**Geologic Controls on the Morphology of the Chattooga River**

Scott E. Brame  
Geological Sciences  
Clemson University  
Clemson, SC 29634
dand

Robert D. Hatcher, Jr.  
Earth and Planetary Sciences  
and Science Alliance Center of Excellence  
University of Tennessee  
Knoxville, TN 37996–1410

**Abstract**

The East fork of the Wild and Scenic Chattooga River drains the south side of Whiteside Mountain in North Carolina and flows in a predominant southwesterly direction following the predominant joint direction, and to a much lesser extent the foliation, until it turns sharply to the southeast becoming part of the Savannah River system and flows to the Atlantic Ocean. Paralleling the northeast to southwest trend is the Brevard fault zone and two other river systems, the Chauga River in South Carolina and the Chattahoochee River in Georgia. The Chauga follows a pattern similar to that of the Chattooga, turning sharply to the southeast after flowing predominantly to the southwest from its headwaters.

The locations that mark the abrupt turn of the flow of the Chattooga and Chauga Rivers from the southwest to the southeast are likely the result of stream piracy as proposed by Acker and Hatcher. The upper sections of the Chattooga and Chauga represent an extension of the Dahlonega Plateau with a topographic surface that has a maximum elevation of approximately 1600 feet. The 1600’ surface is a piedmont surface at the base of the Blue Ridge. Differential erosion along northeast- and northwest-trending joint sets has exerted a powerful control on the development of the landscape. The northwest-trending joint sets have encouraged headward erosion and breaching of the Dahlonega Plateau surface resulting in stream capture of both the Chattooga and Chauga watersheds by the Savannah River system.

The Chattooga River is deeply incised into Tallulah Falls Formation gneisses, schists, and amphibolites. The river landscape contains large rocks jutting steeply from the river bed, exciting rapids, and cascading waterfalls where tributaries enter the river. While the section of the river above the capture point flows southwest, the river channel has an angular appearance in map view as it is oriented parallel to either northeast-southwest or northwest-southeast trending joints. While this crudely rectangular drainage pattern suggests that the major and minor fracture orientations are responsible for the larger morphological characteristics of the river, a close examination of the bedrock exposed in the river section of this field trip does not reveal abundant fractures along those trends but that the river has cut its channel by excavation of potholes. A possible explanation is that discontinuous fractures were responsible for initially setting the course of the river and once the river became entrenched in its bedrock channel; there was not a need for a continuous fracture system to maintain the channel orientations. Widely spaced fractures are present in the massive biotite gneisses, but the more highly fractured schists which are not resistant to mechanical erosion have been eroded and thus are not frequently exposed.
Introduction

The Chattooga River in northwestern South Carolina is one of the premier whitewater rivers in the US. It was declared a Wild and Scenic River by an act of Congress on May 10, 1974. A large majority of the river occurs in National Forest lands and, as a result, the Chattooga has remained relatively undeveloped and water quality is exceptionally high. A series of dams was proposed along the river by Georgia Power Company, but were never constructed, and the Chattooga remains a free-flowing river for more than 50 miles from its headwaters in the North Carolina mountains to the end of Section IV where it is impounded by Tugaloo Lake. At this point, the river joins the extensive dam network of the Savannah River system (Fig. 1).

![Chattooga River Sections 2-4
Chauga River Sections 1-3](image)

Figure 1. Whitewater sections of the Chattooga and Chauga Rivers (the numbered arrows indicate the start of each respective section). Also note the subparallel abrupt SW- to SE-changes in the trend of both rivers.

The section of the river that will be explored on this field trip is the upper part of Section III from Earl’s Ford to Sandy Ford. The U.S. Forest Service (FS) rates this section as a Class III run, although many of the rapids are of a Class I and II difficulty with one Class IV (only at high water levels, flows exceeding 4000 cfs). The Chattooga is considered a “technical” whitewater river.
This designation implies that considerable maneuvering is required to negotiate the rapids and avoid the ever-present rocks (Appendix B).

The main points of interest along this stretch include the formation of major rapids by the migmatitic biotite-muscovite gneisses of the Tallulah Falls Formation, the joints that control the drainage pattern of both the Chattooga and its tributaries, and the possibility that the Chattooga is a pirated headwaters stream of the Chattahoochee River (Acker and Hatcher, 1970). Acker and Hatcher (1970) explored and detailed the relationship between landscape evolution and fracture control on drainages in this area (Appendix A). The stretch of the river covered in this field trip has been mapped in detail by Hatcher (in press a, b), Hatcher and Liu, in press; and Hatcher et al. (in press).

The Chattooga River plays an important role in the development of the landscape of northwestern South Carolina. Exploring the Chattooga at river level allows one to experience firsthand the results of millions of years of mountain stream evolution.

**Geology**

**Geologic Province**

The river portion of the field trip will take place entirely in the Blue Ridge Foothills. The close proximity of the Chattooga to the Brevard fault zone (BFZ) marks the transition from the Piedmont to the Blue Ridge. The influence and significance of the BFZ is discussed below.

**Geologic History**

The southern Appalachians formed through a series of arc, exotic terrane, and continent-continent collisions involving the eastern margin of the ancestral North American continent, distal deep-water equivalents of the rifted margin sedimentary and volcanic rocks (Inner Piedmont-eastern Blue Ridge), a Neoproterozoic Peri-Gondwanan arc (Carolina superterrane), and the western margin of proto-Africa (Hatcher et al., 2007).

In the Neoproterozoic, supercontinent Rodinia was rifted apart into North America, Australia, Siberia, Europe, and Gondwana. Large fragments of Laurentian continental crust left in the wake of rifting later became part of the western Blue Ridge, while smaller fragments were rifted into the Iapetus ocean to become surrounded by ocean crust in the eastern Blue Ridge and western Inner Piedmont (Tugaloo terrane). The Iapetus ocean closed during the Ordovician when a subduction zone formed off Laurentia producing a volcanic-plutonic arc, part of which became the Poor Mountain Formation (mafic and felsic volcanics, quartzite, marble) in the Inner Piedmont, which unconformably overlies the Tallulah Falls (and Chauga River) Formation. This arc was accreted to Laurentia during the Ordovician (Taconic orogeny).

The Theic ocean remained open between composite Laurentia and Ordovician accreted terranes, but began to close from Late Devonian to Mississippian time as Carolina superterrane collided obliquely (N to S) with all terranes to the W and subducting them to depths where wholesale melting occurred in Inner Piedmont and eastern Blue Ridge rocks (Tugaloo and Cat Square terranes), and closing the remnant ocean basin where Siluro-Devonian Cat Square terrane (eastern Inner Piedmont) rocks were deposited. This was the Neoacadian orogeny. While the Chattahoochee-Holland Mountain fault forms the western boundary of the Tugaloo terrane, the primordial Brevard fault zone formed by decoupling the western from the eastern Tugaloo (and Cat...
Square) terrane during this orogeny at elevated temperatures and pressures, and may have moved 400 km southwestward with the western Tugaloo terrane (that probably moved half that distance) (Hatcher and Merschat, 2006; Merschat and Hatcher, 2007).

The Rheic ocean separating terranes previously accreted to Laurentia from Gondwana remained open. This ocean closed obliquely during the Pennsylvanian-Permian reactivating the Brevard fault zone again dextrally, at lower greenschist facies conditions (chlorite grade), producing an unknown amount of displacement. The northwestern part of the Brevard fault zone was reactivated again later as a thrust fault (Rosman fault), probably during the final, head-on collision of Africa with Laurentia, forming the Blue Ridge-Piedmont megathrust sheet (Hatcher, 2001, 2002). Tectonic activity in the Alleghanian orogeny ended with the formation of supercontinent Pangea.

The Mesozoic history of the southern Appalachianians is marked by the breakup of Pangea. Initial rifting produced the Triassic-Jurassic basins, diabase dikes, and a series of brittle faults characterized by multiple reactivation, brecciation, and precipitation of vuggy quartz. The E-W trending Warwoman lineament in northeastern Georgia is a valley that locally contains siliceous cataclasite (Hatcher, 1971). This lineament is not traceable into South Carolina, but projects eastward across the Chattooga River and Oconee County into northern Pickens and Greenville Counties where the Pax Mountain lineament and fault zone have been mapped (Birkhead, 1973; Garihan et al., 1993). These lineaments are part of a system of Jurassic faults that are coeval with diabase dike emplacement in the Blue Ridge and Inner Piedmont (Birkhead, 1973; Snipes et al., 1979; Garihan et al., 1993; Hatcher et al., 2005). These fault and diabase dike systems are related to the Triassic-Jurassic extensional stress field that set up in the crust during the breakup of Pangea (May, 1971). This extensional field persisted until the Cretaceous when ridge-push stress reversed the stress field in eastern North America to compression with an ~N 70° E orientation, one that persists to today (Prowell, 1988; Zoback and Zoback, 1991).

The Appalachian Mountains were in a state of erosion since the end of the Paleozoic, but today’s topography is probably not a product of static erosion, as concluded by Naeser et al. (2001) and Matmon et al. (2003). Instead, the Appalachianians were probably eroded to very low relief during the late Mesozoic (see truncation of the Appalachianians at the Coastal Plain overlap in the Gulf Coastal Plain in Alabama in any geologic map, e.g., King and Bekman, 1974), then uplifted again during the Cenozoic (Prowell and Christopher, 2000; Prowell, 2006). This renewed uplift of the Blue Ridge is probably related to isostatic readjustment above the 50 km-thick crust that exists beneath the Carolinas-Tennessee-northern Georgia Blue Ridge (Hawman, 1996). The present topography, including that in northwestern South Carolina, was etched by erosion into this newly uplifted crust.

The Chattooga River along the field trip route flows across parts of the Satolah and Whetstone 7.5-minute quadrangle in the Blue Ridge geologic province (Figs. 2 and 3). Its course is determined by orientation of dominant joint sets, and to a lesser extent, by the orientation of dominant \(S_2\) foliation.
Figure 2. Geologic map of the Whetstone quadrangle. Section A-A’ just intersects the portion of the Chattooga River traversed by the field trip (see Fig. 3). The Chauga River flows in rocks of the Brevard fault zone until it turns at its capture point and flows southeast. (from Hatcher et al., in press). The pink, tan, and lavender rocks in the upper left are Tallulah Falls Formation. All others to the southeast belong to the Chauga River and Poor Mountain Formations, and Henderson Gneiss.
Figure 3. Cross section along line A-A’ from Hatcher et al. (in press) illustrates the tightly folded nature of the Tallulah Falls Formation rocks underlying the Chattooga watershed.

Rock Units

The main course of the Chattooga River flows in Tallulah Falls Formation rocks (Hatcher, 1971). Rocks of the Tallulah Falls Formation initially present themselves as a repetitious mix of biotite gneiss, schist, and amphibolite. However, Hatcher (1971, 1976) and Hatcher et al. (2005) were able to divide the units using the intermediate garnet-aluminous schist member. All three members of the Tallulah Falls Formation are present on the river trip. They are: (1) the upper graywacke-schist (biotite gneiss) member; (2) the middle garnet-aluminous schist member; and (3) the lower graywacke-schist-amphibolite (biotite gneiss) member. The upper member contains metagraywacke (quartz-biotite-plagioclase-muscovite gneiss), muscovite schist, muscovite-biotite schist, and minor amounts of amphibolite. The garnet-aluminous schist member consists of muscovite-garnet-kyanite (or sillimanite) schist with interlayered amphibolite, muscovite schist, and metagraywacke. It is generally recognizable by abundant garnet and kyanite or sillimanite. The lower member contains metagraywacke, amphibolite, muscovite schist, and biotite schist.

The Tallulah Falls Formation is a heterogeneous mix of metasedimentary and mafic metavolcanic rocks of Neoproterozoic to early Paleozoic (?) age (500 to 650 million years old). The Tallulah Falls Formation was named for exposures of similar rock types found around Tallulah Falls in northeast Georgia by Hatcher (1971). Underlying the Tallulah Falls Formation are the basement Wiley, Sutton Creek, Wolf Creek, and Toxaway Gneisses (1150 Ma; Carrigan et al., 2003; Hatcher et al., 2004, 2005). Hatcher (1977) has interpreted the basement-Tallulah Falls Formation contact as unconformable.

Biotite gneiss (metagraywacke) is the dominant rock type derived from the original deep-water marine sedimentary deposits. Amphibolites constitute a minor but tectonically significant component. These rocks are likely the metamorphosed mafic volcanic rocks, which were interlayered with the original sedimentary sequence as sills, lava flows, and possibly pyroclastic deposits (Hatcher, 1971; Hatcher et al., 2004).

When the Tallulah Falls Formation was metamorphosed during the Paleozoic, metagraywacke and partially melted (did not melt fully) mica schist crystallized into pods, stringers, and dikes of granitoid and pegmatite that are abundant in the rocks exposed along the river.
Influence of the Brevard Fault Zone and Blue Ridge Escarpment

The Brevard fault zone can be recognized as a very linear topographic feature from Alabama to Virginia. In northeastern Georgia, northwestern South Carolina, and south-western North Carolina, the fault zone is incised into the Dahlonega Plateau in northeastern Georgia and northwestern South Carolina across the Tugaloo Lake and Whetstone 7.5-minute quadrangles. Northeast of the Whetstone quad, the fault zone crosses the topographic front in the Tamassee quad and occurs at the lower elevations of the Piedmont. To the northeast, however, it traverses the 700-m Blue Ridge escarpment into North Carolina (Mills, 2004).

Many hypotheses have been suggested for the origin of the Blue Ridge Escarpment (e.g., a normal fault, White, 1950; Knapp et al., 2002). The present landscape appears to be a product of Cenozoic isostatic uplift in conjunction with the erosive power of streams preferentially flowing to the Atlantic Ocean rather than to the Mississippi drainage and the Gulf of Mexico (Hack, 1982). The result is that the escarpment and the Eastern Continental Divide are migrating westward through headward erosion and stream piracy.

This process has had a powerful influence on the landscape over time. The headward migrating streams will eventually intercept, or capture, streams that once flowed toward the southwest. Acker and Hatcher (1970) recognized present-day stream patterns that preserved evidence of past stream capture along the Blue Ridge Escarpment in nearby South Carolina.

Hydrology

The Chattooga drainage has two main tributaries in its headwaters (the East and West Forks of the Chattooga) and numerous other significant streams that drain the Blue Ridge west and east of the river. These tributaries collect precipitation from an area that has the highest recorded rainfall in the Southeast. The Chattooga watershed includes the Highlands and Cashiers areas of North Carolina, and the Rabun Bald area in Georgia. Typically, the Chattooga experiences moderate rainfall during the winter punctuated by large episodic events, high rainfall in late winter and spring, and decreasing rain as summer turns into fall.

The large rainfall events (25,000-30,000 cfs) recorded at the U.S. 76 bridge hydrograph in the early 1940s indicate flows that might possibly have changed the shape and flow of the river by moving large boulders in the bed load (Fig. 4). In general, the large flood events that exceed 10,000 cfs and occur every 10-20 years probably have little effect on the overall shape of the river valley. The short term effect of these floods is their accumulation or removal of sand on the banks, shifting of gravel beds, and of creating or removing log jams. The reason that the floods have so little effect is that the Chattooga is a bedrock controlled river. While the floods may redistribute the sand and gravel, the course of the Chattooga is determined by its ability to grind away the resistant paragneisses of the Tallulah Falls Formation. The current theory is that the majority of this grinding takes place during very large flood events spread out over geologic time and that very little modification takes place during normal flow conditions.
Figure 4: Historical record of streamflow on the Chattooga River at the U.S. 76 Bridge from 1939-2003 (USGS, URL: http://ida.water.usgs.gov/ida/available_records.cfm?sn=02177000).

More recent hydrographs (Figures 5 and 6) reveal significant rainfall fluctuations. The last ten years of record demonstrate the recurring cycles of drought that have created record low river flows punctuated occasionally by large flood events. Periods of low flow cause erosion of sand deposited along the banks by past floods and permit deposition in areas of the river normally scoured out by turbulent flood waters. Low flow periods allow fallen trees to accumulate along the river, which are then picked up by subsequent high flow events and moved downstream, commonly becoming lodged in narrows and in some rapids. The major influence of high water with regard to human uses of the river, such as paddling, is the redistribution of logs.

The flow record shows that a four year drought across the Southeast ended in 2002. The years 2003 to 2006 exhibited a return to wetter conditions with accompanying increases in baseflow. A particularly large event (~19,000 cfs) in 2004 coincides with the very heavy rainfall from Hurricane Ivan that caused landslides and flood conditions throughout much of the Southeast. Starting in 2007, another drought gripped the southeast US. This drought culminated in the lowest recorded flow in 68 years of record keeping in the fall of 2008.

After 2008, rains returned to the southeast. The winter of 2009/2010 was one of the wettest in the last 10 years.
Figure 5: Streamflow from 2001 - 2011 for the Chattooga at the U.S. 76 Bridge. (USGS, URL: http://waterdata.usgs.gov/ga/nwis/).

Figure 6: Hydrograph of the Chattooga River from 2007 to 2011. (USGS, URL: http://waterdata.usgs.gov/ga/nwis/).
Steam and Landscape Evolution

The landscape of the areas around the Chattooga and Chauga Rivers has been heavily dissected by erosion along dominant joint sets (Fig. 7). The dominant joint sets trend N 40°-50° W and N 30°-50° E and produce the characteristic rectangular and angulate drainage patterns. The large lineament oriented N 80° E in the upper half of the image in Georgia is a Mesozoic fault called the Warwoman lineament.

Figure 7: Hillshaded Digital Elevation model of the Whetstone, Rainy Mountain, Satolah, and Rabun Bald quadrangles.
Field Trip Stops

Departing from the Madren Center parking lot on the Clemson University campus, turn left at the entrance and drive to Perimeter Road. Turn left on Perimeter Road and proceed to SC 93. Drive west (left) on SC 93 to the intersection of U.S. 76/123 SC 93 ends here). Drive west again on U.S. 76/123 through Seneca to Westminster, SC. On the west side of Westminster, U.S. 76 and U.S. 123 divide. Take U.S. 76 toward Long Creek, SC. The distance from the Madren Center to this turnoff is approximately 18 miles.

0.0 Miles: 76 and 123 divide; drive toward Long Creek, SC on U.S. 76.

3.0 Miles: Cross the Chauga River.

11.6 Miles: Road Stop One at Intersection of U.S. 76 and Brasstown Valley Road.

Road Stop 1: Brevard Fault Zone and Chauga River Stream Piracy

Brasstown Valley has long been believed to represent the original steam bed of the Chauga River prior to its capture by the headward erosion of a westerly eroding stream (Acker and Hatcher, 1970) (Figs. 7 and 8). The topographic position of these drainages suggests that stream capture has occurred. From its beginnings in the Mountain Rest, South Carolina area approximately 8 miles to the northeast, the Chauga follows the Brevard fault zone lineament to within 1 mile of this stop. At that point, the river turns sharply to the southeast, where it has carved a deep and fairly inaccessible gorge except by foot or boat. The section of the Chauga downstream of this turn contains several Class III, IV, and V rapids that are floatable only at very high water levels by experts.

Downstream of this turn the Chauga contains numerous hanging valleys. The term hanging valley refers to the waterfalls formed by tributaries at their confluence with the Chauga. The formation of these waterfalls is consistent with the hypothesis that the river would experience exceedingly higher flows below the capture point than before the piracy, and thus would carve the main channel at a higher rate than the tributary streams, leaving them “hanging” above the main channel.

Visible evidence for the stream capture at this location is the presence of the wide, well developed floodplain in Brasstown Valley located 1/2 mile southwest of U.S. 76. Given that the valley has few tributaries at that point to contribute flow for the creation of a floodplain, it is likely that the valley is a remnant of the pre-piracy period.

Continue on U.S. 76 westward 3.8 miles to the intersection of Chattooga Ridge Road. (S.C. 196)

15.4 Miles: Turn right onto Chattooga Ridge Road.

19.4 miles: Road Stop Two: Whetstone Valley Overlook.
Figure 8: Topographic relationships between the Chattooga, Chauga, and Chattahoochee Rivers and Brasstown Creek in the study area suggest stream piracy has occurred.

**Road Stop 2: Major Northwest-Southeast Fracture Zone and Possible Stream Piracy**

This overlook provides a view of almost the entire Whetstone Valley. This broad valley represents a major northwest-southeast trending fracture zone that extends across the river into Georgia. Acker and Hatcher (1970) inferred from a study of topographic features that Whetstone Creek was captured by the Chattooga from the Chauga. Whetstone Creek originates close to the divide between the Chattooga and Chauga in a well-defined NW-SE oriented valley. As it flows southeast out of this valley, it turns abruptly 90° to the southwest, then again abruptly 90° to the
northwest toward its confluence with the Chattooga. Differential erosion along the predominant northwest trending joint set that created Whetstone Valley lowered the divide between the Chattooga and Chauga to the point that the drainage pattern of Whetstone Creek was changed (Fig. 9).

Figure 9: Hill-shaded relief map showing the relation of Whetstone Creek to the Chattooga and Chauga watersheds, the horseshoe bend pattern of Whetstone Creek, and the location of Road Stop 2.
Continue northeastward on Chattooga Ridge Road to the four-way stop intersection with Earls Ford Road (S.C. 193)

21.4 Miles: Turn left on Earls Ford Road and enter Whetstone Valley.

Earls Ford road will turn to gravel in about a mile and a half. After the change in road surface, continue straight ahead for 3 miles to the Earls Ford parking lot, which is the put-in for the river section of this field trip. On the way to the Earls Ford parking area, Forest Service Road 721-A turns off Earls Ford Road to the left 1.4 miles after the road becomes gravel. FS Road 721-A ends at the Sandy Ford parking lot, which is the takeout for this trip.

Before floating this section of the Chattooga, you must register your craft and party. There are forms available at the Earls Ford put-in. After registering, you must transport your boats and gear ¼ mile to the river. The launch site at the river is a small cobble beach (or sand on top of cobbles depending upon the last flood deposition). Examining the rocks here will give you an idea of the bedrock geology upstream.

River Stops

Some of the river stops have no particular geologic interest, but are informative with regard to running the river (Fig. 10). Several other stops will not be visited as it is not feasible for a large group to do so. The locations not visited are useful for gaining an understanding of the relation of the river to the underlying geologic structure, especially as one proceeds downstream.

Stop 1: Earls Ford put-in beach.

This small pebbly beach marks the start of Section III of the Chattooga River. From this point, it is 13 miles to the U.S. 76 Bridge, which is the beginning of Section IV. Warwoman Creek enters the Chattooga across the river on the Georgia side. There are no outcrops on the beach.

Stop 2: Rock on river right - 100 yards downstream of put-in.

This is the first measurable outcrop. The foliation here strikes N 20° E and dips 30° SE. The foliation is at angle of 45° to the river course.

Stop 3: River bends to the right and a small rapid.

This is the first rapid of the trip, and is rated as a Class I rapid. The foliation strikes N 45° E and dips 50° SE. The river direction is perpendicular to the foliation.
Figure 10: Location of Chattooga River stops with the geology overlain on a topographic map of the area. The geology was modified from Hatcher, et al. (in press) and Hatcher (unpub. data)
**Stop 4: Warwoman (Examination) Rapid**

Warwoman Rapid (Class II - III) requires maneuvering skill at low to moderate water levels. To negotiate this rapid, enter from river left and move diagonally right to the main chute. There is a prominent rock in the chute that complicates the run at low water.

The rocks that form this rapid have a foliation that strikes N 25° E, with a dip of 30° SE. The river trend is N 75° W and flows perpendicular to the foliation. In the rocks on river left that form the rapid, there is a small nearly vertical fracture trending N 60° W and is the only one readily visible. The rocks show remarkably little evidence of fractures.

Prominent potholes can be found on the downstream side of the ledge. These tend to develop primarily on the scarp face (Fig. 11), but they are also found on the dip face. As water cascades over the drop (at higher water) the turbulence produced by the fall facilitates pothole formation. In the absence of fractures, potholes are the primary mechanism the river has to wear down the resistant bedrock. If abundant fractures are present, the river is able to widen, loosen and eventually pluck blocks of rock out along the fractures. Exploiting the weakness along existing fractures involves less work and is mechanically more efficient than the slow process of grinding out potholes.

*Figure 11: Warwoman Rapid showing potholes in migmatitic Tallulah Falls biotite gneiss (metagraywacke) on river left.*
Stop 5: River turns left with small rapid. 

The river changes direction from slightly northwest to parallel to the foliation, and coincidentally, along the strike of the predominant northeast trending joint set. The strike of foliation is N 25° E. The large rock outcrop on the right contains no visible fractures.

Stop 6: River bends to left, large “fin” in middle of river.

The large dipping tabular outcrop at this location is characteristic of this section of the river. These resistant outcrops of the Tallulah Falls Formation follow the foliation and are referred to in this guide as fins. The river still trends parallel to foliation to the bend. Below the bend, the river runs N 35° W, in the direction of the dominant northwest-trending joint set. The foliation strikes at N 20° E and dips 60° SE. The implication is that the foliation is not a major controlling factor in river orientation.

Stop 7: Outcrop on river left.

Just after the bend at Stop 6 is an outcrop of the lower Tallulah Falls Formation on river left. Pods of amphibolite are exposed that contain large garnets (up to 0.5 in.). The foliation and dip are similar as those observed at Stop 6. Amphibolite rocks are indicative of the lower part of the Tallulah Falls.

Stop 8: First Island Rapid (Class I/II). Large fins perpendicular to river flow and a small rapid.

The large flat rocks that form this small rapid belong to the upper Tallulah Falls Formation. The foliation strikes at N 30° E and dips 30° SE. The overall river direction is slightly oblique to the trend of these rocks, but is essentially perpendicular to the foliation. The rocks and large fins at this stop have created a large island immediately downstream as a result of trapping sand and silt during high water events. During these flood events, these rocks form large eddies. In an eddy, the water flows back upstream to fill the void caused by the deflection of the water, creating a deposition zone.

The large flat exposures of biotite hneiss on the upstream side of this outcrop display migmatitic textures with abundant quartz, feldspar, and mica. Folds here exhibit limb thinning and crest thickening indicative of ductile flow and formation at great depth.

The fins at this stop are more laterally extensive than seen upstream. This indicates a lack of fractures which would help to dissect the fins into less continuous features. While above and below this rapid the river flows S 25° E, following the predominant northwest-trending joint set and thus perpendicular to the foliation, here the river flows parallel to the foliation to circumvent the laterally extensive fins. This demonstrates that while the river course is usually constrained by the regional joint trends, the foliation is able to exert a local influence. Most likely, this type of local control is ephemeral, as eventually the river will seek to dissect these long fins into discrete units.

There is a very large fin (Fig. 12) just downstream of the large flat rocks. The strike of foliation is N 25° E with a 35° SE dip. Very likely the rocks in the foreground protect this fin from

17
excessive erosion. On the upstream face of this fin is lineation that trends from the upper left to lower right. This is the result of two planes of foliation intersecting each other at a low angle and is indicative of multiple deformation events.

Figure 12. Very large fin of migmatitic biotite gneiss (metagraywacke) at First Island Rapid.

**Stop 10: Rock Garden Section**

This small but highly scenic rapid is identified by the large fins that are inclined upriver (Fig. 13) and the tight bend made by the river to the right. The river turns from trending almost due east to S 45° W. The rocks that compose this rapid contain a few (up to 2" wide) quartz-filled veins. The two veins on the large rock on the far left intersect each other at 50°. One vein strikes N 35° W and the other N 15° E. There is a highly visible 2" quartz-filled vein on the first rock in the middle as you approach the Rock Garden. It strikes N 25° W. All of these veins are vertical or nearly vertical. These veins are noteworthy in that these types of features have not been observed on the river up this point.

The foliation is oriented slightly different here. Most of the way down the river, the strike of foliation has been a fairly consistent N 25° E to N 30° E. The foliation here strikes N 50° E and dips 40° SE. Standing on or near the prominent rock fin that forms the core of the Rock Garden and looking downstream, several other fins line up along the same foliation.

**Stop 11: Drew’s Rock**

This large prominent fin is named after a character from the movie Deliverance, which was filmed here in the late 1960s, demeaned the local people, and popularized the river. This fin rises almost 20 feet out of water and is aligned with the foliation of the prominent fin at Stop 10, along with several smaller fins in between. Noteworthy enough just for its scenic value, Drew’s Rock also offers some clues as to the often discrete nature of the tabular fins (Fig. 13).
Examining the exposure from the river right side, a large fracture (Fig. 14) can be observed on its downstream side. This fracture has been preserved precisely because it is on the downstream side and has been protected from widening and erosion from stream action, but eventually the river will take advantage of this fracture to isolate the main part of Drew’s Rock from the smaller downstream fin. The vertical fracture runs almost perpendicular to the foliation at N 30° W.

**Stop 12:** Large rocks in river immediately below Drew’s Rock and small rapid.

The large rock island marks the end of the Rock Garden section (Fig. 15). The river parallels the foliation through these rocks. The upstream edges of the large rock island are being divided into thin fins as the water action erodes the less resistant layers. In addition, there are small fractures in this large rock mass that dissect the outcrop at angles perpendicular to the foliation and will most likely eventually allow the river to shorten and divide the long fin into smaller fins. The fractures on this rock strike N 70° W and N 80° W.

The best whitewater run is to the far right of the large middle rock. Immediately downstream of these rocks, the left bank forms a 5-foot high rock wall at river edge. Potholes have formed on the downstream scarp face of the wall. This wall displays periodic fractures along its length that trend perpendicular to the river direction.
Figure 14: Fractures between Drew’s rock and the smaller fins downstream.

Figure 15: Fins stacked on top of another being slowly divided as less resistant layers are preferentially eroded away.
Stop 13: Three Rooster Tails Rapid

This rapid is marked by a high (40’-50’), fairly steep cliff on river right just before the river turns sharply to the right. This rapid is rated as a Class 2+. At higher water levels, a standing wave develops in the drop (Figure 16) and turbulent hydraulics develop at the base of the rapid, sometimes causing problems for boaters in small craft.

Figure 16. Catherine Ruprecht running the standing wave halfway down Three Rooster Tails rapid.

This is the first rapid on the river on this section with large detached boulders (float) littered at the top and base of the river (Fig. 17). Several of these boulders display highly pronounced migmatitic texture.
Stop 14: Dicks Creek Rapid

This rapid is also referred to as First Ledge by local whitewater rafting companies. This river-wide rapid forms a distinct horizon line as you approach it which makes it impossible to discern the proper place to run the rapid from your boat. The standard rule of thumb in these situations is to pull over upstream and walk down to scout the rapid before running it. Dicks Creek Rapid is also easily identified by the spectacular sight of Dick’s Creek as it enters the Chattooga by forming a large cascading waterfall on river right just below the rapid.

Dicks Creek Rapid is rated a Class 3. At flood level, the fairly smooth ledge acts like a low head dam, forming an almost river-wide hydraulic. At those levels it becomes a Class 4/5 run with little margin for error.

Dicks Creek rapid is formed by a massive exposure of biotite gneiss (metagraywacke). There is an abundance of quartz-filled veins and open fractures (Fig. 18). On the large rock in the middle of the river, which is accessible at typical water levels and serves as a place to scout and/or portage the rapid, some veins are up to 1’ wide (Fig. 19). Some veins are oriented N 20° E, as are the unfilled joints, although two fractures have a N 70° E orientation. The foliation strikes N 40° E, dipping to the southeast, which is perpendicular to the river above the rapid but parallel to the river below the rapid. This characteristic forms one of the more striking aspects of the rapid as the river makes an almost 90° turn to the left immediately below the rapid indicating a large fracture system has changed the orientation of the river.

The large rock in the middle is not large enough to hold more than about 30 people at a time. About 50 yards above the rapid on the right is a convenient place to pull over and wait your turn to examine these features if there is a crowd on the rock.
Figure 18: Large open fractures intersecting and being terminated by other fractures at Dicks Creek Rapid.

Figure 19: Late pegmatite vein at Dicks Creek Rapid.
In addition to the fractures and quartz filled veins, there is a spectacular exposure of migmatite in an amphibolite “pod” on the downstream side of the central outcrop at this rapid. The term “pod” refers to the interlayering of discrete amphibolites bodies within the dominant biotite gneiss. The pods represent remnants of island arc volcanism that were mixed into the original sedimentary sequence as sills and lava flows. Within this pod are boudins and folds of migmatitic quartz and feldspar (Figure 20). During metamorphism, the surrounding biotite gneiss underwent partial melting (migmatization) while the amphibolite with its higher melting temperature stayed in a solid, yet ductile phase. The partially melted quartz and feldspar invaded the amphibolites and was thickened and thinned forming the pinch-and-swell structures.

Figure 20. Boudins and folds in an amphibolite body at Dicks Creek Rapid.

Stop 15: Sight on Rock Rapid

This rapid is about 200 yards downstream from Dicks Creek rapid. It is identifiable by a 5 foot high fin dipping to river left just above the rapid. The river direction is parallel to the foliation. Positioning your boat just to the right of this fin lines it up for the main channel below. This is a
Class 3 rapid with turbulent hydraulics and requires some maneuvering to avoid the numerous rocks at the base of the rapid.

An intriguing geologic feature at this rapid is the existence of a well-developed (50’ - 70’ wide) dry river channel on river left immediately at the top of the rapid (figure 21). It is not feasible to stop and examine this channel unless you are paddling a smaller craft, such as a canoe or kayak. The bed of the dry channel contains abundant boulders and steep walls devoid of excessive vegetation. The unanswered question is whether this is simply an overflow channel or the original route of the river, abandoned long ago, but scoured out occasionally by very high water events.

![Figure 21: Dry river bed on river left at Sight on Rock Rapid. This is used by the river as an overflow channel at high water. Note the vegetation growing in the channel.](image)

**Stop 16: Sandy Ford Rapid**

This is the last rapid on the river for the field trip. A large island separates the rapid into right and left runs. The entrance for the right chute is marked by a massive log jam (Fig. 22) on the upstream side of the island. As of April 2005, the log jam makes the right chute dangerous for all but experts in craft smaller than rafts.

The log jam is a definite hazard and must be avoided. This is a fairly long technical rapid that requires considerable maneuvering.
Figure 22: Massive log jam at Sandy Ford Rapid that prevents safe use of the right channel for rafts (photo taken April, 2005 but still present as of April 2014).

Stop 17: Sandy Ford Takeout Beach

About 50 or so yards after the last rapid, a large sandy beach (and possibly cars) is visible on river right that marks the Georgia side of the river. It is possible to drive a vehicle down to Sandy Ford on the Georgia side, but not on the South Carolina side. Immediately across the river on the left side is a small muddy beach that marks the trail to the Sandy Ford parking lot. Don’t miss it.

Optional Stop (time permitting): The Narrows

Leave the boats here and hike downstream 250 yards on the South Carolina side.

The Narrows consists of a narrow gorge and deep channel cut through Tallulah Falls Formation biotite gneiss (metagraywacke). There are breached potholes in the near-vertical wall on the Georgia side of the river, some of which have a width of ~15 feet. Some of the bedrock on the South Carolina side contains two distinct foliations, one of which is compositional layering, while the other is produced by parallel orientation of phyllosilicates and possibly other minerals.
Acknowledgements

Thanks to Rick Wooten and Rebecca Latham of the North Carolina Geologic Survey for their input and interpretations. RDH acknowledges support from the South Carolina Geological Survey, the Georgia Geologic Survey, and National Science Foundation grants GA-1409, GA-20321, and EAR-8417894 for support for field work and other research in this area.

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