of three periods of regional metamorphism, 338 to 312 Ma (Alleghanian), 365 to 344 Ma (Acadian), and 470 to 430 Ma (Taconic), younging from northwest to southeast. Except for the northwesternmost assemblage, the thrust sheets or thrust sheet assemblages were probably metamorphosed before emplacement upon thrust sheets to the northwest. After the major thrust sheets or assemblages of thrust sheets were joined there was probably continued intermittent movement under brittle conditions along some of the major faults until they were thrust along a master décollement to their present position upon unmetamorphosed Paleozoic rocks of the Valley and Ridge near the close of the Paleozoic.

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