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The Geology of the Flag Pond Quadrangle, Tennessee-North Carolina

Ebraham Shekarchi

University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Ebraham Shekarchi entitled "The Geology of the Flag Pond Quadrangle, Tennessee-North Carolina." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Geology.

George D. Swingle, Major Professor

We have read this dissertation and recommend its acceptance:

E. E. Stansbury, Paris B. Stockdale, Robert E. McLaughlin, Harry J. Klepser

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

May 27, 1959

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Dale Wantling
Dean of the Graduate School

THE GEOLOGY OF THE FLAG POND QUADRANGLE, TENNESSEE-NORTH CAROLINA

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Doctor of Philosophy

by

Ebraham Shekarchi

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CHAPTER I

INTRODUCTION

Location and Size of the Area

The thesis area is the Flag Pond Quadrangle (190-SE) largely in Unicoi County, Tennessee, but includes portions of Greene and Washington Counties in Tennessee and Madison County in North Carolina (Figure 1). The area is seven miles wide and eight and three quarter miles long or about sixty square miles. It is bounded on the south by the Sams Gap Quadrangle (191-NE), on the north by the Telford Quadrangle (190-NE), on the west by the Greystone Quadrangle (190-SW), and on the east by the Chestoa Quadrangle (199-SW).

Purpose and Scope of the Investigation

Several workers, as indicated in the following section, have commented upon the geology of the Flag Pond Quadrangle, but none have mapped or studied the area in detail--nor indeed, much of the adjacent region. Consequently, the purpose of this investigation is to obtain a comprehensive picture of the geology of the quadrangle.

The geology of the quadrangle is divisible into two natural units or parts, each with problems unique unto itself. The first of these units is the crystalline complex, the second is the sedimentary sequence which rests upon the crystalline rocks. The purpose of this study with regard to the crystalline group is first to determine the character of

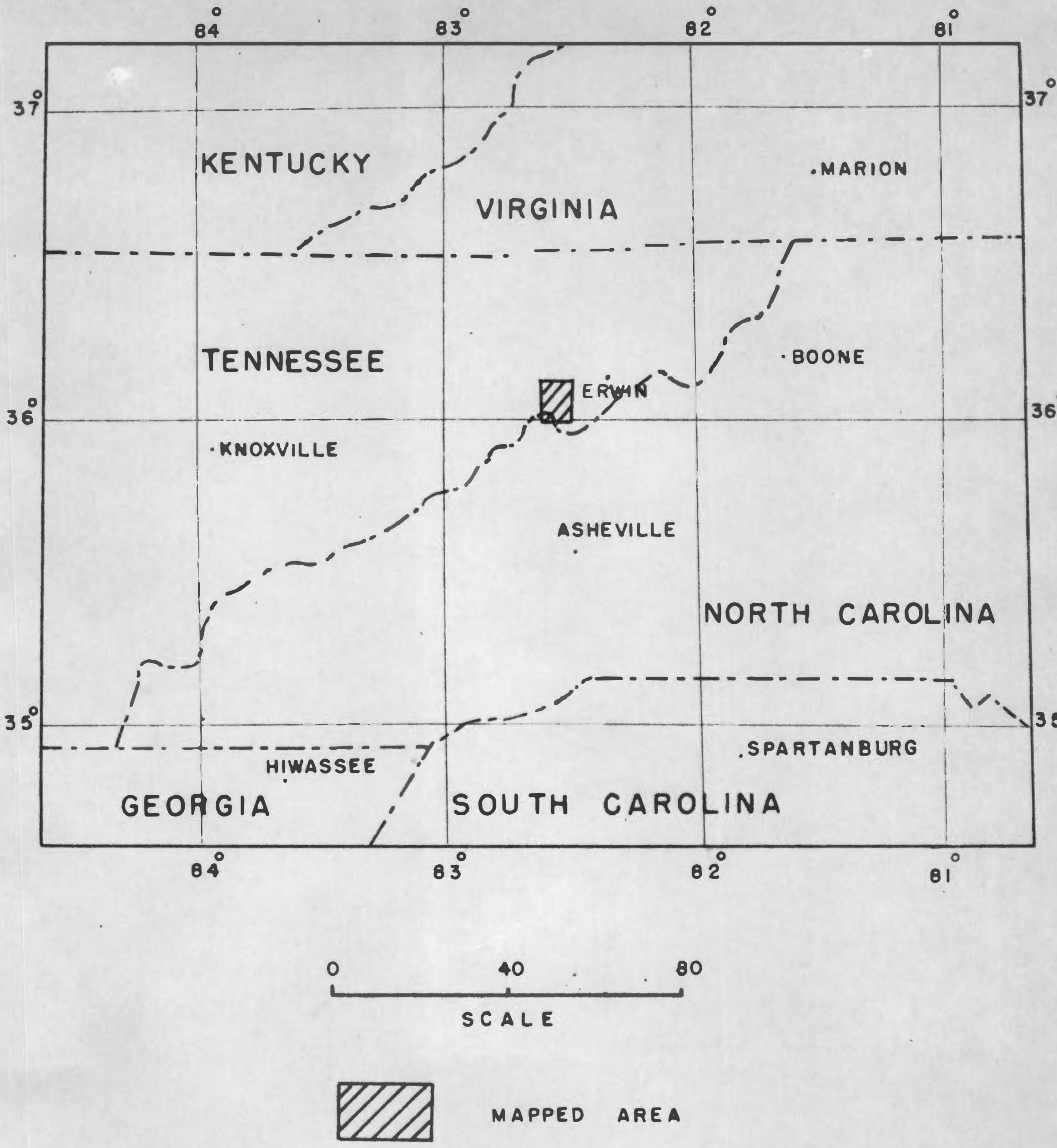

Figure I- Index map showing location of the Flag Pond Quadrangle.

these rocks and to delineate mappable units within them. Secondly, an attempt is made to establish the chronological and structural relationships of the mappable units. Finally, tentative conclusions as to the origin and history of the crystalline complex are presented. The study of the crystalline rocks of the area is based exclusively on field examination and thin-section analysis. Laboratory investigations of the crystalline rocks are beyond the scope of this investigation.

The sedimentary rocks have been studied, subdivided and described by various workers at several localities outside the Flag Pond area. This study is concerned with the stratigraphy of the Flag Pond area, the character and distribution of the formations, their relationship to other rock units, and, finally, their geologic history. A few representative thin sections of each formation were studied.

Previous Work

Appalachian geology has long been a subject of considerable interest. As early as 1809, Maclure (1809, p. 417) studied the relationship between the granitic rocks and the overlying sedimentary rocks as well as their general structure in the Appalachian region. In 1818, in the text accompanying the publication of his second map and five structural cross sections, Maclure (1818, pp. 37-38, 77) compared Appalachian geology with that of Western Europe (Alps). Using the Wernerian rock classification (primitive, transitional, secondary, and alluvial) he indicated that the rocks within the Flag Pond Quadrangle are composed of transitional rocks of early Silurian age.

Troost (1841, p. 3), the first state geologist of Tennessee, after study of the works of Murchison and Sedgwick, proposed that the rocks classified as transitional in this area were not Early Silurian but were Cambrian.

Probably the outstanding early work was by Safford (1856, pp. 151-153), who made the first geologic map of the state of Tennessee. In the accompanying text he included structural interpretations and for the first time defined the Ocoee series and Chilhowee group.

In 1874, Bradley (1874, pp. 519-520) defined and described the Unakite type granite from the Unaka Range of the Blue Ridge. His specimens were collected primarily from Bluff, Max Patch, and Walnut Mountains, approximately seventeen miles south-southwest of the Flag Pond Quadrangle in Cocke County, Tennessee.

Kerr (1875, pp. 138-140) in his extensive text on the geology of North Carolina classified the granitic rocks as Laurentian and the sedimentary rocks as Huronian. He was familiar with the work of Safford and pointed out that the problems involved in the geology of East Tennessee and Western North Carolina would only be solved when units were traced across the state line.

On the basis of megascopic and microscopic observations, Watson (1904, pp. 394-398; 1906, pp. 171-174) classified the granites of Western North Carolina into (1) massive, even-granular granites, (2) porphyritic granites, and (3) banded or schistose granites (granite-gneiss). Although his work was confined to a twenty-five square mile area, his suggestion that the rock units could be extended into Tennessee was confirmed by subsequent studies (Watson 1910, p. 171 and Keith, 1904, Greeneville folio).

The most detailed geologic map of the Flag Pond Quadrangle currently available was prepared by Keith in 1904 and published in the U. S. G. S. Greeneville folio. The present writer is in general agreement with Keith; however, some major differences are presented in the present thesis.

Stose and Jonas (1944, pp. 367-390, 410-416) discussed the distribution and structural relationships of the Ocoee series and the Chilhowee group. They concluded that the Ocoee series is uppermost Precambrian and not lower Cambrian, which is in agreement with opinions expressed in this paper; however, the writer does not agree with their proposed classification of the Ocoee series in the Flag Pond Quadrangle.

King, et al. (1944, p. 275), prepared maps of northeastern Tennessee which include a small section of the Flag Pond Quadrangle. This work was concerned largely with manganese deposits. Since the manganese bearing formations (chiefly the Shady dolomite) do not extend quite into the Flag Pond Quadrangle only the contact between the clastic and granitic rocks was mapped. The clastic rocks which contain very little or no manganese were not subdivided.

The most recent geologic map of the Flag Pond Quadrangle is that of Rodgers (1953, Plate 4). This map is largely a compilation of previous mapping with but minor reinterpretation. Although the map throughout most of East Tennessee is excellent, Rodgers' source material for the Flag Pond Quadrangle was inadequate and many changes are therefore proposed by the present writer.

Lowry (1948, unpublished Ph.D. thesis) mapped the southwest end of the Mountain City Window adjacent to the eastern boundary of the Flag Pond Quadrangle. She indicated that four fault blocks, associated with the window, were in the Flag Pond area. The positions of the fault blocks are not in agreement with the findings presented in this report. Lowry also indicated a barite prospect 800 feet northeast of the junction of Tennessee Highway 81 with Clearbranch Road. However, the writer was unable to locate the deposit.

Present Work

The field work for this study was done from July 1, 1957, to November 15, 1957, and from April 1, 1958, to August 10, 1958. Aerial photographs were studied with the view of using them as base maps, but the heavy vegetation made them of little value. Instead, the Tennessee Valley Authority Flag Pond topographic map (190-SE) was used as a base map. This map (scale 1/24,000) was found to be sufficient for a base map without enlarging. In the field, attitudes of the rocks were plotted on the map with conventional symbols, and rock types were indicated by colors.

In addition to the field work, thirty-four thin sections of representative rock specimens were prepared and examined microscopically. The locations of these specimens, plotted according to the Tennessee coordinate system (Plate I), are presented in Table I. The thin sections were studied during the summer and fall of 1958, and photomicrographs of the outstanding features were made.

TABLE I

LOCATION OF ROCK SAMPLES COLLECTED FOR THIN SECTIONS. LOCATIONS ARE IN FEET BASED ON THE TENNESSEE COORDINATE SYSTEM

Sample	East	North
1	2,999,100	641,000
2	2,999,500	643,000
3	3,019,650	637,350
4	3,014,850	632,925
5	3,005,000	629,500
6	3,005,225	630,200
7	3,017,425	627,175
8	3,018,450	629,150
9	3,008,900	623,000
10	3,031,650	635,725
11	3,023,450	636,325
12	3,005,750	620,850
13	3,007,700	620,750
14	3,015,800	621,300
15	3,015,225	621,450
16	3,016,250	622,750
17	3,014,500	622,000
18	3,030,400	609,500
19	3,002,750	606,100
20	3,026,800	613,150
21	3,028,450	615,800
22	3,003,000	606,200
23	3,008,300	611,000
24	3,018,100	615,700
25	3,019,400	615,730
26	3,024,000	619,350
27	3,024,700	611,800
28	3,030,400	628,650
29	3,019,850	608,000
30	3,020,500	608,500
31	3,024,200	605,200
32	2,999,500	611,225
33	3,025,000	614,250
34	3,025,100	605,750

CHAPTER II

GEOGRAPHY

Topography and Drainage

The area covered by the Flag Pond Quadrangle lies within the Unaka Range which forms part of the western border of the Blue Ridge Province. The area is situated between Little Bald Mountain (5,185 feet elevation) on the southeast and Big Butt Mountain (4,838 feet elevation) on the central west. Green Ridge Knob in Madison County, North Carolina, is the highest peak in the area with an elevation of 4,880 feet. The lowest elevation, 1,680 feet, is along Cassi Creek, Greene County, Tennessee, in the northwest corner of the quadrangle. The maximum relief of the area, therefore, is about 3,200 feet. There are numerous northeast trending ridges such as Rich Mountain, Flint Mountain, and Coffee Ridge that are over 4,200 feet. Additional elevations over 4,000 feet are found on several mountain crests as Green Ridge Knob (4,880 feet), Wilson Knob (4,580 feet), Frozen Knob (4,420 feet), and High Rock (4,080 feet).

At first glance one is struck by the apparent lack of geologic control of the topography. Study of the area, however, reveals that the mountain tops, ridges, and crests are generally underlain by resistant quartzite and crystalline rock. This shows that, although it is not at first easily seen, there is indeed correlation between the geologic features and topography. The terrain is rugged in areas underlain by sedimentary rocks and is virtually inaccessible in places. In contrast, the topography of the crystalline rock areas is more subdued with rounded mountain crests and gentle slopes. Figures 2, 3, and 4 illustrate typical terrain of the thesis area.

Drainage throughout the area is excellent and with few exceptions is dendritic. The drainage system is divided into two main segments by Rich Mountain which extends from the northeast corner to the west central portion of the area. Streams to the north of Rich Mountain empty directly into the Nolichucky River while those to the south flow into South Indian Creek and then into the Nolichucky River, south of Erwin. Waters in Madison County, North Carolina, flow into the French Broad River in North Carolina. The drainage system has produced V-shaped valleys throughout the area and locally steep cliffs. Figure 2 illustrates such valleys and cliffs along Rocky Fork. Due to the comparative weakness of siltstone and shale and the resistance of quartzite and conglomerate, numerous waterfalls, such as the one illustrated in Figure 5 in North Higgins Creek, have developed.[1]

Big Butt Mountain, Wilson Knob, and Frozen Knob are accessible by the Appalachian Trail and by a fairly good jeep road. The beautiful view of the Tennessee Valley from these points is well worth the climb.

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[1]Since two streams in the area are called Higgins Creek, the author has referred to them on the basis of their location as North and South Higgins Creek.

Figure 2. Steep gorge in sedimentary rocks. Seen from a ridge 1,000 feet northwest of the junction of Long Branch and Rocky Fork Creek. Note the V shaped valley in the foreground; Bald Mountain is in the background.

Figure 3. Typical mountain topography. Flint Ridge is in the foreground; Black Pine Ridge is on the horizon. View from the headwaters of Clearbranch.

Figure 4. Mountain terrain in sedimentary rocks. Near the junction of Birchfield Camp Branch and North Higgins Creek looking east. Note the quartzite ledge (white) capping right slope.

Figure 5. Waterfall in North Higgins Creek. Outcrops are resistant pebbly sandstone unit of upper Unicoi formation.

Transportation

The thesis area can be reached from Erwin, Tennessee, at a distance of approximately eight miles to the southwest by U. S. Highway 23-19W, and Tennessee Highway 81. It is about twenty miles northwest of Mars Hill, North Carolina. Tennessee Highway 81 cuts diagonally through the southeast corner of the area. North Carolina Highway 212 extends across the southwest corner of the area and joins Tennessee Highway 81 at Rocky Fork. These are the only main highways in the area. Several interconnecting secondary roads cross the highways.

Two-thirds of the area is uninhabited, and the only access is by a jeep road crossing from north to south. There are numerous logging roads and trails as indicated in Plate II. The Appalachian Trail cuts diagonally across the southwest corner of the area. The nearest railroad is at Erwin, Tennessee, eight miles northeast of the area.

Climate

Daytime temperature readings during the summer months average seventy-seven degrees. Night time readings drop as low as forty degrees. The high elevation throughout most of the thesis area accounts for this low temperature range.

Rainfall, according to the U. S. Weather Bureau (1957, p. 180), was 47.6 inches in 1957. Local showers of short duration were very common during the summer of 1957. This abundant precipitation supplies year-around water for the main creeks and springs.

Culture

The majority of the inhabitants of the area own and work small farms. For the most part their families have lived here for several generations, and many trace their lineage to the earliest white settlers of Tennessee. They are friendly and cooperative once one has been accepted into the community. Community life centers mainly around church activities.

CHAPTER III

STRATIGRAPHY

Regional Stratigraphy

The rocks that comprise the Blue Ridge Province of the Southern Appalachians can be divided into two main groups, a complex of basement rocks, and an overlying wedge of clastic sediments. The basement complex is generally considered to be Precambrian and consists of various types of igneous rocks, metamorphics, and migmatites. The basement complex is overlain unconformably by several thousand feet of clastic and volcanic rocks. The rocks immediately above the basement complex are the Catoctin greenstone, the Mount Rogers volcanic group, the Chilhowee group, and the Ocoee series. These in places are succeeded by the sediments of the Chilhowee group.

These two main rock groups have been previously studied and subdivided largely on lithology because of the general absence of fossils. Within the past 140 years, there has been a great diversity of opinion as to the origin and geologic history of the basement complex and the subdivision and correlation of the overlying rocks.

Regional Problems of the Basement Rocks

The regional problems concerning the basement rocks are diverse, reflecting the lack of widespread detailed mapping and laboratory studies. Isolated studies have given rise to conflicting opinions and

TABLE II

CORRELATION TABLE COMPARING THE TERMINOLOGY AND AGE RELATIONSHIP PRESENTED BY PREVIOUS WORKERS WITH THAT OF THE PRESENT AUTHOR

Maclure (1818)		Safford (1869)		Keith (1905)		Stose and Schrader (1923)		King et al. (1944)		Stose and Stose (1949)		Rodgers (1953)			King et al. (1958)			Present (1959)		
Age	Formation	Age	Formation	Age	Formation	Age	Formation	Age	Formation	Age	Formation	Age		Formation	Age		Formation	Age		Formation
Silurian	Transition Rocks	Early Silurian		Cambrian	Hesse quartzite	Cambrian	Erwin quartzite	Early Cambrian (Basal Clastics)	Erwin quartzite	Late Precambrian		Early Cambrian	Chilhowee group		Earlier Precambrian Later Precambrian Cambrian and Precambrian	Chilhowee group		Lower Cambrian	Chilhowee group	Erwin formation
					Murray slate						Big Butt quartzite									
			Chilhowee sandstone (Potsdam proper)		Nebo quartzite		Hampton formation		Hampton formation					Erwin formation			Cochran			Hampton formation
					Nichols slate						Nantahala slate			Hampton formation						
					Cochran conglomerate		Unicoi formation		Unicoi formation		Great Smoky quartzite			Unicoi formation						Unicoi formation
			Unconformity		Unconformity									Unconformity						Unconformity
			Ocoee series		Hiwassee slate								Ocoee series	Sandsuck shale		Ocoee series	Walden Creek group		Ocoee series	Sandsuck formation
																	Unclassified formations			
					Snowbird formation						Hurricane graywacke			Snowbird formation			Snowbird group			Snowbird formation
			Unconformity		Unconformity		Unconformity		Unconformity		Unconformity			Unconformity			Unconformity			Unconformity
			Metamorphics	Precambrian	Max Patch granite and Cranberry granite	Precambrian	Granite and schist	Precambrian	Volcanic rocks and granites		Injection Complex	Precambrian		Crystalline Complex			Granite and gneissic rocks	Precambrian		Unakite and Flag Pond granite group

sedimentary rocks were metamorphosed to gneiss and schist. Granitization may have developed during a second stage of metamorphism or may be an end product of more or less continuous metamorphism. . . ." Cameron (1951, p. 1), working in the Bryson City district, North Carolina, believes that the basement complex was developed largely by granitization of the metagabbro, metaperidotite, the associated hornblende and hornblende-biotite schists and gneisses. No satisfactory theory has appeared in the literature concerning the origin of the basement complex. Detailed geologic mapping and further application of age determination techniques will be necessary before this problem is solved. In a later chapter the present writer offers a tentative explanation for the origin of the basement complex based on field observations and microscopic studies.

Problems of the Sedimentary Rocks

Because of the metamorphosed nature of the strata in the Blue Ridge Province and the scarcity of the fossils in them, the task of making their subdivision and correlation has been slow. King, for example, in 1949 (p. 639) suggested that the interpretation of the Ocoee series given by Keith in the United States Geological Survey folios should be rearranged and that some of the terms should be defined more precisely or abandoned completely. In 1958, however, King, et al. (pp. 947-966), presented a series of new names for the Ocoee series with type localities in the Great Smoky Mountains National Park area and vicinity.

More extensive and critical studies have been made of the Chilhowee group than of the Ocoee series and the basement complex, but there are still unsolved stratigraphic problems concerning this group. To illustrate, King (1949, pp. 640-641) states,

> Unfortunately, Safford did not define exactly the base of the Chilhowee. In his description of Chilhowee Mountain (1869, p. 190) he states that strata of the Ocoee series are there exposed beneath strata of the Chilhowee group, which indicates that he placed part or all of what are now termed the Sandsuck shale and Cochran conglomerate in the Ocoee series. Elsewhere in East Tennessee, he generally excluded beds now classed as part of the Cochran conglomerate and Unicoi formation from the Chilhowee, although he was not entirely consistent. . . .

The Chilhowee sediments range in thickness from 2,500 feet near the Potomac River in Virginia to 7,500 feet in parts of Tennessee. Uncertainty exists as to the correlation of the different formations of this group. Except for the upper units, all units are identified solely on a lithologic basis. There is a lack of agreement as to the depositional environment of the rocks; i.e., whether or not they were deposited in isolated, restricted, or connected basins. A unique feature in the basal Chilhowee group is the presence of amygdaloidal basalt. There is disagreement as to the number and extent of these flows. Keith recognized a single flow in the Roan Mountain folio (1907).

Problems at the Base of the Cambrian

The boundary between the Cambrian and Precambrian is a major stratigraphic problem not restricted to the Flag Pond Quadrangle. Howell, et al. (1944, p. 993), of the Cambrian subcommittee of National Research Council, places the base of the Cambrian at the lowest formation that contains diagnostic Cambrian fossils. Snyder (1947, p. 152) suggested that for the sake of uniformity the base of the Cambrian should be drawn at the base of the lowermost fossiliferous formation instead of extending it downward through thick unfossiliferous sediments until an unconformity is found. Wheeler (1947, p. 153), working in the western part of the Great Basins region, proposed that the earliest appearance of the Trilobite genus Olenellus be used as the base of the Cambrian system because faunal evidence is more precise than diastrophism as a time index.

King (1949, p. 634), discussing the base of the Cambrian in the Southern Appalachians, emphasizes the contrast between Ocoee and Chilhowee sediments. The Ocoee series, containing graywacke, sandstone, siltstone, slate, conglomerate and shales was deposited rapidly, in a region of high relief and great tectonic instability, in a rapidly subsiding narrow trough (eugeosyncline). The Chilhowee rocks, largely arkose, quartzose sandstone, and shale, were deposited in a region sinking regularly as deposition progressed (miogeosyncline). Thus King (1949, p. 638) concludes that the base of the Cambrian in the Southern Appalachians can logically be placed at the base of the Chilhowee group, and that this group and its component formations forms the lowest unit of the Lower Cambrian series.

He believes that the Catoctin greenstone and underlying sedimentary rocks, the volcanics of the Mount Rogers area, and the Ocoee series are probably of late Precambrian age, although they may not necessarily be entirely contemporaneous. In 1958, however, King, et al.

(1958, p. 964), suggested that the base of the Cambrian be determined paleontologically. This would mean placing the boundary at the base of the Helenmode member of the Chilhowee group. According to this interpretation the bulk of Chilhowee group would be Precambrian.

If the upper part of the Chilhowee group is fossiliferous (however, none were found in the Flag Pond area) and the lower part is unfossiliferous, it does not seem logical to the writer to place the boundary in the middle of a group of sediments which appears to have been deposited during a single cycle of deposition.

The writer has selected an arbitrary boundary between Cambrian and Precambrian at the base of the Unicoi formation. Here a mappable conglomerate occurs.

Stratigraphy of the Flag Pond Area

In the Flag Pond area the basement rocks include various types of granite, granite-gneiss, diorite, pegmatite, and basic dikes. These diverse rock types have been divided into two units, the Flag Pond granite group and the Unakite granite group. The overlying clastic rocks consist of the Ocoee series and the Chilhowee group. The Ocoee strata consists of arkose, quartzite, sandstone, siltstone and sandy shale. Within the Ocoee two formations are recognized, the Snowbird formation (with a lower and upper member) and the Sandsuck formation. The Chilhowee group consists of conglomerate, basalt, arkose, various types of sandstone, and sandy siltstone and shale. It is divided into three formations, the Unicoi (with lower and upper members), the Hampton, and the Erwin. The validity of these subdivisions is discussed in a later section. A generalized section of formations in the Flag Pond quadrangle is presented in Table III.

Crystalline Complex

General Statement

Safford (1869, pp. 151-156) considered the rocks of the region to be within his metamorphic group (Eozoic). Keith (1903, pp. 2-3) differentiated three rock types in western North Carolina and eastern Tennessee as granites, gneisses, and schists, interbedded with a group of granites and granite gneisses. In the Flag Pond area, Keith mapped the granite gneisses as Cranberry granite. The Cranberry granite according to Keith was intruded by a coarse, massive and porphyritic rock, the Max Patch granite. Watson (1910, p. 116) working on the granites of North Carolina described an epidote granite in Madison County, North Carolina.

Prior to the field work in the Flag Pond Quadrangle it was hoped that additional terminology could be avoided. However, after a few months of field work it became apparent that the boundaries of the rock types outlined previously by Keith and others were not traceable and therefore their terminology could not be used. In the present study the term "crystalline complex" is used to include granites, granite gneisses, diorite bodies, mylonite, basic dikes, and pegmatites. These rocks are present in the southern one-third of the Flag Pond Quadrangle. On the basis of their appearances in the field, degradation products, and microscopic characteristics, rocks of the crystalline complex are divided by

TABLE III

GENERALIZED SECTION OF FORMATIONS IN THE FLAG POND QUADRANGLE

Age	Symbol	Formation	Member	Character	Thickness in Feet
Early Cambrian	Ꞓe	Erwin		Clean vitreous white quartzite composed mostly of uniform well-rounded quartz grains; alternating shale and sandy shale bands 1-4 cm. thick; massive vitreous white quartzite with occasional large quartz pebbles; dense, massive, fine- to medium-grained ferruginous sandstone; brown to dark brown slate (cleavage well-developed; pebbly vitreous quartzite with pebbles 5-20 mm. in diameter; silty sandstone and sandy siltstone in alternating bands 1-4 cm. thick.	1,000 - 1,200
	Ꞓh	Hampton		Sandy shale, shale and sandy siltstone in alternating bands 1-6 cm. thick showing spheroidical weathering; medium-grained micaceous sandstone with some pebbles; white to gray pyritic quartzite with scattered small pebbles; fine-grained; cross-bedded feldspathic sandstone; fine- to medium-grained pebbly cross-bedded sandstone with limonite patches.	1,300 - 1,600
	Ꞓu	Unicoi	Ꞓuu	Green to blue-green shale; amygdaloidal basalt 20-30 feet thick, dark green to dull red, dense with amygdules, containing quartz, chlorite and calcite; sandy shale and sandy siltstone in alternate bands 2-15 cm. thick, sandy shale showing some graded bedding; brown to dark brown slate with prominant cleavage; pebbly white to gray, medium-grained pyritic quartzite; vitreous massive quartzite without pebbles; micaceous sandstone without pebbles; well-rounded pebbly quartzite.	1,000 - 1,200
			Ꞓul	Conglomerate with pebbles 1-4 cm. in diameter; gray pyritic quartzite with alternate beds of shale; amygdaloidal basalt 25-50 feet thick as described above (Ꞓuu); red to reddish brown sandy shale and sandy siltstone in alternating bands 8-14 cm. thick; vitreous massive white quartzite in some places pebbly and not well cemented; feldspathic sandstone graded in lower portion, cross-bedded in upper section; dark to light red argillaceous massive sandstone; pebbly quartzite with pebbles 2-10 mm. in diameter; micaceous medium-grained sandstone; medium- to fine-grained, buff to brown yellow, cross-bedded sandstone; coarse-grained quartzite pebbly in lower section pyritic in upper portion.	1,500 - 1,800

TABLE III (continued)

GENERALIZED SECTION OF FORMATIONS IN THE FLAG POND QUADRANGLE

Age	Symbol	Formation	Member	Character	Thickness in Feet
Precambrian	P€ss	Sandsuck	P€ss	Brown shale with some pebbles in the lower portion; massive arkosic sandstone; thin-bedded sandy siltstone and shale; gray to white graded feldspathic sandstone; brown to chocolate brown slate with well-developed cleavage; fine- to medium-grained, poorly cemented, cross-bedded sandstone, in places argillaceous; medium- to coarse-grained white to gray micaceous sandstone, with pebbles in some places.	1,000 - 1,200
	PCsb	Snowbird	P€sbu	Sandy shale with distorted bedding; silty sandstone (graded bedding); medium-grained pyritic quartzite; medium- to fine-grained feldspathic sandstone; gray to brown shale, sandy in some places; gray to white pebbly quartzite with pebbles 3-10 mm. in diameter; vitreous massive white quartzite; interbedded brown to bluish brown argillaceous sandstone and shale.	1,500 - 1,800
			P€sbl	Gray, coarse-grained arkose with lenses of pyritic quartzite; well-rounded, pebbly quartzite with pebbles ranging from 3-8 cm. in diameter; vitreous massive, uniform medium-grained quartzite; thin-bedded, uniform, medium-grained feldspathic sandstone; sandy siltstone with smoky gray, medium-grained quartz.	1,000 - 1,200
	P€ug	Unakite granite group		(Coarse-grained granite, biotite granite, epidote granite, unakite granite, chlorite granite, coarse-grained biotite granite, pegmatites, mylonites, diorite bodies, basic dikes and granite gneiss).	
	P€fpg	Flag Pond granite group		(Coarse to medium-grained granite, biotite granite, coarse-grained granite, chlorite granite, sheared biotite granite, mylonites, basic dikes, diorite bodies, granite gneiss and pegmatites).	

the writer into two groups, the Unakite granite group and the Flag Pond granite group.

The Unakite granite group is named for a typical exposure of Unakite, which crops out in a road cut 500 feet south of Rocky Fork School on Tennessee Highway 81. This group consists of Unakite and coarse-grained granite, granite gneiss, diorite bodies, mylonite, pegmatites, and basic dikes. The group occurs in a southeast trending belt which is 8,000 to 12,000 feet wide and restricted to the southern portion of the quadrangle. Excellent outcrops may be seen along Tennessee Highway 212 and 81.

The Flag Pond granite group is named for the Flag Pond community, Unicoi County, Tennessee, near which many outcrops of the group appear. This group consists of fine- to medium-grained granite, granite gneisses, mylonite, diorite, pegmatite and basic rocks and no Unakite. The group occurs in two areas, one in the southeastern corner of the area and the other in the southwestern corner. Typical outcrops of the Flag Pond granite group may be seen along Slip Creek, Coffee Ridge Road, South Higgins Creek, and Carter Road in the southeastern part of the area. In the southwest, excellent exposures may be seen along Mill Creek Road in Madison County, North Carolina.

Both granite groups are sheared and faulted. Shearing is marked by mylonite zones (Plate II). Faulting is seen in many places along road cuts where one unit of the group is faulted over another. Such faulting occurs so frequently that it could not be recorded on a map of the scale used. Good examples could be seen in road cuts 500 feet south of Rocky

Fork School and at the junction of Highway 81 and Carter Branch Road. Lateral as well as vertical variation could be seen within units of both granites. The boundary between the Unakite and Flag Pond granite groups is gradational.

The weathering products of each group are distinctive and color of the residual soils aids in the mapping of the two groups where no outcrops can be discerned. The soil overlying the Unakite granite group is generally reddish to whitish red. The soil produced by the Flag Pond granite group is, however, yellow to yellow brown. The basic dikes found in both groups are deeply weathered and give rise to a loose, dark brown soil. Rhombohedral fracture may be found in the weathered portion of the dike. The diorite bodies present in both granites do not weather easily and retain their diabasic texture, which is especially conspicuous when the surface is wet. Mylonite of both granites weathers easily, and produces a sandy white to yellow soil.

In the field the following criteria could be used to differentiate between the two granite groups.

1. The rocks of the Unakite granite group are coarser grained than those of the Flag Pond granite group.

2. The relative amount of mafic minerals in the Unakite granite group is greater than that of the Flag Pond group.

3. The Unakite granite group has epidote in large quantities in the Unakite. Smaller quantities occur as accessory minerals in other rocks of the group. Very little epidote is found in the Flag Pond granite group.

4. Soils produced from the Unakite granite group are mostly red to reddish white, whereas those of the Flag Pond granite group are chiefly yellow to yellow brown.

Flag Pond Granite Group

Two bodies of Flag Pond granites are recognized in the area covered by the quadrangle, one in the southwestern corner in Madison County, North Carolina, and the other in the southeastern corner of the quadrangle in Unicoi County, Tennessee. The best exposures of this group may be seen along Slip Creek, Coffee Ridge Road, and South Higgins Creek.

The boundary between the Flag Pond granite group and the Unakite granite group is not distinct (Plate II). Rather, it is gradational. It is very difficult to follow characteristic features in the field for a long distance, and in addition, lush vegetation and deeply weathered surfaces add to this difficulty.

The Flag Pond granite group is composed of fine- to medium-grained granites, granite gneisses, mylonite, diorite, pegmatite and basic rocks. The best exposures of these units will be discussed individually in the following sections.

Generally, the weathered product of this group yields a yellow to yellow-brown soil. Basic rocks, mylonites and pegmatites weather easily whereas the diorites show great resistance to weathering. In areas where the rocks are deeply weathered, well-rounded knobs and ridges such as Coffee Ridge and Tilson Mountain result.

Lithology and petrology. Samples from representative rocks of the Flag Pond granite group were collected and certain specimens were chosen from which thin sections were prepared. At the beginning of the microscopic study, an attempt was made to obtain quantitative data of mineral constituents by means of the mechanical stage. However, this was not feasible, because the samples were highly altered and the crystal outlines could not be identified. The mineral content was approximated rather than actually counted. The percentages thus derived were used for identifying the rock type according to Johannsen's classification (1939, p. 144).

Sample 29. This sample was collected from a cut along a secondary road parallel to South Higgins Creek, 1,000 feet east of Tennessee Highway 81. It is a coarse- to medium-grained granite, pale yellow to yellow gray. The grains measure from one to four centimeters in diameter. Within 100 feet southeast of this outcrop gradational changes to the adjacent fine-grained granite unit could be seen. The granite shows no lineation or foliation. No inclusions have been noted in this type of granite.

Closely interlocking grains of quartz and feldspar, plus chlorite may be seen in the hand specimen. It also contains some fine-grained material, probably saussurite, but this is best observed in thin sections. Hornblende and chlorite crystals are present throughout the specimen. Probably the chlorite is the alteration product of hornblende or biotite.

Microscopically the sample contains approximately 30 per cent microcline, 36 per cent perthite, 20 per cent quartz, 10 per cent fine-grained material, possibly saussurite, and 4 per cent chlorite and hornblende. The replacement of perthite by quartz is very common. This is evidenced as a rugged outline of perthite which surrounds the quartz. Only in one place on the slide was a pseudo-augen texture seen, in which case a subhedral crystal of hornblende, pale brown in color was surrounded by chlorite showing foliation on a microscopic scale. A photomicrograph of this sample is shown in Figure 6.

Sample 30. Biotite granite of the Flag Pond granite group was collected 500 feet northeast of the location of sample 29 on South Higgins Creek Road. It is highly altered granite, which weathers readily and yields a yellowish to tan soil. Somewhat altered inclusions of Unakite granite can be seen in this outcrop. These inclusions are thought to be the contamination of Flag Pond granite by Unakite granite through metasomatism. This granite shows good foliation and lineation. An extension of the biotite granite outcrop, having a northeast and southwest trending foliation, can be seen south of the Flag Pond Post Office in South Indian Creek.

Megascopically this granite is distinguished from the other granites by the presence of smoky quartz and pyrite. It is finer-grained than specimen number 29 (five to ten millimeters). On the weathered surface scattered reddish spots can be seen which upon close examination appear to be composed of hematite which resulted from the alteration of magnetite grains.

Microscopically this granite consists of approximately 40 per cent quartz, mostly euhedral, 25 per cent orthoclase, 10 per cent saussurite, 13 per cent biotite, 10 per cent hornblende and chlorite and 2 per cent well-rounded zircon, apatite, pyrite, magnetite, limonite, and garnet. Some of the quartz grains show wavy extinction. A photomicrograph of this sample is shown in Figure 7.

Sample 31. Coarse-grained granite of the Flag Pond granite group was collected along South Higgins Creek Road one mile southeast of sample 30. It contains a small amount of mafic minerals, and small inclusions of Unakite. Inclusions roughly trend northeast and southwest. Even though it is a coarse-grained granite, the feldspar grains nevertheless show rough alignment. Upon close examination, cataclastic structure could be seen. The granite is highly jointed and three sets of joints can be discerned. This granite seems to weather more readily than the fine-grained granites of this group. Several outcrops of this granite occur along the west tributaries of Mill Creek, North Carolina.

Megascopically, orthoclase grains measure from two to six centimeter in length and are highly fractured. Hornblende and chlorite are scattered throughout the outcrop. The chlorite perhaps is the alteration product of hornblende, since it occurs chiefly as a matrix surrounding the hornblende grains.

Microscopically the sample consists of approximately 70 per cent orthoclase, microcline and sericite (which is an altered product of the potash feldspar), 20 per cent hornblende, chlorite and augite and 10 per cent quartz. The hornblende occurs as the core in chlorite which has been altered from it. On the slide made from this sample the microcline appears to have replaced the plagioclase to produce a

Figure 6. Photomicrograph of coarse-grained granite of Flag Pond granite group. Note feldspar partially altered (white and surrounded by sevicite. Sample 29, X-nicols (50X).

Figure 7. Photomicrograph of biotite granite of Flag Pond granite group without perthite. Note altered orthoclase (white) and saussurite in left half. Sample 30, X-nicols (50X).

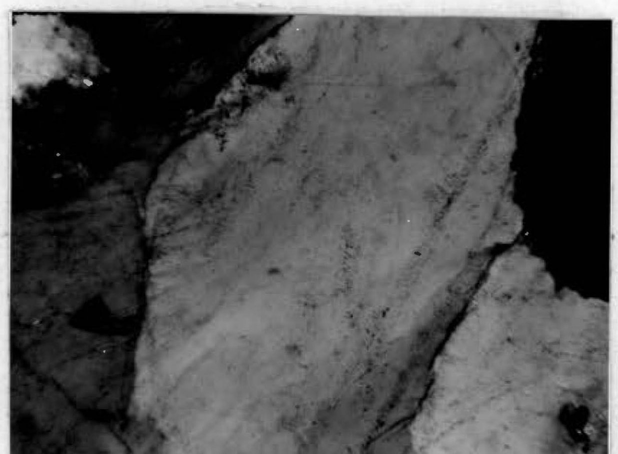

Figure 8. Photomicrograph of coarsely crystalline Flag Pond granite. Observe well interlocked crystals of orthoclase and quartz. Sample 31, X-nicols (50X).

should be consulted for references to these arguments. The uniform lamellar arrangement of perthite within the crystals of the granites suggest that the most logical explanation for its appearance here is replacement or possibly exsolution. The outlines of feldspars are difficult to follow due to alteration along the edges of the grains. In this sample streaks of epidote and chlorite are observed. They are not related to the alteration of biotite as observed in other samples because the epidote and chlorite do not seem to be associated with biotite. The epidote, however, is associated with plagioclase, whereas the chlorite shows alteration from hornblende. Pyrite is the most abundant opaque mineral. Ilmenite grains, the edges of which are usually altered to leucoxene, were seen in several places in this section. Zircon and apatite occur largely as inclusions within the quartz. A photomicrograph of this sample is shown in Figure 9.

Sample 33. This is a sample of the sheared-biotite granite of the Flag Pond granite group which was collected from a road cut parallel to Carter Branch near BMU 112-2669. In the field it is distinguished by good foliation.

Megascopically, the sample is a fine-to medium-grained granite. Foliation of chlorite and, to a lesser degree, biotite, can be seen in hand specimens. The feldspars, chiefly microcline and perthite, although crushed and broken, nevertheless show lineation.

Microscopically, this granite consists of approximately 50 per cent perthite and microcline; 30 per cent quartz; 18 per cent chlorite, biotite, and sericite; and accessory minerals consisting of well-rounded zircon, magnetite, pyrite, and rutile. Under high magnification, the mottled and streaky appearance of perthite penetration could be seen in microcline. Rutile seems completely altered to leucoxene. A photomicrograph of this sample is shown in Figure 10.

Unakite Granite Group

The name Unakite was proposed by Bradley (1874, p. 519) for the granitic rocks occurring in the Unaka Range of North Carolina and Tennessee. The description as given by Bradley follows:

> The character relied upon for the separation of the species is the constant replacement of the mica of common granite, or the hornblende of the syenite, by epidote. The amount of this ingredient present is quite variable, in some cases even exceeding one half of the whole mass. The feldspar present is orthoclase, of various shades of pink, forming from one-fourth to perhaps one-third of the whole. The quartz is mainly white, but occasionally smoky; its isolated portions form but a small part, say one fourth of the mass; it is veined in structure, but this is probably not a constant character. Small grains of magnetite are scattered through the rock, but not so thickly as in many granites. No other ingredients have as yet been detected.

The best exposure of Unakite in the Flag Pond area is located in a deep road cut along Tennessee Highway 81, 500 feet south of Rocky Fork School. The Unakite granite group is named in this paper for rocks found at this location. Here the Unakite consists mostly of pink feldspars, epidote, and some quartz (Figure 11).

The Unakite granite group consists of coarse grained granite, Unakite proper, granite gneiss, mylonite, pegmatite, diorite, and basic rocks. The best exposures of this group in the area may be seen along Tennessee Highways 81 and 212.

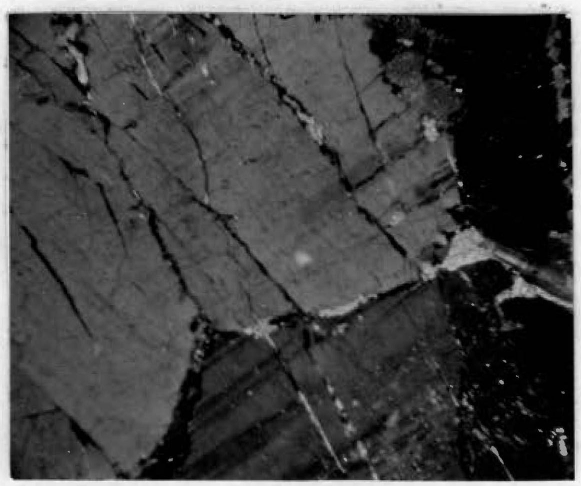

Figure 9. Photomicrograph of chlorite granite of Flag Pond granite group. Note directional penetration of perthite in orthoclase in upper left corner. Sample 32, X-nicols (80X).

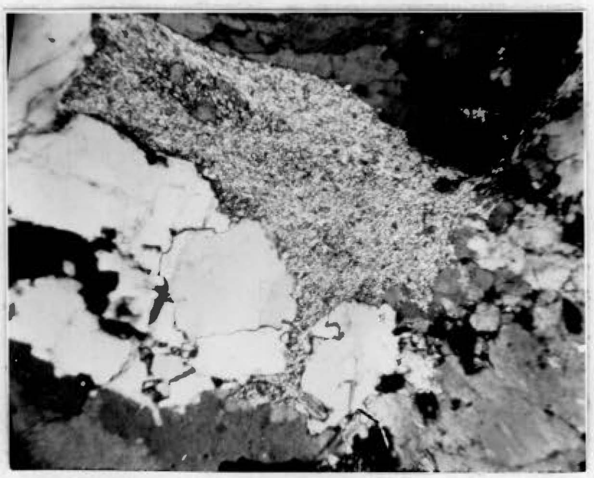

Figure 10. Photomicrograph of sheared biotite granite of Flag Pond granite group. Note sericite (middle) and white sutured quartz crystals. Sample 33, X-nicols (50X).

In the field the Unakite granite group is distinguished from the Flag Pond granite group by having Unakite in addition to being coarse-grained, having a greater per cent of epidote, and the characteristic color of the soil produced by weathering. The group generally weathers to a red to reddish white soil, which may be seen on the road cuts along Tennessee Highway 81 and 212.

Lithology and petrology. Several samples from representative areas of the Unakite granite group were collected and thin sections were prepared. The following field and microscopic observations were made.

Sample 22. This is a sample of coarse-grained granite of the Unakite granite group which constitutes approximately 20 per cent of the group. It was collected from an outcrop 500 feet southeast of BMA 52-3107 on the Appalachian Trail near Devil Fork Gap. In the field, large phenocrysts of the orthoclase measuring from four to twenty millimeters in length may be seen in a groundmass of chlorite and quartz. No inclusions were seen in this outcrop. The large phenocrysts of feldspar show a rough alignment in a northeasterly direction.

In hand specimens phenocrysts of feldspar were found shattered. The quartz grains, which are mostly colorless, have prominent outlines in the groundmass of chlorite. The phenocrysts of feldspars and the quartz grains give the rock a coarse texture.

Microscopically, the sample consists of approximately 60 per cent orthoclase and microcline, 5 per cent plagioclase (albite and oligoclase), 10 to 15 per cent chlorite and sericite, and 10 to 20 per cent quartz. Accessory minerals, such as rutile, ilmenite, leucoxene, epidote, magnetite, and kaolin were found. In many places ilmenite is replaced by rutile and rutile in turn is replaced by leucoxene. The feldspars particularly show a great deal of alteration. Sericite and epidote may be seen to enclose the grain boundaries as well as to fill the fractured area. A photomicrograph of this sample is shown in Figure 12.

Sample 23. This sample is identified as the biotite granite of the Unakite granite group. This type of rock constitutes about 10 per cent of the group. The sample was collected a half mile from Tennessee Highway 212 on a road cut north of Sweet Water School. The feldspars, chiefly orthoclase, have a northeast lineation. In many places on the outcrop fluxion structure was seen. Inclusions of smaller Unakite type may be observed in the exposure. The granite seems largely altered and sheared in places.

Megascopically it is a medium-grained granite (two to five millimeters). The mafic minerals are largely chlorite, biotite, and hornblende. The feldspars are milky to white and show good cleavage. The quartz grains are colorless.

In a microscopic examination of this granite, the following analysis was made. It consists of approximately 50 per cent orthoclase, 15 per cent quartz, 25 per cent sericite, epidote, and chlorite, 7 to 10 per cent biotite, and hornblende, and 2 per cent zircon, rutile, apatite, garnet, and leucoxene. Orthoclase appears to be almost completely altered to sericite. Since alteration along the edges of the grains is pronounced, the crystal outlines in the groundmass are difficult to discern. Penetrations of chlorite and/or epidote into feldspars is observed in many places on the prepared slide. A photomicrograph prepared from this slide is shown in Figure 13.

Sample 24. This sample represents the epidote granite of the Unakite granite group which constitutes 25 per cent of this group. The sample was collected 600 feet northwest of Horn Cemetery near Rocky Fork community. This outcrop has numerous inclusions of Unakite. The fluxion structure is a very prominent feature seen at exposures of the granite. The granite contains more mafic minerals than samples 22 and 23. Within a few hundred feet of this location, the granite grades into typical Unakite granite.

Upon close examination of hand specimens pink feldspars (perthite) appear to be broken. The epidote seems to be scattered in the groundmass along with individual anhedral grains. Many pyrite grains, some of which were completely altered to limonite, were seen in this sample.

The microscopic analysis of this granite shows that it contains about 60 to 70 per cent microcline and perthite, 15 per cent epidote, 10 per cent chlorite, sericite, hornblende, and biotite, 15 per cent quartz, and 2 per cent ilmenite, magnetite, leucoxene, and pyrite. In many places, the quartz was observed to replace perthite. Myrmekitic intergrowths were also seen. The feldspar grains exhibited cataclastic deformation and quartz grains were strained. The edges of ilmenite grains were usually altered to leucoxene. Magnetite in one place occurs as segregated concentrations; in other places it is altered to hematite or limonite. Quartz, epidote, and sericite have replaced orthoclase

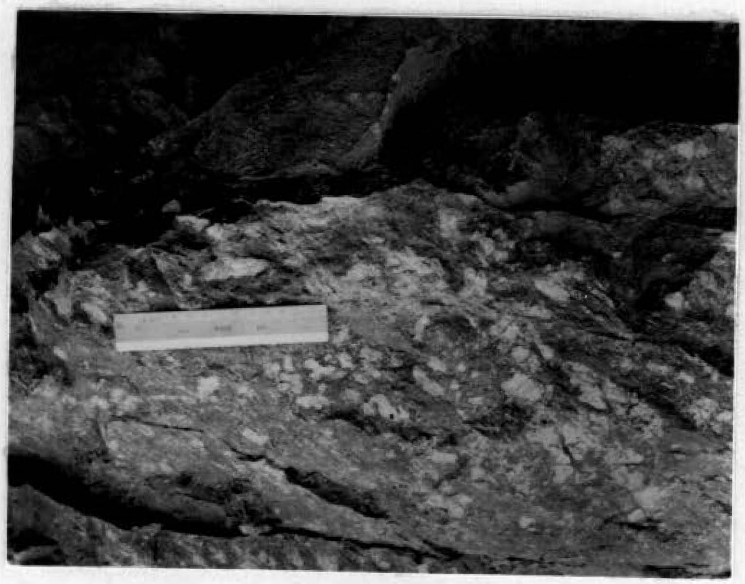

Figure 11. Texture of typical Unakite. Note large porphyroblasts of feldspar (perthite) in the groundmass of chlorite and epidote. Outcrop is 500 feet south of Rocky Fork School, on Highway 81.

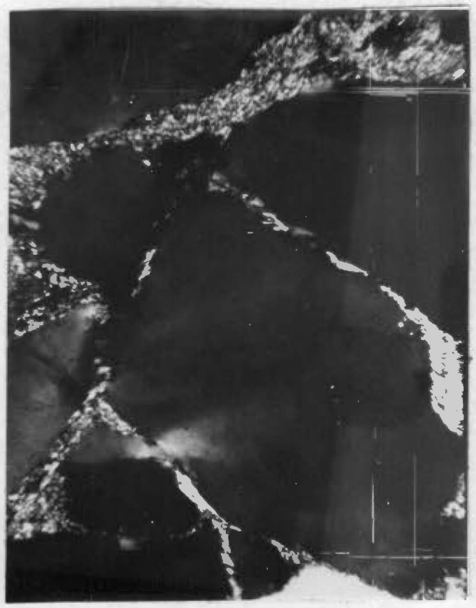

Figure 12. Photomicrograph of a coarse-grained granite of Unakite granite group. Sericite fills the highly fractured surfaces (perthite). Sample 22, X-nicols (80X).

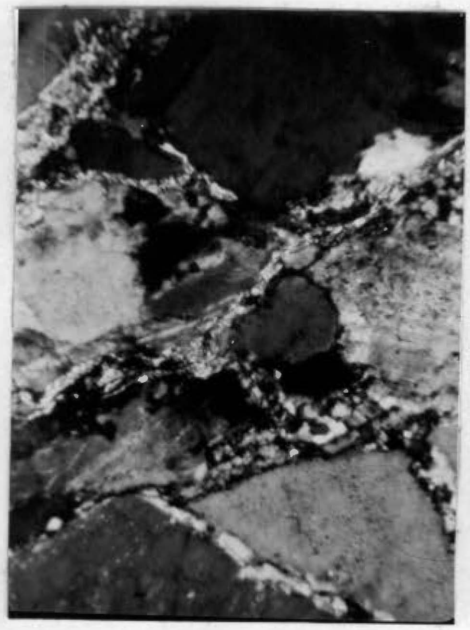

Figure 13. Photomicrograph of biotite granite of the Unakite granite group. Note sericite filling between the crystals. Sample 23, X-nicols (50X).

along fractures and along the edges of the grain. A photomicrograph of this sample is shown in Figure 14.

Sample 25. This sample represents the Unakite of the Unakite granite group. It constitutes approximately 10 per cent of this group. The sample was collected from a deep road cut 500 feet south of Rocky Fork School. As seen in the outcrop, large phenocrysts of perthite measuring from one to three centimeters in length and pink to flesh in color are scattered in a matrix of epidote and chlorite (Figure 11). Lineation is not recognized immediately but upon close examination it appears that the long axis of the feldspar grains shows alignment in a general northeast direction. The contact of this granite with other adjacent rocks is gradational. The color of epidote varies from yellowish green to olive green. The fracture of epidote is uneven. The quartz grains although very few, are clear to smoky.

Under microscopic examination, perthite is found to constitute approximately 50 to 60 per cent of the sample, epidote 20 to 30 per cent, quartz about 5 per cent, chlorite 10 per cent, and pyrite, magnetite, and hematite 1 per cent. In many places, the epidote cuts through the feldspar grains, thus indicating that the epidote was solidified after the feldspar. In several grains, directional penetration of the epidote and chlorite into perthite grains has been noticed. In one place, myrmekitic intergrowths within the perthite have been seen. There are microperthite grains scattered throughout the slide, also. A photomicrograph of this slide is shown in Figure 15.

Sample 27. This is the chlorite granite of the Unakite granite group. It constitutes approximately 25 per cent of the group. The sample was collected from an outcrop one-half mile south of Big Branch on Tennessee Highway 81, near BMD 52-1985. At this locality, as well as on road cuts northwest of Big Branch, cataclastic structures of this granite may be observed. Little lineation, if any, could be seen in the field. Inclusions of typical Unakite may be seen in this outcrop. Generally this granite is medium- to fine-grained, and this variation could be traced within a short distance along Big Branch Road. Chlorite is the main mafic mineral. Hornblende, some of which had been altered, was observed occasionally.

The thin section prepared from this granite shows approximately 30 to 40 per cent perthite, microperthite, and orthoclase, 10 to 20 per cent plagioclase (albite and oligoclase), 15 to 20 per cent quartz, 10 to 20 per cent chlorite, 3 to 5 per cent hornblende and biotite, and 2 per cent well-rounded zircon, ilmenite, and pyrite, leucoxene, garnet, and apatite. The perthite and microperthite occur as subhedral grains. The plagioclase occurs as subhedral to anhedral grains. In many cases the edges of the grains of the plagioclase have been converted to orthoclase. Orthoclase shows many myrmekitic intergrowths. Biotite, occurring as minute grains and shreds, appears mainly to be the alteration product of hornblende. Chlorite seems chiefly to be the alteration product of hornblende and biotite. Well developed micro-cataclastic texture may be seen in this sample where twin planes of the feldspar have been dislocated. A photomicrograph of this sample is shown in Figure 16.

Figure 14. Photomicrograph of epidote granite of Unakite granite group. Note microcline twinning lower part, highly altered feldspar upper corner, and sericite (groundmass). Sample 24, X-nicols (50X).

Figure 15. Photomicrograph of typical Unakite. Perthite is fractured, and veined by epidote. Sample 25, X-nicols (80X).

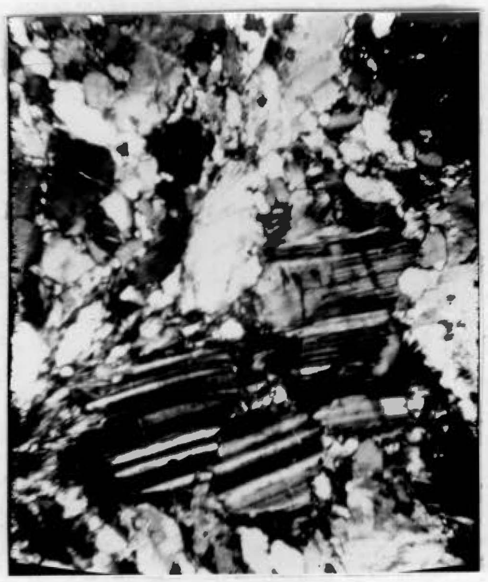

Figure 16. Photomicrograph of chlorite granite of Unakite granite group. Note dislocation of plagioclase twinning (lower). Highly altered albite (right center) and sericite (groundmass). Sample 27, X-nicols (50X).

Sample 28. This sample represents the coarse-grained biotite granite of the Unakite granite group and constitutes approximately 10 per cent of the group. This sample was collected 700 feet northwest of BME 52-1869 on Tennessee Highway 81. Several inclusions of Unakite were seen in this outcrop. Fluxion structure is one of the outstanding features of this granite. In a hand specimen, biotite grains may be identified. In some places, chlorite has been seen in association with biotite. The orthoclase grains measure from two to five centimeters in length. In the inclusions mentioned above patches of epidote were seen associated with orthoclase, and in places these minerals form the greater segment of the inclusion.

Microscopically the following minerals were identified: microcline and perthite, 45 per cent, plagioclase (albite and oligoclase) 10 to 15 per cent, quartz, 20 per cent, biotite, 5 to 10 per cent, and chlorite, 10 to 15 per cent. Ilmenite, magnetite, subrounded zircon, leucoxene, and pyrite occur as accessory minerals. Replacement by sericite along the edges of the feldspar grains completely obliterates the grain boundaries. Myrmekitic intergrowths are seen in many places in this slide. Occasionally, quartz will appear as granules or irregular outlines around and included in the feldspar grains. The oligoclase seems to be altered to saussurite along the grain boundaries as well as along fractures. The outline of most of the grains in the slide seem rugged and in places indistinguishable. Biotite occurs in large grains as well as small disseminated grains. The large biotite grains are altered to chlorite as evidenced by the chlorite surrounding the biotite grains. Epidote seems to replace and to fill fractures of the orthoclase grains. Pyrite is the most abundant and widespread of the opaque minerals. Ilmenite is evenly distributed throughout this sample of granite. No photomicrograph of this slide was made.

Mylonites

The term mylonite is not used here in the restricted sense that Lapworth (1885, p. 558) used it. He gives the following criteria for mylonite:

1. Microbrecciation produced by milling
2. Possession of lamination
3. Retention of coherence
4. Presence of cataclastic texture

Instead, the broader definition of mylonite presented by Termier (1928, p. 1,247) with some modification by the present writer seems more applicable. Termier uses the term in a tectonic sense to include all material formed by crushing, regardless of origin. In a footnote in his paper (1928, p. 1,247) he expresses this view clearly: "comme tous les tectoniciens, nous appelons mylonite toute roche ecrasie, quell qu ail ete sa nature originelle et quel que soit le type de son ecrasement."

In this thesis the term "mylonite zone" is used for a zone that includes rocks which show augen texture, lamination, crushed appearance, and microbrecciation, regardless of the nature of crushing.

In Plate II mylonite and sheared zones are identified as elongated bodies following the general trend of the clastic rocks--a northeast direction. These zones vary from a few feet to several thousand feet thick.

The best exposures of these zones in the Flag Pond area may be seen on a secondary road connecting Lizzie Branch Road to Clearbranch Road. The field appearance of this zone is shown in Figure 17.

The mylonite zones and the shear zones show little resistance to weathering, the product of which is largely a white to yellow-white soil.

Mineralogically the mylonite zone is very similar to adjoining granite rocks. The augen texture could be seen with the aid of a hand lens in many outcrops. Some of the sheared zones show highly developed foliation and cataclastic structure.

Six thin sections were prepared from samples taken from mylonite and sheared zones (see Table I for location). Petrographic analysis of these samples show the sheared phase of the granite to be almost mineralogically identical to the massive phase. The quartz and feldspar grains in the sheared and mylonite phase are elongated and cataclastic deformation is more intense than in the massive phase. Secondary growth of quartz was seen in three samples. Augen texture is well developed in many of the specimens examined. Highly fractured augen-shaped phenocrysts of orthoclase or quartz were observed. At the ends of the long axis of the phenocrysts smaller grains derived from the phenocrysts may be seen to "pinch out" away from the parent mineral. Quartz and feldspar in every specimen examined indicate abundant masking and peripheral shattering. Photomicrographs prepared from the thin sections are shown in Figures 18, 19, and 20.

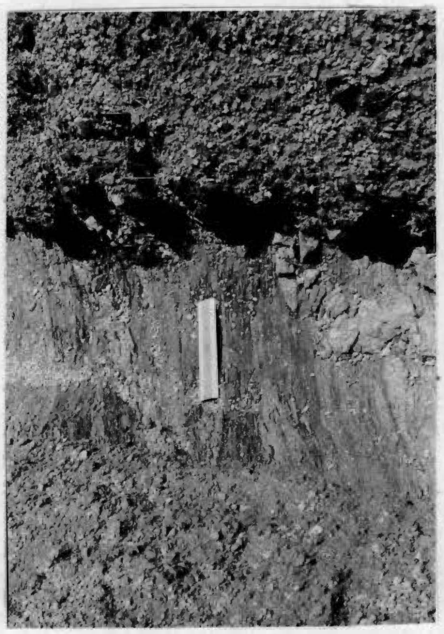

Figure 17. Strongly sheared granite. Exposure is in a ditch 1,000 feet east of BMU 112-2669, on Carter Branch. The rule is parallel with the shear planes.

Figure 18. Photomicrograph of sheared granite. Banded structure of chlorite and sericite (black), feldspar and quartz (white. Sample 19, X-nicols (30X).

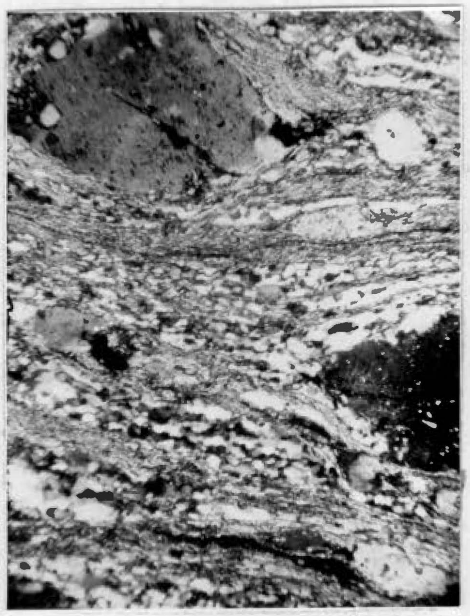

Figure 19. Photomicrograph of augen texture. Note quartz in the center of the augen. Sample 20, X-nicols (50X).

Figure 20. Photomicrograph of a mylonite unit. Detailed outline of fluxion texture. Sample 21 (80X).

Pegmatites

The term pegmatite as used in this paper is in the sense used by Anderson (1931, p. 3) who states that:

> Pegmatites are mineral associations crystallized in situ, decidedly more coarse-grained than similar mineral associations in the form of ordinary rocks and differing from these in having more irregular fabrics of the mineral aggregates.

Numerous pegmatites are found in both granite groups in the area. It seems, however, that the Unakite granite group contains more pegmatites than the Flag Pond granite group. The pegmatites occur as elongated bodies which pinch and swell in an irregular manner. The size of the pegmatites varies from a few inches to two feet in width and up to twenty feet in length. They appear to have either a concordant or a discordant relationship with the wall rock.

In most outcrops pegmatites of both granite groups seem to be more resistant to cataclasis than the host granite rocks, and show very little, if any, effect of recrystallization. These phenomena were observed to be true in most outcrops of the pegmatites. The contact between granites and pegmatites is not gradational. There is no brecciation or rotation of the host rock and no offshooting dikes.

No thin sections were prepared of the pegmatites of the Flag Pond Quadrangle. The mineral content of the pegmatites identified megascopically consists of feldspar and quartz phenocrysts, chlorite, and biotite. The quartz grains are milky white and the feldspar (orthoclase and perthite) crystals are white to pink and measure from one to three centimeters in length. In a few places a crude zonation with quartz as a core is observed.

Good examples of pegmatite can be seen along Tennessee Highway 81, between Edwards Branch and Big Branch (Figure 21), and near Higgin Barite mine. The latter is easily reached by a road parallel to Rocky Fork Creek about three-fourths of a mile north of the junction of Rocky Fork Road with Tennessee Highway 81 (Plate II).

It is possible that the pegmatites formed when high silica and radioactive bearing volatiles invaded the weak zones of the crystalline complex and solidified. This is evidenced by sharp contacts, non-gradational boundaries, and lack of brecciation or rotation of the host rocks. If this interpretation is assumed, then the pegmatites originated after the crystalline complex was formed and before the Buffalo Mountain thrust took place.

Basic Dikes

In the crystalline complex of the Flag Pond Quadrangle numerous basic dikes, occurring singly or as multiple dikes, were found. A good example of one of the single dikes may be seen along Tennessee Highway 81 between Rocky Fork and Clearbranch Road about two miles northeast of the junction with Tennessee Highway 81.

In most cases the contact between dikes and the country rock is distinct and uniform even on weathered surfaces (Figure 22). In a few cases, however, the contacts have been effected by later shearing and show minor curves and bulges.

Generally in the weathered dikes, the chilled zone could be observed. These chilled zones suggest that the basic dikes intruded after the solidification of the granites described previously. Since no basic dikes were found to extend into the younger rocks of the Ocoee series and the Chilhowee group, it is concluded that these dikes originated later than the granites and earlier than the sedimentary rocks.

The dikes generally weather easily, and because of this they could not be traced beyond the outcrops. On Plate II, they are shown, therefore, as discontinuous outcrops. The saprolite of these dikes is dark-reddish to dark yellowish and easily distinguished from the soils of surrounding materials.

The dikes have various attitudes. In the majority of cases the strike is roughly northeast, and the dip of some of them is very steep.

Diorite Bodies

The writer observed three diorite bodies which have intruded the crystalline complex in the Flag Pond area. Locations of these diorite bodies are as follows: (1) on a secondary road between South Higgins Creek and Coffee Ridge Road, 500 feet from the junction with South Higgins Road, (2) 2,500 feet northeast of the second junction on Mill Creek Road, North Carolina, (3) approximately one mile north of Slipper Spur Gap on the secondary road.

The outcrops are exposed only along the road cuts. The contacts of the diorite bodies with the country rock are obscured by heavy vegetation in most cases. The exposed length of these bodies varies from ten to thirty feet.

Unlike the surrounding rocks, these bodies show no foliation or lineation. The diabasic texture is an outstanding feature that may be seen clearly when the surface is wet (Figure 23). The diorites are very resistant to weathering.

Upon close examination the diorite is observed to be a medium-grained, dense, and massive rock composed of well-interlocked pyroxene, hornblende, and feldspar grains. Several scattered biotite grains were also seen. The presence of hornblende and pyroxene imparts a dull green color to the rock.

A thin section of a sample from the same locality as the previously described sample 34 was prepared. The following minerals were identified and their approximate percentages calculated. About 30 to 40 per cent plagioclase (oligoclase, albite, and andesine), 5 to 10 per cent orthoclase, 20 to 30 per cent hornblende, 10 to 15 per cent pyroxene, 2 to 4 per cent biotite, and 1 per cent quartz, magnetite, ilmenite, leucoxene, and limonite.

The alteration features observed in the above specimen are as follows: (1) dark relicts of plagioclase, (2) relict of augite, (3) in places partial or complete substitution of relict augite by aggregates of pale green pyroxene and hornblende, (4) alteration of ilmenite, in most cases to leucoxene. A photomicrograph of this sample is shown in Figure 24.

In contrast to the surrounding rocks the diorites are not foliated. It would appear, therefore, that the diorite bodies were either not affected by the forces which produced foliation of the crystalline rocks, or they were intruded into the crystalline complex after foliation had already taken place. The writer believes the second possibility is more logical.

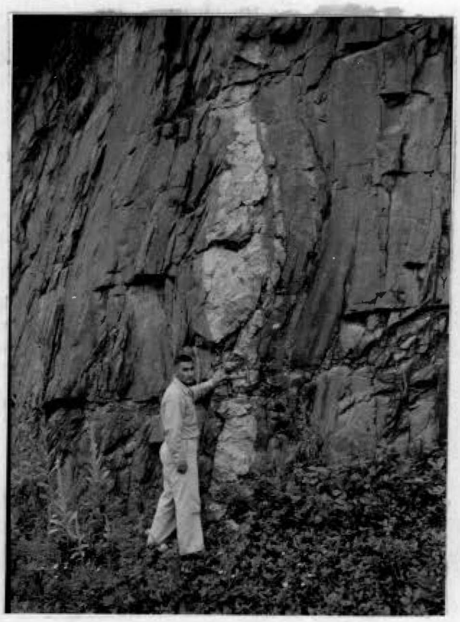

Figure 21. Concordant pegmatite in Unakite granite. Observe strong foliation. Outcrop is 500 feet southwest of Mire Branch on Highway 81.

Figure 22. Weathered basic dike (upper right corner) in granite gneiss saprolite. Outcrop is in a road cut on Carter Branch.

Figure 23. Diabasic texture in diorite. Outcrop is near a secondary road between South Higgins Creek and Coffee Ridge, 500 feet from its junction with South Higgins Creek.

Figure 24. Photomicrograph of a diorite. Note feldspar laths (white) in hornblende (dark). Sample 34, X-nicols (30X).

Granite Gneiss

Granite gneisses occur in both granites of the Flag Pond area. The alternating bands of white (feldspar and quartz) and dark-green (chlorite and in places, epidote and hornblende) are an outstanding feature. Some of these bands measure from one to two inches in width.

Granite gneisses are very similar in lithology to adjacent rocks in that they are mainly composed of feldspar (orthoclase, microcline, and perthite), plagioclase, quartz, chlorite, epidote, hornblende, and, rarely, pyrite and magnetite.

There are foliated fine-grained gneisses consisting of thin lenses of quartz and potash feldspar, bands of crushed plagioclase and quartz, and straight continuous folia of chlorite and sericite. These lenses are one to three centimeters thick and are markedly lineated.

The coarse-grained variety of granite gneiss contains lenses of pink potash feldspar measuring two to four centimeters thick and several centimeters long. These lenses are associated with granulated quartz and finely crushed gray to gray-white plagioclase. Approximately 20 per cent of the rock consists of crudely branching folia of sericite and chlorite (Figure 25).

Intruded basic dikes a few feet to several feet wide are associated with the granite gneiss. These dikes have the same mineral composition and appearance as the previously described dikes seen in the granites.

One of the major features found in the granite gneisses of the Flag Pond granite group is the presence of isoclinal folds. Figure 26 illustrates a striking example of the layered gneiss seen in this group. It is located three-fourths of a mile north of Edwards Cemetery, along a road cut parallel to the middle prong of Coffee Ridge Creek. The isoclinal folds have a height from trough to crest of two to three feet, and the fold axes trend north 80° east. No isoclinal structures were seen in the banded gneiss of the Unakite granite group, which is so prominent in that group.

Evidence such as the abrupt ending of the bands and their kneaded appearance leads one to think that the partial fusion of the pre-existing rock may have taken place among the grains to a degree that allowed freedom of the movement of the grains, or they were formed by the cataclastic processes.

No thin sections were prepared from granite gneisses. The best outcrops of granite gneisses may be seen in a road cut on Old Clearbranch Road (Figure 27), and in a road cut parallel to Rice Creek, two miles southwest of Flag Pond Church.

The granite gneisses resist weathering better than the mylonites and the basic dikes of the crystalline complex.

Origin of Granites

The origin of granites is one of the most controversial problems in geology. A review of the problem with particular reference to those granites occurring along the Tennessee-North Carolina border is given in the following paragraphs.

Safford (1869, p. 170) considered the crystalline rocks to be sandstone, conglomerate, shale, etc., which lost their original

Figure 25. Granite gneiss of Flag Pond granite group. The hammer handle is parallel with foliation. 600 feet west of the junction of Highway 81 with Carter Branch Road.

Figure 26. Isoclinal folds of Flag Pond granite gneiss. Outcrop is three-fourths of a mile north of Edwards Cemetery, along a road cut parallel to the middle prong of Coffee Ridge Creek.

Figure 27. Granite gneiss of the Unakite granite group. Outcrop is along a road near Faith Tabernacle Church.

character and became metamorphosed by subterranean heat. Bradley (1874, p. 520) thought the epidote of Unakite granite was derived from the constant replacement of the mica of common granite, or the hornblende of syenite. Keith (1904, p. 2) believed that the Cranberry and Max Patch granites mapped in the Flag Pond area were igneous in origin and were later metamorphosed. Watson (1906, p. 173) thought the epidote of the Unakite granite found in Madison County in western North Carolina was derived from the interaction of the ferromagnesium constituents and feldspars of pre-existing rocks. Wegman and Krank (1930-31, pp. 98-99), after studying some of the Unakite granites in southwest Finland, concluded that in granitized country rock an enrichment of magnesium gave rise to epidote. They believe that in association with potassium, aluminum, and silica which entered along the enriched Mg-zone, the Unakite granite was formed.

The restricted occurrence of crystalline complex in the Flag Pond Quadrangle compared with its occurrence in the Blue Ridge Province, and its present faulted position make it difficult to arrive at a definite conclusion regarding its origin. Field evidence and microscopic observations, however, provide a limited basis for suggesting possible modes of formation of the crystalline complex.

Hypothetically, the Flag Pond granite group could have originated from pre-existing old metasediments by regional metamorphism. This is evidenced by gradational boundaries of different units of the group as well as by lateral and vertical variations in texture and composition within the units. Structurally, it shows isoclinal folds and crudely banded gneisses.

The Flag Pond granite group might possibly have originated as an independent plutonic body. Although it lacks the homogeneity of a true granite within the Flag Pond Quadrangle, it does show homogeneity in other areas of northeast Tennessee and western North Carolina (Max Patch granite) according to G. D. Swingle (personal communication).

The Unakite granite group could have possibly originated as an independent plutonic body. However, the lack of homogeneity of the igneous lithlogy in the field, as well as the lack of sharp contacts with the adjoining rocks, and the wide range in texture under the microscope, tends to invalidate the above hypothesis.

The Unakite granite group could have formed by the assimilation of aluminous sediments. The presence of epidote, aluminous hornblende and many rounded zircons, and the vertical and lateral variation within a single unit are in favor of this possibility. However, the lack of recognizable sedimentary features and the nature of the faulting which makes it impossible to trace the rock for any distance preclude testing this hypothesis. It should be noted that the areal extent of this process usually does not measure more than a few hundred feet or yards at the most. This seems to eliminate this possibility, since in some places the width of outcrops of this group exceeds several thousand feet.

The Unakite granite group may have originated by regional metamorphism and metasomatism. The heterogeneity of the units within the group, vertical, and lateral variation in texture and lithology within the units, gradational boundaries between different units and presence of large amount of epidote and chlorite are field evidence in support of this possibility. Petrographic observations such as the presence of unzoned feldspars, myrmekitic intergrowths and some replacement perthites are further evidence of this possibility. However, it was not possible to trace the gradational boundary from this group into older sediments in the area.

It does not appear possible to compare the mineral assemblage of the Unakite group with the common metamorphic assemblages. According to Fyfe, et al. (1958, p. 221), potassium feldspar is virtually unknown in low grade pelitic assemblages which contain quartz, muscovite (sericite), chlorite, epidote, etc. However, potassium feldspar is stable at the lowest grades of regional metamorphism and might persist in a quartzo-feldspathic assemblage which has been subjected to later regional metamorphism. This may explain the mineral assemblages observed, although it does not indicate whether the large orthoclase crystals are relict of earlier phenocrysts or had grown metasomatically before the low grade regional metamorphism was superimposed.

Sedimentary Rocks

General Statement

Safford (1856, p. 151) recognized clastic rocks in Northeast Tennessee and divided them into the Ocoee series and the Chilhowee group of Early Silurian age. Keith (1904, p. 3) divided the sedimentary rocks of the Greeneville folio into seven units unconformably overlying the Archean rocks (Table II) and classed them as Cambrian. He recognized the true succession of the various lithologic assemblages but it is difficult to trace these units from one folio to another. This is probably because his rigid concept of alternating shale and sandstone formations did not allow for local or regional changes in facies. He postulated thrust faults which resulted in apparent thickening of his units by repetition of beds. King, et al. (1944, p. 21), working in Northeast Tennessee recognized the sedimentary rocks as basal clastics and classed them as three Lower Cambrian formations, Unicoi, Hampton, and Erwin. The Unicoi formation as mapped by King, et al., is considered to be equivalent to the Unicoi and the underlying Sandsuck and Snowbird formations of the present author (Table II).

Stose and Stose (1949, p. 271) did considerable work on the upper Precambrian and lower Cambrian of the Southern Appalachians. Their type section of the Ocoee series (late Precambrian) was observed "on the Appalachian Trail from Devils Fork Gap to Big Butt in the Bald Mountains of the Greeneville Quadrangle." Here they recognized four formations; namely, Hurricane graywacke, Great Smoky quartzite, Nantahala slate and Big Butt quartzite. The Hurricane graywacke, the equivalent of Keith's (1904, 1905, 1907) Snowbird formation and Hiwassee slate, is the lowermost formation. This formation, 500 to 1,000 feet thick, overlies the granite unconformably and is overlain by the Great Smoky quartzite which is equivalent to the Cochran conglomerate and part of the Hiwassee slate as mapped by Keith (1905). The Great Smoky conglomerate is 500 to 800 feet thick. Above this formation is the Nantahala slate which corresponds to the Nichols slate described by Keith (1905). It is 200 feet thick, according to Stose and Stose, and poorly exposed. The fourth and uppermost formation is the Big Butt quartzite, which is equivalent to the Murray slate, Nebo quartzite, and Hesse quartzite of Keith (1905). The Big Butt quartzite is 150 feet thick. They do not include Hesse quartzite (Keith, 1905) within the Ocoee series.

In the opinion of the present author the Appalachian Trail is not a suitable location for their type section because it runs along the tops of ridges where lush vegetation covers most exposures. The Appalachian Trail has no good exposures since it is a narrow foot path rather than a road cut and, therefore, the Stose's estimates of the thicknesses of the formations are erroneous and much too low. They state (1949, p. 271) that no traverses of the heavily wooded ranges of the region were made. From field experience the author doubts that they could have covered much of the area in the Flag Pond Quadrangle since most of the section is heavily wooded. It is not surprising that they missed the Big Branch Fault (Figure 53), and the second unit of amygdaloidal basalt of the lower Unicoi formation. For these reasons the classification of Stose and Stose is not used in this work.

Lowry (1950, unpublished Ph.D. thesis) mapped the southwest end of the Mountain City Window in Northeast Tennessee. This area is adjacent to the east side of the Flag Pond Quadrangle. Lowry divided the clastic rocks into five units which are in general agreement with those used in this report. Rodgers (1953, pp. 21-42) recognized in the Ocoee series two units, (1) the Snowbird formation and (2) the Sandsuck shale, both of which are of uncertain age. In the Chilhowee group he described three units, the Unicoi, Hampton and Erwin formations, all of Early Cambrian age.

The Ocoee Series

The Ocoee series was named by Safford (1856, pp. 151-2) from the Ocoee River, Polk County, Tennessee. In 1869 he (1869, pp. 183-198) placed the Ocoee series (Eozoic), composed of conglomerate and slates, in the Lower Silurian. Keith (1905, p. 3) mapped the lower part of the clastic rocks as the Snowbird formation and Hiwassee slate. He placed them in the Lower Cambrian but he did not recognize them as part of the Ocoee series.

Stose and Stose (1949, p. 269) placed the Ocoee series in Late Precambrian (Algonkian) age for the following reasons:

> (1)[1] The sediments of Ocoee series do not resemble those of the Chilhowee group or other facies of lower Cambrian quartzites either in lithologic character or manner of deposition.
>
> (2) . . . that the Ocoee series and the Chilhowee group originated in widely separated areas and that their present proximity is the result of overthrusting; that in Tennessee, in the gorge of the Nolichucky River, basal beds of the lower Cambrian Unicoi formation overlie the Ocoee series with a stratigraphic unconformity although without a marked angular discordance.
>
> (3) . . . that the Ocoee series overlies the early Precambrian injection complex with a pronounced stratigraphic, structural, and metamorphic break and is much younger than the complex.

King (1949, p. 634) placed the Ocoee series stratigraphically beneath the Chilhowee group and suggested that it was deposited in a region of high relief and great tectonic instability, in a rapidly

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[1]Numbers in ( ) are the author's.

subsiding trough (eugeosyncline), possibly unconformable, below the Chilhowee group (at least locally). He related the Ocoee series to Late Precambrian.

King, et al. (1958, p. 951), state that the rocks of the Ocoee series are of sedimentary origin but have been metamorphosed to varying degrees. They are coarse-grained and generally poorly sorted texturally and minerologically. These rocks lie unconformably on Precambrian granitic and gneissic rocks.

Rodgers (1953, p. 24) stated that subdivision of the Ocoee series is very difficult and mapped the Ocoee series as undivided within the Flag Pond area. Much of Rodgers' map in this area was not based on actual experience in the field, and he points out that the information was of an uncertain nature. On the basis of the detailed field work the writer proposes the following modifications in Rodgers' map (1953, Plate 4, Greeneville Quadrangle).

a. The Ocoee series is divided into two formations, the Snowbird and the Sandsuck, and in agreement with Stose and Stose (1949, p. 269) is placed in Late Precambrian (Table II).

b. The separate body of undivided Ocoee forming Flint Mountain is not separated from the main body of clastic rock by rocks of the basement complex, but actually is part of it.

c. In many locations the lower boundary of the Ocoee series on the southern limb of the Rich[2] Mountain syncline should be moved at

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[2]Rich Mountain syncline refers to a syncline composed of sedimentary rocks extending from northeast to southwest in the Flag Pond area.

least 1,000 feet to southeastward (Plate II).

d. The upper boundary of the Ocoee series on the southern limb of the Rich Mountain syncline is not as irregular as indicated by Rodgers. The boundary is essentially parallel to the lower boundary, except in the southwestern section (Plate II).

e. The upper boundary of the Ocoee series on the northern limb of the Rich Mountain syncline should be moved approximately 2,000 feet toward the northwest. Very little change in the lower boundary of the Ocoee series of the northern limb of the Rich Mountain syncline is proposed and this will be discussed in Chapter IV.

f. The width of the Ocoee series outcrops on both the northern and the southern limb of the Rich Mountain syncline is considerably less than that indicated by Rodgers (Plate II).

Snowbird formation. The Snowbird formation was named by Keith (1905, p. 5) from Snowbird Mountain which is located on the boundary between Haywood County, North Carolina and Cocke County, Tennessee. He classed the Snowbird formation, composed of quartzite and interbedded conglomerate, as being the oldest sedimentary rocks in the region. Keith (1905, Greeneville folio) extended the formation across the area of the Flag Pond Quadrangle. The present writer is in general agreement with the boundaries of the Snowbird formation as presented by Keith. However, his extensions of the upper boundary of the Snowbird formation on the southern limb of the Rich Mountain syncline is approximately 3,000 feet northwest of the actual boundary observed in the vicinity of North Higgins Creek. The small arm of the Snowbird formation extending southwestward from the area of North Higgins Creek across South Indian Creek and just east of Edwards Branch was found not to be attached to the main body of the sedimentary sequence but to be instead an outlier separated from the Snowbird formation by Precambrian complex. The outlier is composed of metamorphosed rocks of the lower Snowbird formation. The lower boundary of the Snowbird formation on the southern limb of the Rich Mountain syncline should be on the southern flank of Flint Mountain instead of the northern flank as drawn by Keith.

The lower boundary of the Snowbird formation is usually faulted throughout the area (Plate II). However, there is one deep cut in Rocky Fork Creek where traverse in the creek bed showed that the contact between the basement complex and the clastic rocks is gradational, i.e., the amount of feldspar in the adjacent Unakite granite group decreases with the transition from granites toward the sediments. A similar transition was observed regarding the well-rounded grains of quartz which decrease from the sediments toward the basement complex. This gradational zone which is a couple of hundred feet thick is considered to be the zone of unconformity. Several traverses were made across Flint Ridge in an attempt to find similar conditions to those on Rocky Fork, but all failed due to the lush vegetation and heavy coverage. Therefore, the contact along the southern slopes of Flint Mountain between the sediments and the basement complex is interpolated. Since this is the only locality showing a paraconformity, it is possible that similar zones will be found elsewhere in the Southern Appalachians. The upper boundary of the Snowbird formation is marked at the top of

50 feet of vitreous massive quartzite which separates it from the overlying Sandsuck formation.

The Snowbird formation is resistant to chemical weathering characteristic of the Southeastern United States, due to the presence of several quartzite units. Unweathered units of arkose and quartzite have been seen capping high mountains with steep slopes such as Flint Mountain and Blackpine Ridge (Figure 28).

Outcrops of the Snowbird formation were seen chiefly on the southern limb of the Rich Mountain syncline, extending from the northeastern corner to the southwestern edge of the area. The Snowbird formation is divided into an upper and a lower member. Good exposures of the lower member of the Snowbird formation, composed of massive arkose, various quartzites, feldspathic sandstone, and sandy siltstone, were seen only on the southern limb of the Rich Mountain syncline along Rocky Fork. Exposures of the upper member of the formation, composed of feldspathic sandstone, pyritic and pebbly quartzite, shale, sandy siltstone, sandy shale, silty sandstone, and argillaceous sandstone were seen along Long Branch, Big Creek, Clark Branch, and Clause Branch. The members are differentiated by the lack of arkose in the upper member and by the lack of argillaceous sandstone, shale, and sandy shale in the lower member. The lithology of the two members will be discussed separately.

Lithology of the lower member of the Snowbird formation. The lower member of the Snowbird formation consists of arkose, pyritic and pebbly quartzite, vitreous, massive quartzite, feldspathic sandstone, and sandy siltstone. This lower member is best exposed along Rocky Fork in the central part of the quadrangle.

The lowest unit is a gray, coarse-grained arkose 500 feet thick. In places lenses of pyritic quartzite are seen scattered in it. The microscopic analysis of a sample (14) collected from this arkose unit, 1,200 feet southeast of the junction of Long Branch and Rocky Fork, consists of 25 per cent orthoclase, 12 per cent microcline, 45 per cent quartz, 8 per cent plagioclose and 10 per cent sericite. A photomicrograph of this sample is shown in Figure 29. Above this unit is 200 feet of pebbly quartzite with well-rounded pebbles some of which measure three to four inches in diameter (Figure 30). A vitreous, massive, medium-grained quartzite, without recognizable pebbles overlies this unit. This quartzite is 150 feet thick. Sample number 15 collected 900 feet southeast of the junction of Long Branch and Rocky Fork is representative of this quartzite unit. In thin section it shows well cemented subhedral quartz grains with no cement between the grains. A photomicrograph of this sample is shown in Figure 31.

The next overlying unit in the lower member of the Snowbird formation is a layer 100 feet thick of medium-grained feldspathic sandstone. It is highly jointed, thin-bedded and of uniform grain size. The best outcrops could be seen in a jeep road just southeast of the Long Branch junction with Rocky Fork.

A layer of sandy siltstone separates the lower member and upper member of the Snowbird formation. Due to contortion in the siltstone caused by movements of the Big Branch fault, bedding planes in this

Figure 28. Lower Snowbird quartzite outcrops. Beds dip steeply to the left (Southeast). Picture taken from a ridge 1,000 feet northwest of junction of Long Branch and Rocky Fork Creek.

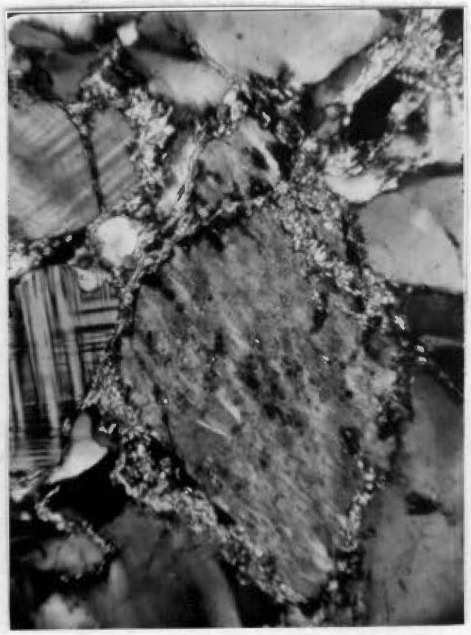


Figure 29. Photomicrograph of arkosic quartzite of the lower Snowbird formation. Note well-rounded quartz and feldspar grains. Sample 14. X-nicols (30X).

Figure 30. Pebbly quartzite of the lower Snowbird formation. Well-rounded pebbles (white) of vein quartz seen in the center and above the ruler. Rocky Fork, 800 feet northwest of the checking station

Figure 31. Photomicrograph of massive quartzite of lower Snowbird formation. Observe well-cemented subhedral quartz grains. Sample 15, X-nicols (30X).

unit are completely destroyed. A crushed and crumbled layer of sandy siltstone shown in Figure 32 is all that remains. The sand grains in this siltstone occur as irregular "patches" within a groundmass of silt-sized particles. The quartz grains that make up these sand patches are smoky-gray in color and of medium size.

Lithology of the upper member of the Snowbird formation. The upper member of the Snowbird formation consists of several alternating layers of various quartzite, feldspathic sandstone, sandy siltstone, sandy shale, argillaceous sandstone, silty sandstone, shale, and sandy shale. The total thickness is approximately 1,400 to 2,000 feet.

The lowermost part of the member consists of 100 feet of sandy shale. Along the Big Branch fault this shale is crumbled and distorted so that bedding planes are obliterated. Thin section of this unit reveals euhedral crystals of quartz in a matrix of distorted shale and clay minerals. These euhedral quartz grains exhibit well developed undulatory extinction. A photomicrograph of this sample is shown in Figure 33. The sample was collected from the headwaters of the first northern tributary of Rocky Fork. Above this unit is 200 feet of silty sandstone. In thin section studies, sample number 17 collected 300 feet north of the junction of Long Branch and Rocky Fork shows well to sub-rounded quartz grains cemented with silt particles. A photomicrograph of this sample is shown in Figure 34. Upon close examination in the field this silty sandstone shows graded bedding on a minute scale.

Above the sandy siltstone unit is 100 feet of pyritic quartzite without pebbles. The pyrite is scattered throughout the unit and is

Figure 32. Contorted sandy siltstone of lower Snowbird formation. Along a jeep road near Long Branch.

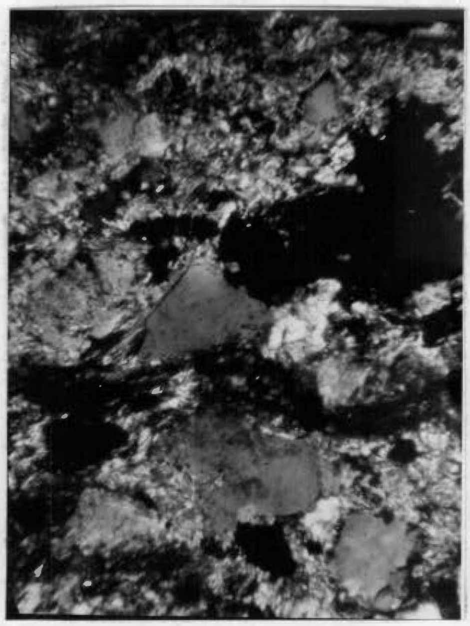


Figure 33. Photomicrograph of sandy shale of the upper Snowbird formation. Anhedral quartz grains (center) in a clay mineral matrix. Sample 16, X-nicols (50X).

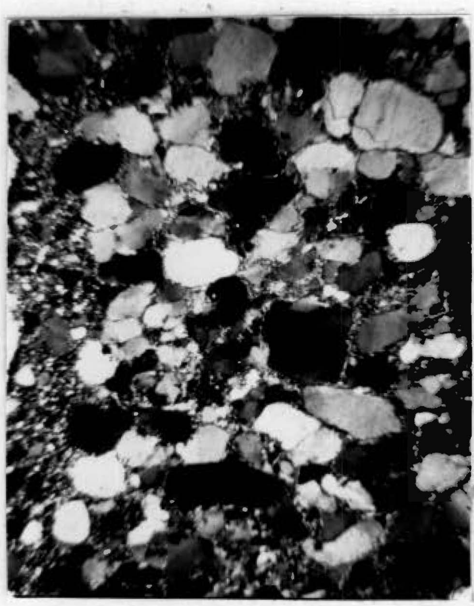


Figure 34. Photomicrograph of silty sandstone, of the upper Snowbird formation. Note well-rounded quartz grains, cemented by silt particles. Sample 17, X-nicols (30X).

rarely localized in small pockets. The best exposure of this pyritic quartzite may be seen on Rocky Fork and Clark Creek. It is a medium-grained quartzite with approximately 2 per cent feldspar.

The pyritic quartzite is overlain by 300 feet of feldspathic sandstone. It is a medium- to fine-grained sandstone with coarse feldspar grains making up approximately 15 per cent of the rock. Occasionally, pyrite grains are scattered throughout the lower portion of the unit. The feldspathic sandstone shows graded bedding which can be utilized in determining the attitude of bedding. Exposures of this unit may be seen on North Higgins Creek. Above the feldspathic sandstone is a gray to brown-gray shale unit 100 feet thick which at some places thins to only 5 feet. This shale may, in some places be quite sandy, and occasionally it contains well-rounded grains of feldspar that are usually weathered.

The shale unit is overlain by 100 feet of pebbly quartzite. This is one of the high ridge forming units of the member, since it resists weathering. It is gray to whitish gray, with pebbles ranging from three to ten millimeters in diameter. The pebbles are commonly derived from vein quartz though a few were recognized as feldspar. In the outcrop, the weathered feldspar pebbles give rough surface to the rock. Exposures of this unit may be seen on Mill Creek, North Carolina, Clause Branch and the junction of Chigger Branch and Clark Creek.

Above the pebbly quartzite unit is a second unit of alternating sandy shale and siltstone very similar to that in the lowermost part of this member except that bedding planes are preserved and could be easily recognized in the field. This unit has an average thickness of 150 feet, but minimum and maximum thickness may range as much as 50 feet from this average. Good exposure could be seen along a jeep road parallel to Rocky Fork and North Higgins Creek. Above this unit is the second pebbly quartzite unit 100 feet thick and very similar in color and pebble content to that of the first unit mentioned above. The pebbly quartzite unit grades into a vitreous, massive, well-cemented quartzite, which is rather clean, white, and without pebbles.

There is another unit of vitreous quartzite of the same description which is utilized as an alternate horizon marker to separate the Sandsuck formation. When one of these two units was absent the other unit was used in determining the boundary. The upper most quartzite bed is usually 50 feet thick and the lower one is around 200 feet in stratigraphic thickness. Between these two quartzite units is an alternating argillaceous sandstone and shale of about 200 feet thickness, which is brown to bluish brown in color. Good exposures of alternating quartzite units and argillaceous sandstone may be seen on Big Branch near the water falls.

Sandsuck formation. The Sandsuck formation was named by Keith (1895, p. 3) for the exposures on Sandsuck Branch of Walden Creek, Sevier County, Tennessee. According to Keith in the type section, "There were no variations in the formation and it consists of bluish-gray shale with lighter-gray bands. When weathered the shale is dull yellow in color."

Keith (1905, p. 3) used the name Hiwassee slate for approximately the same formation with the exception of including calcareous beds which are interstratified with the slates. Ferguson (Oriel 1950, p. 23) in studying Keith's Sandsuck type area finds that the formation contains some lenses of conglomerate not described by Keith.

The formation above the Snowbird in the Flag Pond Quadrangle was found to be lacking the calcareous beds of the Hiwassee and containing thin beds of conglomerate which have been reported to be present in the type area of the Sandsuck. This led the writer to believe that the name Sandsuck should be used for the formation above the Snowbird, since it has priority and also the Flag Pond Quadrangle is closer to the type locality of the Sandsuck formation.

The Sandsuck formation outcrops on both sides of the Rich Mountain syncline. Best exposure can be seen on a jeep road parallel to Rocky Fork north of Long Branch, Clark Creek, and the southern slope of Snakeden Ridge. The thickness of the Sandsuck formation is approximately 1,000 to 1,400 feet. The thinner region is on the northeast flank of the Rich Mountain syncline; thickening occurs toward the southwest.

The arkose and feldspathic sandstone of this formation tops high ridges such as Snakeden and Green Ridge Knob. Very steep slopes result from weathering of the shale and siltstone part of the formation. The soils produced by weathering of shale and siltstone of the formation are red to reddish brown in color.

The lower boundary of the Sandsuck formation is placed at the top of a vitreous quartzite of the Snowbird formation. The upper boundary with the Unicoi formation is formed by a thick unit of conglomerate of the lowermost unit of Unicoi formation.

Lithology of the Sandsuck formation. The Sandsuck formation is differentiated from the Snowbird formation by having cross-bedded sandstone, slate and micaceous sandstone, and by lacking pebbly quartzite and pyritic quartzite.

The Sandsuck formation consists of various units of shale, sandy shale, sandy siltstone, arkosic quartzite, sandstones, slate, and micaceous sandstone.

The lowermost unit is a brown shale layer 50 to 100 feet in thickness, which separates this formation from the Snowbird formation. In some places it thins out to as little as 5 feet in thickness, as is seen along Chigger Creek and Clark Creek. Locally, at least, it contains 2 to 3 feet of conglomerate.

Conglomerate was seen in two places, one on the Chigger Creek traverse where it could not be traced along strike and the other on North Fork Sill Branch, in the northeast corner of the area, where it was even more localized. The shale, usually brown to buff color produces very loose soil.

The next overlying unit is 200 feet of massive arkosic quartzite. Huge blocks formed during mechanical weathering of this unit cause difficulty in passage in Rocky Fork and Devil Fork Creeks. Coarse euhedral crystals of feldspars are contained in a well cemented matrix of gray to dark gray quartzite. This unit is overlain by a 100 foot thick unit of sandy siltstone and shale, which is thin bedded and shows remarkably well developed banding. The best exposure of this unit is along Clark Creek where the alternating greenish to gray bands of siltstone and shale give an outstanding feature to the outcrops.

Above the sandy shale and siltstone unit is a feldspathic sandstone, gray to gray-white in color. Highly developed graded bedding is usually displayed throughout the entire stratigraphic thickness of the 100 foot outcrop. The weathering of feldspars at the surface gives a porous feature to the rock. A thin section of the feldspathic sandstone, sample 12, collected on a logging road as it turns sharply north on Snakeden Ridge shows well interlocked grains of feldspar with subrounded quartz grains. The mineral analysis shows approximately 15 per cent feldspar (albite, oligoclase, and microclase), 75 per cent quartz, some of which shows strain shadows and 7 per cent clay minerals, pyrite, and accessory minerals. A photomicrograph of this sample is shown in Figure 35.

Overlying this unit is a slate which has a maximum thickness of 50 feet. It is brown to chocolate-brown in color with well developed slaty cleavage. This unit could be traced along the southern flank of the Rich Mountain syncline and best exposures are on the jeep road along Rocky Fork Creek, Big Branch, and North Higgins Creek. The slate is overlain by a second unit of arkosic quartzite of this same formation. It is very similar to the first unit, and is about 200 feet thick.

The arkosic quartzite is overlain by 100 feet of sandstone that is highly cross-bedded. This distinctive feature was utilized in determining the top and bottom of the overturned beds. It is a fine- to medium-grained sandstone, poorly cemented, and in places argillaceous. Good exposures of this unit may be seen on Devil Fork Branch, Big Branch, and Blockstand Creek. The next unit above the cross-bedded sandstone is 50 feet of sandy siltstone, greenish to greenish brown in color, which in turn grades into the last unit of the Sandsuck formation.

This last unit is a micaceous sandstone 100 feet thick with mica flakes concentrated in bedding planes. The sandstone itself is medium- to coarse-grained with a white gray buff color and is highly jointed. Occasionally large pebbles have been seen in the localities along North Higgins Creek and the headwaters of the middle fork of Cassi Creek. A thin section of micaceous sandstone, sample 13, was collected from an outcrop at the headwaters of the first southern prong of Blockstand Creek. It shows well-rounded quartz grains, with mica flakes possibly chlorite or muscovite, concentrated on bedding planes. The matrix is fine-grained clay material. A photomicrograph of a thin section is shown in Figure 36.

<u>Chilhowee Group</u>

Safford (1856, pp. 152-3; 1869, pp. 198-203) named the Chilhowee group for the Chilhowee Mountain (Sevier and Blount County), Tennessee. Keith (1905, p. 3) subdivided the group into Cochran conglomerate, Nichols slate, Nebo quartzite, Murray slate and Hesse quartzite. Later he (1907, p. 3) stated that Hiwassee and Snowbird were equal to the Unicoi formation; the Nichols slate and Cochran conglomerate were equal to the Hampton shale; and Hesse quartzite, Murray slate, and Nebo quartzite were equal with the Erwin quartzite.

Figure 35. Photomicrograph of feldspathic sandstone of Sandsuck formation. Albite twinning dark upper left corner, oligoclase twinning with altered edges, lower and center, and quartz. Sample 12, X-nicols (50X).

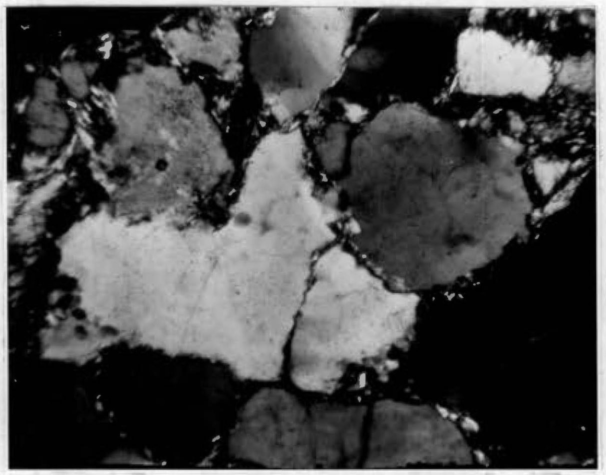


Figure 36. Photomicrograph of micaceous sandstone of Sandsuck formation. Note well-rounded quartz grains with strain shadows, cemented by micaceous and clay minerals. Sample 13, X-nicols (50X).

Since Keith was inconsistent in mapping formations from one folio to another and in naming his subdivisions, the present writer adopted the classification used by most workers in northeast Tennessee, particularly that of King, et al. (1944, p. 27), which divides the Chilhowee group into three formations, Unicoi, Hampton and Erwin (Table II). In many places King, et al., have indicated the presence of Scolithus in the Unicoi formation (p. 38), Hampton formation (p. 37) and Erwin formation (p. 31). This writer generally agrees with their classification but was not able to find Scolithus in any of the above mentioned formations mapped in the Flag Pond Quadrangle.

King (1949, p. 513) placed the Chilhowee group in the Cambrian. Later King, et al. (1958, p. 964), designated the uppermost fossiliferous zone of the Chilhowee group (Helenmode formation) as Cambrian and the remaining unfossiliferous formations below it as Precambrian, although he states (1949, p. 641) that "grouping of the Cochran and Unicoi with the Ocoee series is unnatural." Since as yet there is no general agreement on the age of the Chilhowee group, the present author designates the entire group tentatively as Cambrian.

The boundary between the Ocoee series and Chilhowee group in the Flag Pond area is at the base of a thick conglomerate of Unicoi formation, which is traceable throughout the area.

The Unicoi formation. Although he did not establish a type locality, the Unicoi formation was named by Campbell (1899, p. 3) at the suggestion of Keith for Unicoi County, Tennessee. King, et al. (1944, p. 37, Sec. G, Figure 6), have shown good exposures along the gorge of the Nolichucky River southeast of Unaka Springs in Unicoi County. These investigators did not divide the formation into separate members. In the Flag Pond Quadrangle within the Rich Mountain syncline Rodgers (1953, Plate 4) indicated the Unicoi formation surrounded by the undivided Ocoee series. It was found, however, that the boundaries drawn by Rodgers were not exact and also that a thick unit of the Hampton formation is present along the trough of the synclinal structure (Plate II).

The Unicoi formation is distinguished from the Sandsuck formation by the presence of amygdaloidal basalts and from the Hampton formation by the presence of large amounts of quartzites and very little shale.

This writer separates the formation into a lower member consisting of conglomerate, sandy siltstone and shale, feldspathic sandstone, vitreous quartzite, argillaceous and cross-bedded sandstone, pebbly quartzite, pyritic quartzite, micaceous sandstone, and two units of amygdaloidal basalt; and into an upper member consisting of one amygdaloidal basalt, shale, micaceous sandstone, slate, pyritic, pebbly, vitreous quartzite, sandy shale, and siltstone. Outcrops of both members are seen on the two limbs of the Rich Mountain syncline. The best exposures can be seen on a jeep road parallel to Fort Davie Creek, North Higgins Creek, and along South and North Fork Sill Branch. The thickness of the Unicoi formation ranges from 2,500 to 3,000 feet.

The upper member of the Unicoi formation is differentiated from the lower by a lack of thick conglomerate, feldspathic sandstone, massive argillaceous sandstone and cross-bedded sandstone. It contains only one unit of amygdaloidal basalt while the lower member has two. The lithology of the two members will be discussed separately.

The lower boundary of the Unicoi formation is an easily traceable, thick unit of conglomerate which is seen on both limbs of the Rich Mountain syncline. This conglomerate marks an unconformity between the Ocoee series and the Chilhowee group at least locally. The upper boundary of the Unicoi formation is marked at base by a white, pebbly quartzite which is, in some places, lenticular and thus not traceable. In those places where the quartzite lenses out the boundary is gradational from sandy siltstone of Unicoi formation to the lower shale unit of Hampton formation.

The siltstone and shale of the formation weathers easily to form a reddish yellow to gray soil. The resistant beds of quartzite and sandstones form high ridges in the area, such as Frozen Knob, Higgins Ridge, and Rich Mountain, where relief may be as much as 3,000 feet.

<u>Lithology of the lower member of Unicoi formation</u>. The lower member of the Unicoi formation consists of various quartzites, conglomerate, two units of amygdoloidal basalts, various sandstones, sandy siltstone, and shale.

The lowermost unit of the lower member of the Unicoi formation is twenty-five to fifty feet of conglomerate, which is observed on both flanks of the Rich Mountain syncline. The pebbles that constitute this conglomerate measure from one to four centimeters in diameter. Seventy-five per cent of the pebbles are well-rounded quartzite and chert and the remaining pebbles are feldspar, some of which are completely weathered to clay minerals (Figure 37).

This conglomerate is overlain by 100 feet of gray pyritic quartzite with thin alternate beds of shale. The best exposure of this unit may be seen at the junction of Blockstand Creek and Rocky Fork. Above this unit is the first unit of amygdaloidal basalt measuring from 25 to 50 feet in thickness.

Keith (1905, p. 3) did not recognize amygdaloidal basalt on the Greeneville folio. In the Roan Mountain folio (1907, p. 3), however, it was recognized and called amygdaloid. King, et al. (1944, p. 20), called these rocks amygdaloidal basalt. Stose and Stose (1949, p. 272) called them metadiabase. The writer prefers amygdaloidal basalt because this term most closely describes the unit as seen in the field. It is dark green or dull red, dense and usually amygdaloidal. The amygdules are abundant at the top of the flows. The unit usually weathers to red, brown, or gray soil.

Sample 11 was collected from an outcrop on the north side of a jeep road at the junction of Birchfield Camp Branch and North Higgins Creek. In thin section it is difficult to determine the nature of the matrix; however, the basaltic texture could be seen in the groundmass. The minerals which fill the amygdules are identified as quartz, chlorite, and calcite. A photomicrograph (Figure 38) shows some of the amygdules.

The most accessible exposure of the amygdaloidal basalt in the Flag Pond Quadrangle may be seen on the second northern tributary of

North Higgins Creek after entering the area from the east. Along the northern flanks of the Rich Mountain syncline no amygdaloidal basalt was found.

The amygdaloidal unit is overlain by 200 feet of sandy siltstone and sandy shale, mostly reddish to reddish brown in color. The siltstone and the shale alternatively produce bands of 2 to 4 inches in thickness which readily may be seen in the field. Sample number 10 is an example of this sandy siltstone. It was collected 1,400 feet north from North Higgins Creek on a logging trail which connects this creek with Tennessee Mill Creek. In thin section well-rounded quartz grains are seen interspersed with well rounded feldspar in a matrix of clay minerals. A photomicrograph of this unit is shown in Figure 39. This unit weathers easily to produce reddish to reddish yellow soil. Above this unit is 100 feet of vitreous massive quartzite, very similar to that described in the upper member of the Snowbird formation. In some places where it is pebbly and not well cemented, it breaks along grain boundaries. This quartzite is one of the high ridge making units of the lower member of the Unicoi formation. A thin section of sample number 7, collected 3,200 feet northwest of Big Branch Church, shows well-rounded quartzite pebbles interlocking with subrounded quartz grains. A photomicrographic of this unit is shown in Figure 40.

Fifty to 100 feet of sandy shale separates this quartzite unit from a unit of feldspathic sandstone that is 200 feet thick. Sample number 9 was collected on a jeep road south of the junction of Broad Branch and Rocky Fork. In thin section it shows well-rounded quartz

Figure 37. Conglomerate in the lower Unicoi formation Observe well-rounded and somewhat weathered pebbles. Located on a jeep road one-half mile from junction of Rocky Fork and Long Branch.

Figure 38. Photomicrograph of amygdaloidal basalt of Unicoi formation. Amygdule, in center, filled with calcite and quartz, in a basaltic matrix. Sample 11, X-nicols (50X).

Figure 39. Photomicrograph of sandy siltstone of lower Unicoi formation. Showing well-rounded quartz and feldspar grains with oligoclase twinning in a matrix of silt (clay mineral). Sample 10, X-nicols (50X).

grains with wavy extinction. In several places there can be seen altered microcline grains interlocking with well-rounded quartz grains. A photomicrograph of this unit is shown in Figure 41. In the lower part of the feldspathic sandstone some graded bedding was noticed, whereas, in the upper portion it is highly cross-bedded. Light gray to dark gray is the prevailing color of the feldspathic sandstone.

Above the feldspathic sandstone is the second unit of the amygdaloidal basalt, varying in thickness from 10 to 20 feet. This variation is perhaps due to weathering or the surface of deposition or poor preservation of this unit. The amygdaloidal basalt is very similar in lithology and appearance to that already described. The best exposures of this unit could be seen on the headwaters of the Blockstand Creek and south of Broad Branch and Rocky Fork. The amygdaloidal basalt is overlain by 200 feet of massive argillaceous sandstone, dark red to light red in color. It is a uniform, medium-grained sandstone and in some places mica flakes have been seen concentrated on bedding plane. This unit is easily traceable particularly along the northern flank of the Rich Mountain syncline.

The argillaceous sandstone is overlain by 100 feet of pebbly quartzite with pebbles ranging from two to ten millimeter in diameter. A thin section made from sample number 8 collected 2,000 feet northeast of sample number 7 shows well interlocking grains of quartz with very little cement. Quartz grains show mostly strain shadows. A photomicrograph of this sample is shown in Figure 42. Above this unit is a micaceous sandstone. Mica flakes were observed as accumulations mostly on the bedding plane. It is approximately 100 feet thick. The sandstone is very uniform medium-grained and weathers easily. The best outcrop of micaceous sandstone may be seen near the Appalachian Trail on the deep cuts of the headwaters of Blockstand Creek.

The micaceous sandstone grades into an overlying cross-bedded sandstone of 80 feet thick. This sandstone is medium- to fine-grained, and buff to brown yellow in color. Excellent exposures of it can be seen along North Higgins Creek, Big Branch, and the northern headwaters of Blockstand Creek. The uppermost unit of the lower member of the Unicoi formation is a quartzite bed which is pebbly in the lower portion and pyritic in the upper portion. This quartzite is a traceable unit and an excellent marker in the field. The pebbles in the lower portion range from four to twenty millimeter in length. The quartzite is coarse-grained and in many places it shows graded bedding. It is a very resistant unit and is the second ridge making unit of the lower Unicoi member. Good exposures of this unit may be seen along a trail connecting Squibb Creek Trail to that of Rocky Fork Trail.

Lithology of upper member of the Unicoi formation. The upper member of the Unicoi formation consists of various quartzites, micaceous sandstone, one unit of amygdaloidal basalt, slate, and sandy shale.

The boundary between the upper and lower member of the Unicoi formation is marked by a 50 feet thick, green to bluish-green shale. This shale is well exposed on the southern limb of the Rich Mountain syncline; on the northern limb it thins to 5 feet. Exposures of this unit may be seen on the headwaters of Longarm Branch where a jeep road crosses it. Above the shale unit lies the third amygdaloidal basalt layer which is 20 to 30 feet thick and is similar in lithology to those already described. The best exposure of the amygdaloidal unit is in a jeep road 300 feet north of the junction of Birchfield Camp Branch and North Higgins Creek. The amygdaloidal unit is overlain by 200 feet of alternative layers of sandy shale and sandy siltstone. These layers vary in thickness from one inch to five inches. In places sandy shale shows graded bedding on a minute scale. Overlying this unit is 10 to 20 feet of brown to dark brown slate, with prominent slatey cleavage. The best exposure of this slate is on the headwaters of South Fork Sill Branch and on a jeep road parallel to Fort Davie Creek before the road turns to east.

The slate unit is overlain by pyritic quartzite that is 180 feet thick. It is gray to white gray in color and has small scattered pebbles in places in the lower portion. The grain size is generally medium. A sample of this pyritic quartzite was collected north of the junction of Rocky Fork with Fort Davie Creek on a jeep road shows in thin section well-rounded pebbles some of which are altered. In several places altered grains of pyrite were noticed. Occasionally altered material served as cement between grains. A photomicrograph of this sample is shown in Figure 43.

Overlying the pyritic quartzite mentioned above is 80 feet of vitreous massive quartzite, very similar in lithology to that seen in the lower member of the Unicoi formation. It is very resistant to

Figure 40. Photomicrograph of a vitreous quartzite of the lower Unicoi formation. Note the well interlocked subrounded quartz grain with very little cement. Sample 7, X-nicols (30X).

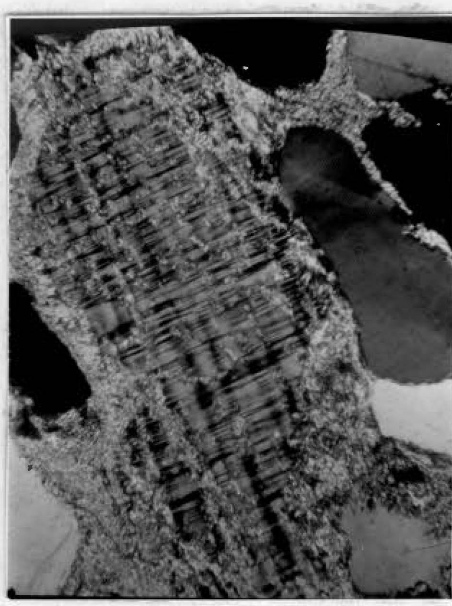


Figure 41. Photomicrograph of feldspathic sandstone of lower Unicoi formation. Note microcline twinning with altered edge (center) surrounded by well-rounded quartz grains. Sample 9, X-nicols (80X).

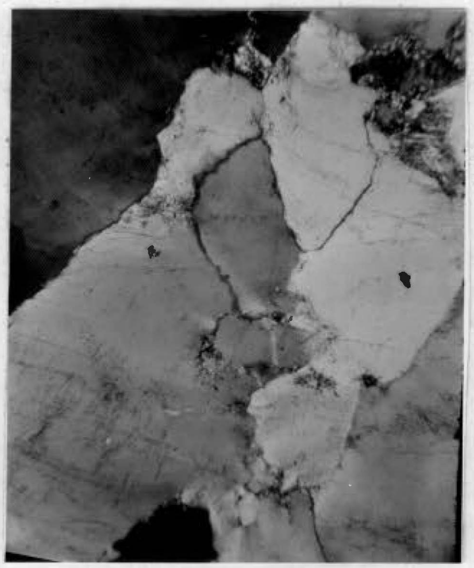


Figure 42. Photomicrograph of massive quartzite of lower Unicoi formation. Quartz grains are well interlocked with practically no cement. Sample 8, X-nicols (50X).

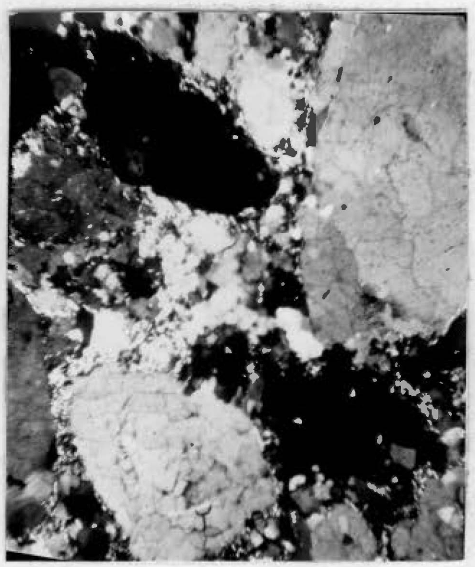


Figure 43. Photomicrograph of pyritic quartzite of upper Unicoi formation. Rounded pebbles in lower right corner and weathered pyrite in upper and right lower corner (black). Sample 5, X-nicols (30X).

weathering, breaks up into large blocks several feet in diameter, and frequently results in the formation of steep waterfalls in the creek beds as in Figures 5 and 44. Above this vitreous quartzite is 120 feet of micaceous sandstone similar to that described in the lower member of the Unicoi formation. The exposures of the micaceous sandstone can be seen in a jeep road on the headwaters of Longarm Branch.

Overlying the micaceous sandstone is 200 feet of sandy shale and siltstone alternating so that a banded structure is produced. The bands measure from a few millimeter to several centimeter in thickness. The alternate bands of bluish to blue green siltstone and reddish sandy shale may be readily seen in the field. Good exposures of this unit could be seen on a jeep road, 1,500 feet northwest of Wilson Knob.

The last unit of this member is a pebbly quartzite 50 feet thick. This quartzite in places is lenticular and does not show the maximum thickness. In those instances when the quartzite lenses out it is difficult to distinguish the boundary between Unicoi formation and Hampton shale. Good exposures of pebbly quartzite may be seen along a jeep road parallel to North Higgins Creek and on a trail on the headwaters of Chigger Branch. A thin section prepared from this quartzite shows that the well-rounded pebbles are mostly fractured, and that usually they are surrounded by well-rounded to subrounded quartz grains. In the matrix of the thin section in places several well-rounded plagioclase feldspars grain was seen. A photomicrograph of sample 6 was collected 1,000 feet north of sample 5 on the west bank of Fort Davie Creek and is shown in Figure 45.

Figure 44. Small anticline in the upper Unicoi formation. Exposure is in North Higgins Creek, 400 feet northeast of its junction with Birchfield Camp Branch.

Figure 45. Photomicrograph of pebbly quartzite of the upper Unicoi formation. Note the fractured large well-rounded pebble, surrounded by fragments of quart and feldspar. Sample 6, X-nicols (30X).

Hampton formation. Campbell (1899, p. 3) named Hampton formation for the town of Hampton in Carter County, Tennessee. Butts (1940, p. 37) noted the presence of this formation in southwest Virginia, but all the formation he recognized was shale. King, et al. (1944, p. 35, Figure 5, Section B), verified the typical outcrop of the Hampton formation in the Doe River Gorge and Iron Mountains near Hampton, Tennessee. Rodgers (1953, Plate 4) did not recognize the presence of the Hampton formation within the Flag Pond Quadrangle.

In the present study the Hampton formation was identified as the youngest formation of the Rich Mountain syncline, and it is suggested that the formation should be extended to the northeast beyond the Flag Pond Quadrangle where Ordway (1959, p. 623) recognized the presence of the same formation.

The Hampton formation is found to be a composite of layers of sandy shale and siltstone in lower and upper portion and quartzite and feldspathic sandstone in middle portion. In this report no attempt was made to separate the Hampton formation into members. The thickness of the formation ranges from 1,000 to 1,400 feet.

The lower boundary of the Hampton formation is made up at the base of alternating beds of sandy shale, shale and sandy siltstone which lie conformably over the pebbly quartzite of the Unicoi formation. In places where the pebbly quartzite was not present the boundary was found to be gradational with sandy siltstone and shale. The upper boundary which separates it from the Erwin formation is at the top of a thin layer of vitreous quartzite 10 to 20 feet thick.

One of the outstanding features of the sandy siltstone unit of this formation is the manner in which it weathers. The unit is weathered mechanically by exfoliation. Mechanical attack takes place by way of freezing and thawing on the exposed surfaces of sandy siltstone and sandy shale, which changes the volumes of minerals and weakens the bonds between them. At the same time, the low heat conductivity of rock limits diurnal expansion and contraction to a thin outer rind, a shell of altered rock that is alternately tightened and loosened until it separates from the rock within. A sample of the exfoliation in sandy siltstone is shown in Figure 46.

The best exposures of the Hampton formation in the Flag Pond Quadrangle are along Rich Mountain road cuts and trails, such as the road cut parallel to the headwaters of North Higgins Creek, Tennessee Mill Creek, and a jeep road connecting Bearwallow Gap to the northeast corner of the area.

Lithology of the Hampton formation. The Hampton formation consists of sandy shale and siltstone, various sandstone units and pyritic quartzite. It lacks ferruginous sandstone which is seen in the Erwin formation and lacks amygdaloidal basalt units which appear in the Unicoi formation.

The lowermost portion of the Hampton formation consists of 400 feet of alternating layers of sandy shale, shale, and sandy siltstone. Spheroidical weathering is a typical field feature of this unit. The alternating sandy shale and sandy siltstone produces bands of blue to bluish red color. The thickness of the bands vary from one to three inches. The best outcrops of this unit can be seen 300 feet northwest of Frozen Knob on a jeep road parallel to the second prong of North Higgins Creek.

A thin section of sample 4 from the above locality shows silt and shale particles in the groundmass with well to subrounded quartz grains. Some of the quartz grains show strain shadows. In several places yellowish grains of limonite were seen. The alternating bands are more conspicuous with high magnification and show good bedding. A photomicrograph of a thin section is shown in Figure 47.

Overlying this unit is 100 feet of micaceous sandstone with detrital mica flakes accumulated particularly in bedding planes. It is a medium-grained sandstone, white to white yellow in color. In a few places pebbles of one to three millimeter in diameter have been seen on the lower portion of the sandstone. Good exposures of this unit may be seen along a jeep road on the northwest slopes of Rich Mountain. Above this micaceous sandstone is 50 feet of pyritic quartzite which is the only such unit in the Hampton formation. In lithology and field appearance it is very similar to the pyritic quartzite beds described in the upper Unicoi formation.

The pyritic quartzite is overlain by 250 feet of feldspathic sandstone, which is highly cross-bedded as well as being very fine-grained. No thin section was prepared from this unit. The best exposures of feldspathic sandstone can be seen along a jeep road on Chestnut Knob near the south prong of Tennessee Mill Creek. Above the feldspathic sandstone is approximately 100 feet of shale and sandy siltstone in alternating bands. This shale and sandy siltstone unit does not show spheroidical weathering as has been seen in the lower portion of the Hampton formation. The bands measure from two to five inches in thickness. Overlying this sandy siltstone and shale unit is a cross-bedded sandstone 100 to 150 feet thick containing some pebbles in the lower portion. These pebbles measure two to eight millimeter in diameter. The sandstone is fine- to medium-grained and there are several patches of limonite scattered in the outcrops. The limonite patches give to the sandstone a yellow to yellowish red color. Good exposures of cross-bedded sandstone can be seen along a jeep road between Wilson Knob and Frozen Knob.

Overlying the cross-bedded sandstone is the uppermost unit of the Hampton formation, which is a thick unit of 250 to 350 feet of sandy siltstone and shale. The best exposures, showing alternating bands of two to ten inches in thickness can be seen along Cassi and Painter Creek. A thin section was made from sample 3, which was collected 500 feet southwest of Bearwallow Gap on a road cut parallel to North Higgins Creek. The thin section shows several euhedral quartz grains in a matrix of silt and shale size particles. Bedding of alternative bands could be seen readily under microscope. A photomicrograph of the thin section is shown in Figure 48.

The best outcrops showing exfoliation weathering may be seen at the locality where sample number 3 was collected.

Erwin formation. Keith (1903, p. 5) named the Erwin quartzite for the town of Erwin, Unicoi County, Tennessee. He described it as being a

Figure 46. Exfoliation of sandy siltstone in the Hampton formation. The head of hammer is parallel with bedding. One-fourth mile south of Bearwallow Gap on a jeep road.

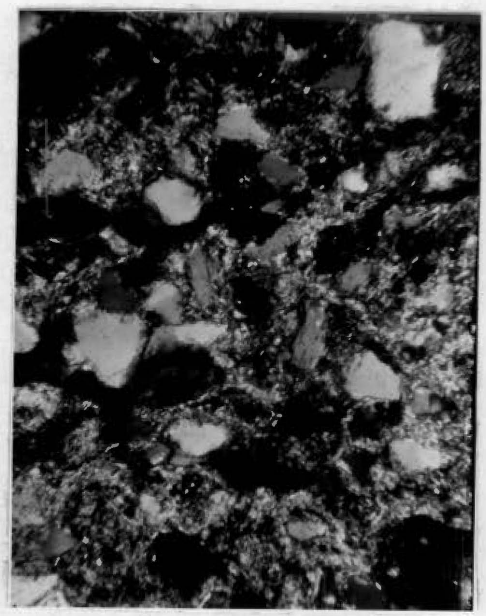


Figure 47. Photomicrograph of sandy siltstone and shale unit of Hampton formation, showing the subrounded grains of quartz in a matrix of silt. Sample 4, X-nicols (30X).

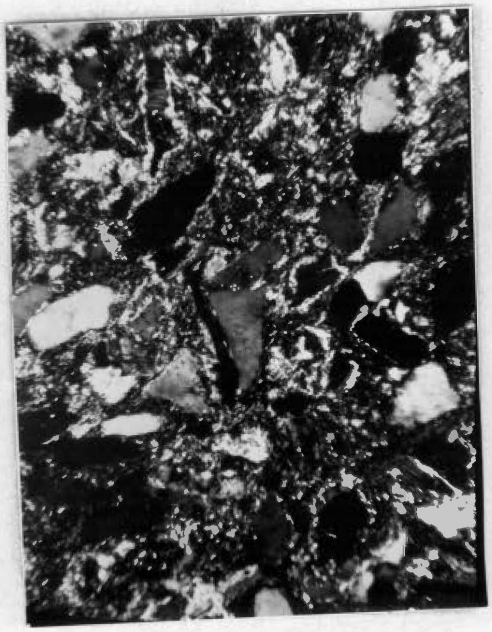


Figure 48. Photomicrograph of sandy shale of the Hampton formation. Note angular quartz crystals in a matrix of clay minerals. Sample 3, X-nicols (30X).

> . . . white sandstone and quartzite, 500 to 700 feet thick, of very uniform appearance. The strata are composed of fine white sand, more or less cemented by secondary silica. The layers are very massive and show scarcely any shale and thin sandstone, in which are found a few lower Cambrian fossils of the Olenellus. Scolithus borings are common on the quartzites.

More recently King, et al. (1944, p. 30), gave the name Erwin formation for a formation containing vitreous quartzite, shale, siltstone, and ferruginous quartzites. The type exposure is described near Erwin on the Nolichucky River southeast of Unaka Springs.

In the Flag Pond Quadrangle three exposures of the Erwin formation are found in the northwest corner of the area. They consist of vitreous quartzite, interbedded shale and siltstone, slate, and three units of ferruginous sandstone. The thickness of the formation as calculated from the field maps ranges from 1,000 to 1,400 feet. Since the upper part of the Erwin formation is faulted in the Flag Pond area, in every calculation the thickness was postulated.

The base of the Erwin formation is placed at the bottom of a ledge formed by resistant white quartzite that overlies a shale unit of the Hampton formation.

Rodgers (1953, Plate 4) recognizes the presence of two areas of the Erwin formation in the northwest section of the Flag Pond Quadrangle. This writer has mapped three areas, two of which correspond generally with those of Rodgers.

The best exposures of the Erwin formation can be seen on Painter Creek, and north of the junction of the east and middle branches of Cassi Creek.

The vitreous quartzites of the Erwin formation are very resistant to weathering. In many cases they form resistant ledges along the slopes of the mountain which can be seen from a distance. The shale and siltstone units weather easily and produce a yellow to yellow white soil.

Lithology of the Erwin formation. The presence of various quartzites and particularly ferruginous sandstone distinguishes the Erwin formation from the other formations in the Chilhowee group. The Erwin formation consists of various quartzites, ferruginous sandstone, shale, slate, silty sandstone and sandy siltstone.

The lower boundary of the Erwin formation is 20 feet of typical clean, white vitreous quartzite that is composed of uniform, well-rounded quartz grains. It is easily traceable and good exposures of it can be seen along Cassi Creek, Clark Creek, and Painter Creek. An outcrop of this quartzite is shown in Figure 49. Above this quartzite unit is 30 to 100 feet of shale and sandy shale which forms alternating white to dark green bands measuring from one to four centimeters in thickness. Usually the white bands are silty and dark green bands shaley. Good exposures of this unit can be seen southeast of Flatrock Branch. Overlying this sandy shale and shale unit is massive vitreous quartzite 30 to 40 feet in thickness, with occasional large quartz pebbles. This quartzite is white to gray or buff when fresh, and weathers to light-colored surfaces.

Sample 1 was collected from an outcrop of this vitreous quartzite 2,000 feet north of the junction of Cassi Creek with the East Fork of Cassi Creek. A thin section prepared from this specimen shows well cemented and fine textured quartz grains and in some places it is difficult to see the outlines between adjacent grains. In other places very little silica cement could be seen between the grains. A photomicrograph of this sample is shown in Figure 50.

Above this quartzite unit is the first hematitic and glauconitic sandstone. The hematite and glauconite covering the grains, as well as acting as a cement, gives the sandstone a reddish color. The sandstone is dense, massive, and uniformly medium-grained with well- to subrounded quartz grains. The thickness of this ferruginous sandstone is from 20 to 40 feet, and the best exposures of it can be seen in Painter Springs and about 2,000 feet north of the junction of Middle Cassi Creek with the East Fork of Cassi Creek.

Overlying the ferruginous sandstone is 30 to 40 feet of shale with lenses of slate. The slate is brown to black-brown in color. Slaty cleavage is well developed in most of these slate lenses. Good exposures of the shale and slate lenses could be seen in Painter Creek and Cassi Creek. The second unit of ferruginous sandstone lies above this shale unit and can only be differentiated by stratigraphic position. It is not as thick as the first ferruginous sandstone unit. The maximum thickness of the unit is only 15 feet and it is difficult to follow along the strike. Lithology and appearance of this unit is very similar to that of the first ferruginous sandstone unit.

Above this second ferruginous sandstone unit is 100 feet of massive and, in places, pebbly vitreous quartzite. The pebbles have diameters of five to twenty millimeters. The quartzite is white when fresh and in weathered surfaces it is reddish. The best exposure of this unit can be seen on the East Fork of Cassi Creek. Overlying the pebbly quartzite is 100 to 150 feet of shale and silty sandstone in alternating bands measuring one to four centimeters in thickness. A pebbly quartzite overlies this unit with well-rounded quartz pebbles ranging from one to four centimeters in diameter. This unit is 100 to 150 feet in thickness and easily traceable in the field. Best exposures of it can be seen along Clark Creek and Painter Creek. Above this unit is 120 to 150 feet of shale and sandy shale similar to those mentioned above with the exception that graded-bedding was observed in the sandy shale. Good exposures of this unit occur in Hell Hollow and northeast of the junction of North Fork and Painter Creek.

The shale and sandy shale is overlain by the third unit of hematitic and glauconitic sandstone. It is finer grained sandstone than those previously described and the per cent of glauconite seems less than in the two units described above. The thickness of this unit is from 5 to 15 feet at maximum. Good outcrops of this can be seen along the headwaters of Middle Fork of Cassi Creek.

The uppermost unit in the Erwin formation is sandy siltstone, sandy shale and interbedded shaly sandstone of 100 to 150 feet in thickness. The appearance of this unit is very similar to those already mentioned in this formation.

A thin section was made from sample 2 which was collected 800 feet north of the junction of Cassi Creek and East Fork of Cassi Creek. It shows angular quartz and feldspar grains cemented by clay minerals.

The quartz grains show strain shadows. In several places, pyrite grains, some of which are weathered, are seen. A photomicrograph of this thin section is shown in Figure 51.

Figure 49. Ledge making vitreous quartzite of the Erwin formation. Beds dip to the right. Outcrop is at the junction of the East and Middle Forks of Cassi Creek.

Figure 50. Photomicrograph of vitreous quartzite of the Erwin formation. Note well interlocked grains with little cement. Sample 1, X-nicols (30X).

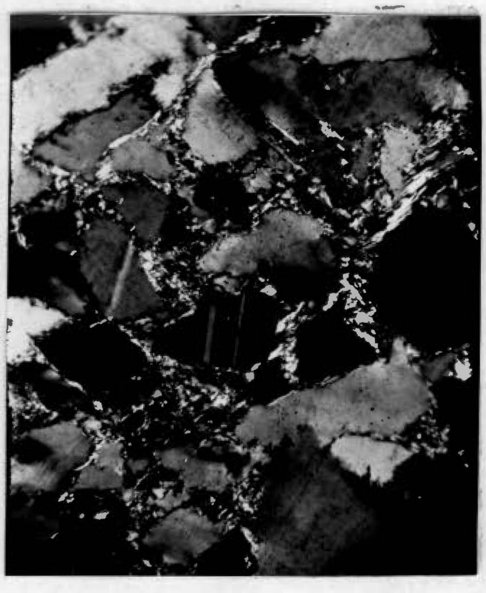


Figure 51. Photomicrograph of shaly sandstone of the Erwin formation. Observe angular quartz and feldspar (center) cemented by shale. Sample 2, X-nicols (30X).

CHAPTER IV

STRUCTURAL GEOLOGY

Regional Structure

The faulted and folded belt of the Appalachian Mountains extends from Alabama to Newfoundland. The physiographic province of the Blue Ridge within this belt rises in Southern Pennsylvania and continues southwestward, in accordance with the general trend of the Appalachian system, to the northern section of Georgia. The Blue Ridge Province is separated from the Great Valley section of the Ridge and Valley Province by marked topographic breaks on the northwest and by the Piedmont Province on the southeast.

The direction of the Blue Ridge as a whole, as well as the minor divides within it, is for the most part independent of structure. The rocks are metamorphosed and show but slight difference in resistance to weathering. Linear ridges of continuous trend are found generally on the western side of the province in a belt of metamorphosed Cambrian and late Precambrian rocks composed of quartzite, slate, schists, conglomerate and some less altered beds. According to Keith (1927, p. 154), the western boundary of this province is determined by the limit of overthrust of the metamorphosed rocks on the unaltered limestone of the Ridge and Valley Province. King (1950, pp. 645-47) does not agree with this concept since the thrust zone is not continuous along the front as indicated by the findings of Cloos (1948, p. 2,162) who does not recognize it in South Mountain, Maryland. Kesler (1940, p. 231) doubted its extension of the thrust sheet in the Cartersville, Georgia, area and King (1943, p. 29) could not find it in Northern Virginia. King, and others (1944, pp. 10-13), recognized the fault only in Northeast and Central Tennessee (Smoky thrust and Holston thrust).

Intense faulting and folding is common in the Blue Ridge Province. It is generally believed that orogenic activity of the late Paleozoic was responsible for most of the major structures of this region. The Great Smoky overthrust named by Keith (1927, p. 154) is one of the most pronounced of these late Paleozoic structures. It is a low angle thrust fault that strikes to the northeast and dips to the southeast. Along the northwestern edge of the Blue Ridge the thrust faults generally dip at low angles to the southeast, although locally reversals of dip occur. Within the Blue Ridge Province, many high angle thrust faults occur, such as Devil Fork Fault in Flag Pond Quadrangle.

Local Structural Features

The Flag Pond Quadrangle is near the western border of the Blue Ridge Province in the Unaka Range. Characteristic folds and faults of the Blue Ridge Province are well displayed in this area. Outstanding structural features include thrust faults, mylonite zones, the Rich Mountain syncline, a transverse-gravity fault, and extensions of the southwest end of the Mountain City Window.

Two factors make identification of the thrust faults easier in clastic section; (1) Discontinuity of the formation such as seen in Big Branch and Clause Branch, (2) repetition of the formations in the upper Chilhowee group such as those seen in the northwest portion of the area. In the crystalline rocks, however, mylonite zones are the chief evidence of faulting.

Structures of the Basement Complex

General statement. The general appearance of the basement complex indicates that it has undergone a long and complicated structural history. Its origin is complex and comparatively obscure. The effects of deformation have greatly altered the original character of the rocks.

Description of the structural features. In the following sections the structural features of the basement rocks are described. These features are grouped in three categories; (1) those related to shearing, such as crushed zones and mylonite, cataclastic foliation and linear features, (2) those related to mineral alterations, and (3) minor features such as cleavages and joints.

Structures related to shearing. Evidence indicates that the basement rocks of the Flag Pond Quadrangle were subjected to two periods of shearing. One is marked by the presence of cataclastic gneiss which is highly foliated and silicified. This shearing probably developed early since subsequent faulting has offset the foliation in these rocks. The other, marked by the presence of mylonite and crushed zones with little or no silicification, could have occurred during late Paleozoic deformation.

Cataclastic foliation. In the crystalline complex, foliation is characteristically represented by thin layers of one or more conspicuous minerals such as feldspar, chlorite and quartz. This parallelism is not the result of stratification of pre-existing rocks because the thin layers are not felted and the controlling minerals are seen megascopically as a disconnected group.

Cataclastic foliation is thought to have occurred prior to the late Paleozoic deformation, since in many outcrops the foliation is cut by late faulting.

One of the best examples of cataclastic foliation is in an exposure one-half mile south of Willis' Store in a cut of Coffee Ridge Road. In this outcrop rocks of the Flag Pond granite group are present and have been ground extremely fine. The outcrop consists mostly of thin lenses of finely crushed quartz and feldspar embedded in a lustrous, siliceous matrix.

A finer-grained variety of cataclastic foliation intercalated with coarse-grained crushed granite and massive granite of the Flag Pond granite group was seen in an outcrop in a road cut parallel to South Higgins Creek. Here gray to dull gray, fine-grained, potash feldspars, and quartz were seen in a siliceous matrix of epidote and chlorite. Offsetting of the cataclastic foliation in this outcrop is not as noticeable as that seen in the exposures south of Willis' store (Figure 52). The foliation produced in cataclastic gneiss has the same general strike and dip as the mylonite and crushed zones.

<u>Crushed zones and mylonites</u>. Mylonites and crushed zones are the most conspicuous structural features of the Precambrian crystalline rocks of the Flag Pond Quadrangle. Where the basement rocks

Figure 52. Cataclastic granite gneiss. Foliation (parallel with hammer handle) is folded and faulted indicating a minimum of two periods of deformation. Exposure is one-half mile south of Willis' store on a road cut.

were carried over the sedimentary rocks along thrust faults, they were generally crushed into mylonites and sheared rocks. Zones of mylonite and sheared rock in the Flag Pond Quadrangle vary from a few feet to several hundred feet in width. Foliation in these zones is grossly parallel to the faults.

Mylonites are best developed along the bases of the thrust sheets. The distribution of these deformed rocks is indicated on the map of the Flag Pond Quadrangle (Plate II) by a wavy symbol. They indicate the presence of high angle thrust faults with a general northeast strike with some exceptions and a southeast dip varying from 50° to 70°.

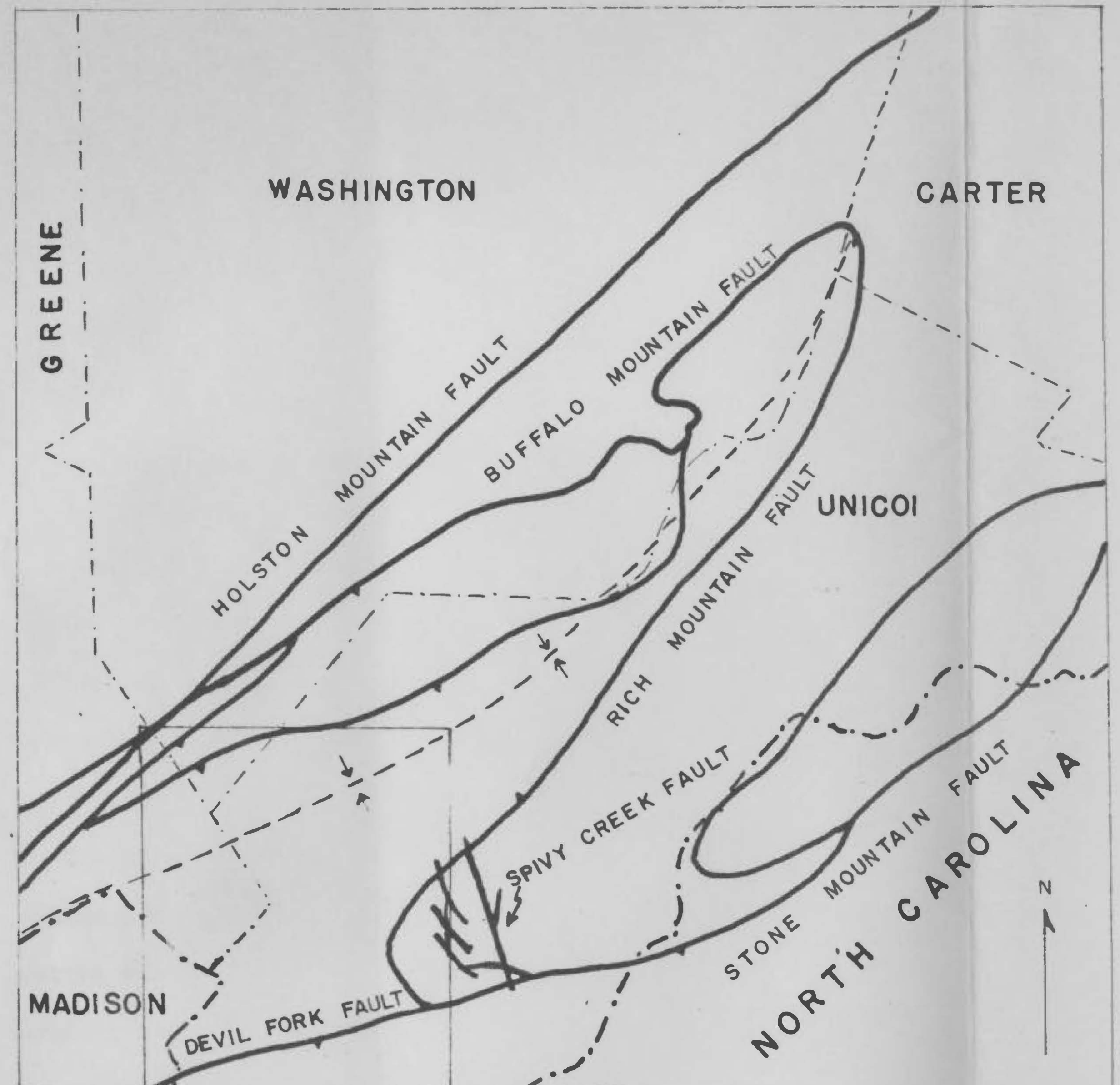
Because of poor outcrops it is not known if the mylonite zones are continuous. On Plate II the extensions of these zones are conjectural. Rodgers (1953) on Plate 4 of the geologic map of East Tennessee interpreted several of these mylonite and sheared zones in the Flag Pond Quadrangle as the Devil Fork Fault. He named it for Devil Fork Creek which is approximately parallel to the fault line in the southwest corner of the area. Rodgers indicated the Devil Fork Fault as cutting across the southern portion of the quadrangle and splitting near Rocky Fork Community. The northeast branch (according to Rodgers) extends to the clastics of the Flag Pond area and the southeast branch extends toward the clastics of the southwest end of the Mountain City Window. The writer was not able to trace the fault as outlined by Rodgers northeast of Rocky Fork Community. From the Rocky Fork Community to the southwest corner of the quadrangle, however, the fault was found to be as Rodgers had suggested.

Devil Fork Fault has local as well as regional structural significance. Rodgers (1953, p. 142) postulated that the Bald Mountain thrust sheet was split into two sheets by the Devil Fork Fault where it extends into the basement complex. Locally it represents the presence of high angle thrust faults in the Precambrian crystalline complex. Regionally the Devil Fork Fault cuts the Flag Pond granite group as well as the Unakite granite group indicating that it occurred after the formation of crystalline complex and prior to late Paleozoic deformation.

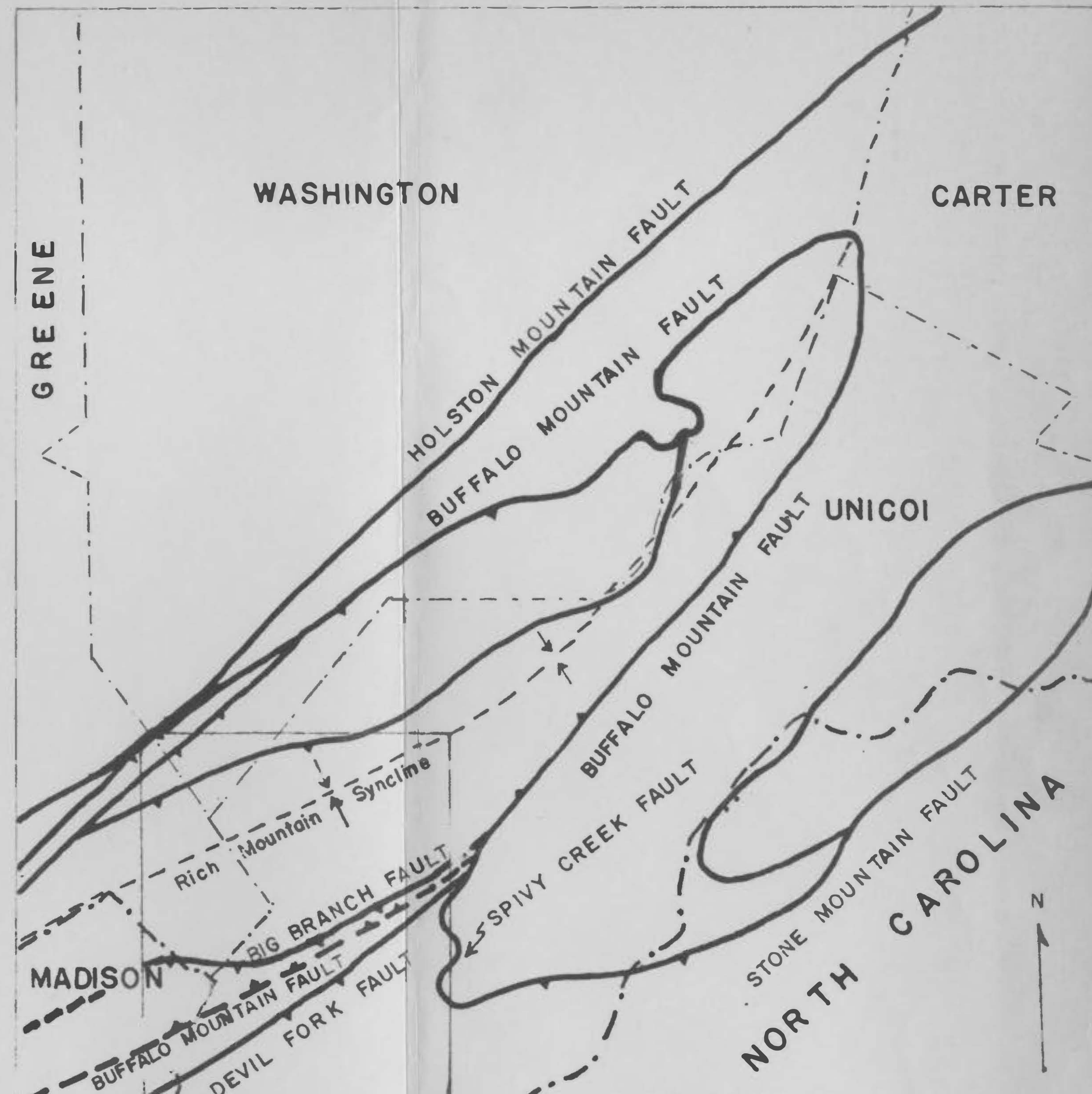
Other mylonite and crushed zones were observed in the Flag Pond Quadrangle but could not be traced for any distance as was the Devil Fork Fault. This could be done only after more detailed field work is completed in adjacent areas. Their general trend, however, suggests that perhaps they were formed during the same period of deformation as Devil Fork Fault (Figure 53).

Linear features. Two types of lineation were recognized in the basement rocks of the Flag Pond Quadrangle; (1) the more prominent type is lineation which is associated with foliation and shows the same general trend N 60-70° E, (2) the second type was found in the massive granite of the Unakite granite group where large phenocrysts of feldspar (perthite) show a general direction of N 10-20° E.

In the first type the long axis of the feldspar and quartz are parallel with the direction of foliation and the shorter axes are perpendicular to it. This type is believed to be secondary flowage lineation which could have originated before late Paleazoic deformation. In the second type the lineated minerals are granulated and strained.



After Rodgers (1953)



According to Present Writer

LEGEND:

— · — · — County line

— · — · — State line

0 5 10 Mile

It is presumed that the tectonic forces involved caused the elongated feldspars to gradually rotate and assume the present position. The feldspars were battered by the process and became granulated and fractured. These probably originated during late Paleozoic deformation.

Examples of the first type can be seen in many outcrops of crushed granite, and good exposures of the second type may be seen in Unakite granite on Tennessee Highway 81, 500 feet south of Rocky Fork School.

Mineral alteration. In the basement complex many alteration products can be seen megascopically as well as microscopically. The alteration products which are identified in the field are epidote, chlorite, hematite, ilmenite and pyrite. Biotite, sericite, leucoxene, and clay minerals were prevalent in most samples examined microscopically.

Chlorite, which was seen in most outcrops, appeared to be the alteration product of biotite, hornblende and augite. In some places the entire outcrop consists of chlorite. Hornblende and biotite appeared in some outcrops as unaltered or partially altered grains, whereas garnet and augite were rarely seen in the unaltered form.

Biotite appeared to have originated in two ways. First, individual crystals seemed to have been formed during a metasomatic or assimilation process and second, alteration halos of biotite occurred around grains of hornblende.

Sericite is one of the most common alteration products recognized. It was probably derived from feldspars (orthoclase) or muscovite since it surrounds nuclei of feldspar crystals or completely replaced muscovite. In every thin section examined this type of alteration was seen.

Epidote, which apparently is the alteration product of the feldspars and ferromagnesium minerals, occurred as grains along fractures and as pods.

In a few samples very fine-grained minerals (saussurite) were seen to surround the plagioclase feldspars. In some cases the minerals completely replaced it.

Ilmenite was seen as an accessory mineral in a few samples of the basement complex. Leucoxene, one of the alteration products of the titanium minerals, usually appeared as a coating or as spots on the ilmenite grains. A few grains of rutile also were seen in some samples.

Another type of alteration which can be seen particularly in cataclastic gneisses is recrystallization. The crushed and granulated rock materials were silicified by addition of silica solutions and the product is a hard, tough and massive granite gneiss. Silicified granite gneiss can be seen three-fourths of a mile on Coffee Ridge Road south of Willis' store, or on Tennessee Highway 81, north of Flag Pond Community.

Recrystallization is seen in joint planes, particularly in the Unakite granite group. Where joint planes are covered with a mineral film less than one millimeter in thickness, the minerals involved are a compound of hematite and pyrite. The hematite is red to dark red. Only in a few places the casts of pyrite, filled with weathered materials, were seen. A test for titanium and manganese on mineral film in the laboratory was negative.

Mineral assemblages in the area are not comparable to metamorphic assemblages commonly reported. Fyfe, et al. (1958, p. 211), states that low grade pelitic assemblages contain quartz, muscovite, chlorite, epidote, etc. He does not include potassium feldspar or muscovite. The sericite is probably the alteration product of muscovite and this may explain its presence in the area. Potassium feldspar is known to be stable at the lowest grade of regional metamorphism and may persist in a quartzo-feldspathic assemblage which may explain its presence in the crystalline complex of the Flag Pond area. Although these theories explain the presence of the mineral assemblages, they do not indicate whether the large orthoclase crystals are remnants of earlier phenocrysts or if they grew metasomatically before the low grade regional metamorphism was superimposed.

Minor structural features. The rocks of the Flag Pond Quadrangle, clastic as well as basement complex, are characterized by strong development of joints. An attempt was made in the field during mapping to record all joint patterns present. However, when these were studied collectively no definitive conclusions could be drawn. The general trend of joints was north 10° east or west to north 80° east or west. Most of the joint planes observed in the area appeared to be the result of late Paleozoic deformation because they crosscut the cataclastic foliation in the basement complex at various angles. The best example of joints in granites is exposed along Tennessee Highway 81 and in clastic rocks along a jeep road parallel to Rocky Fork and Cassi Creek.

In the outcrops of basement complex, where there are highly developed crushed zones, the fault planes show smooth, more or less polished, and in some places striated surfaces (slickensides). These surfaces usually are covered with a coating of a red to dark red mineral, which is probably either weathered iron oxide or chloritic minerals derived from certain original minerals in granite and have recrystallized. The best examples of slickensides occur north of the mylonite zone on a secondary road connecting Tennessee Highways 81 and 212, and in a jeep road cut along Clear Branch Road.

Interpretation of the basement rock structure. The nature of the pre-existing rocks of the basement complex in the Flag Pond area is a matter of speculation since there is no stratigraphic evidence of their original nature. The presence of isoclinal folding in the strikingly layered gneiss of the Flag Pond granite group is evidence that pre-existing rocks of the basement complex were metamorphosed perhaps by regional metamorphism. As a result of the regional metamorphism the granite and granite gneisses were produced. This regional metamorphism, considered to be the first deformation, took place in Precambrian time.

The second period of deformation took place by regional metamorphism, by metasomatism of the pre-existing rocks, or by assimilation of aluminous sediments which resulted in the formation of the Unakite granite group. At the end of these processes pegmatites and basic dikes were intruded into the basement complex. Basic dikes appear concordant in most cases and occasionally discordant with the host rocks. Pegmatites lack gradational contact with the host rock and show no brecciation. It appears that basic dikes and pegmatites invaded the crystalline complex prior to the Buffalo Mountain thrust sheet, and since they are not found in sedimentary sequences, they probably formed during Precambrian time.

The third period of deformation in the area is marked by the presence of diorite bodies very similar in lithology and appearance to those in dikes of the Bakersville area in North Carolina.

Recent studies in the Bakersville and Roan Mountain areas by Wilcox, et al. (1958, p. 1363), suggest a deformation in Ordovician-Silurian time (probably part of the Taconic disturbance). Kelberg (1956, p. 761) found conglomerates of the Chilhowee group in sediments of middle Ordovician age in the Southern Appalachian. Rodgers (1952, p. 425) studying absolute ages of radioactive minerals from the Appalachian region, recognized two periods of deformation in Precambrian time which affected the crystalline Appalachians. A third period of Ordovician orogeny affected the western part of the crystalline Appalachians in the Carolinas and New England. The fourth period of deformation, according to Rodgers, occurred in Mississippian time. It affected eastern New England, especially the belt east of the Connecticut River. Keith (1907, p. 3) in the Roan Mountain folio described these rocks as Bakersville gabbro and postulated that they were intruded into the basement complex in Jurassic time.

Since conglomerate pebbles from the Chilhowee group were transported into the Great Valley region and deposited in middle Ordovician sediments, the writer chooses to correlate the igneous intrusions (diorites) with the orogeny that shifted these conglomerate pebbles.

The fourth period of orogency in the area, marked by thrust faulting of the basement complex, occurred near the end of Paleozoic time. This episode structurally is marked by the presence of mylonite and crushed zones in the basement complex and crosscutting of the older foliation (cataclastic foliation) by younger faults.

Structural Features of the Stratified Rocks

The structural features associated with the stratified rocks of the Flag Pond Quadrangle are much easier to decipher than those of the basement complex. Their stratified nature with the preservation of primary features provides a key to their relationship with each other and to the basement rocks. The most prominent structural elements of the stratified rocks are the Rich Mountain syncline and the fault blocks of the Buffalo Mountain thrust sheet.

Structural setting of the Flag Pond area. The Appalachian movement of late Paleozoic time produced strong structural deformation of the rocks of Northeast Tennessee. Thrust faulting and folding are regional characteristics of these rocks. Within the area thrusting moved thrust sheets composed of great masses of rock many miles northwestward over other rock masses.

In Northeast Tennessee, numerous thrust sheets occur within the Unaka Mountain range, such as the Hampton, Shady Valley, Buffalo Mountain sheets and others. The Flag Pond Quadrangle is located within the Buffalo Mountain thrust sheet which contains rocks of the Ocoee series, the Chilhowee group, and the basement complex.

The Buffalo Mountain thrust sheet lies in parts of Unicoi, Washington, Greene, and Carter Counties of Tennessee, and extends into Madison County, North Carolina.

Buffalo Mountain thrust sheet. The Buffalo Mountain thrust sheet, like many other sheets in Northeast Tennessee, is the result of Appalachian movement which took place presumably in late Paleozoic time. The sheet, according to Rodgers (1953, p. 142) is a tongue-like mass located on the southwestern part of Shady Valley thrust sheet near Roan Mountain in Northeast Tennessee. The fault beneath the thrust sheet was recognized and named the Buffalo Mountain Fault by Keith (1907, p. 8-9). An extension of this fault was mapped on the Greeneville folio by Keith which includes part of the Flag Pond Quadrangle.

The Buffalo Mountain sheet contains rocks of the Ocoee series, the Chilhowee group, and the basement complex in the Flag Pond area. The sheet also contains Shady dolomite in the section northeast of the area.

For clarity the northwest section of Buffalo Mountain sheet will be considered separately from the southeast section.

a. Rodgers (1948, p. 23), studying the mineral deposits of Bumpass Cove in Unicoi and Washington County, Tennessee, observed the merging of the first two thrust blocks in the region. This is north of Flag Pond Quadrangle. The third block, according to Rodgers, forms Rich Mountain, the southwest part of which extends into the Flag Pond Quadrangle.

The northeastern section of the sheet has been mapped by Ordway (1959, p. 628) who recognized three thrust blocks, the Cherokee Mountain block to the southwest, an intermediate block, and the Pinnacle block which forms the main mass of Buffalo Mountain to the southeast.

The writer recognizes the thrust blocks of northwestern slices on the northwestern flank of the Rich Mountain syncline as Rodgers indicated them; however, more detailed mapping shows that the fault lines on Rodger's Plate 4 of the East Tennessee Geological Map should be changed in the following manner.

1. The fault line of the most northwesterly slice which Rodgers extended into the Flag Pond Quadrangle was not found. The lack of Knox dolomite indicates that fault line should be drawn several hundred feet to the northeast where it does outcrop.

2. The most southerly of northwesterly fault lines from Hell Hollow northeastward was found to be as outlined by Rodgers, but southwestward from Hell Hollow the fault line should be moved south several hundred feet (see Plate II).

The Buffalo Mountain Fault through much of its course in the northwestern section follows the base of Rich Mountain syncline in the area; the rocks of upper Chilhowee group rise in escarpments on the mountains, and override Paleozoic rocks as high as the middle Ordovician which forms the lower valleys in the northwestern front of the area (see Plate III, cross section BB' and CC'). The underthrust of Buffalo Mountain Fault is probably adjacent to the basement complex, according to the interpretation considered in this report. The maximum stratigraphic displacement represents nearly the whole sedimentary column and basement complex of the area, which is several thousand feet in thickness. This displacement marks the fault as one of the first order of magnitude.

The best exposures of the northwestern section Fault in the area can be seen on the northern flank of the Rich Mountain syncline, along Clark Creek, Painter Creek, and in several locations on Cassi Creek, mostly dipping to the southeast.

b. The southeastern section of the Buffalo Mountain thrust fault was studied by Ordway (1959, p. 628) and Lowry (1948 unpublished Ph.D. thesis). They named this section of the sheet which runs parallel to Rich Mountain the Rich Mountain Fault. The writer thinks that the Rich Mountain Fault of Ordway and Lowry is actually the southeastern extension of the Buffalo Mountain Fault. The projection of Rich Mountain Fault across their mapped areas corresponds with the Buffalo Mountain Fault outlined in cross section AA', BB' (Plate III) of this report. This conclusion also confirms the prediction of Rodgers (1953, p. 145) that the Buffalo Mountain thrust branches to the southeast to give rise to the Devil Fork Fault, which extends into the basement complex.

The southeastern extension of Buffalo Mountain Fault was not seen in the Flag Pond Quadrangle. However, on the basis of structure it appears that the Buffalo Mountain Fault is replaced by one of its later slices (Big Branch Fault). From cross sections BB' and AA' (Plate III) it is inferred that the Buffalo Mountain Fault is dipping to northwest. Probably Devil Fork Fault was another slice which extended into the basement complex. As may be seen in the structural sections, the Buffalo Mountain Fault has displaced and thrusted the entire stratigraphic column of the area to the northwest.

In an outline map (Figure 53), the various names which have been applied to the Buffalo Mountain Fault are shown along with a map giving the present author's concept of the fault and its branches.

Rich Mountain syncline. The Rich Mountain syncline is embraced by the Buffalo Mountain thrust fault on both sides.

Keith (1904, Greeneville folio) recognized the presence of the Rich Mountain syncline, but he did not name it. Rodgers (1953, Plate 4) also recognized it with boundaries closely related to Keith's but different from those of the present author's. These differences are outlined in the introductions to the Ocoee series and the Chilhowee group. In the present report the syncline is named for Rich Mountain which extends from northeast to southwest in the clastic sections of the Flag Pond Quadrangle. It is considered to be an asymmetrical syncline with the axial plane dipping generally southeast. The southern flank of the syncline is somewhat overturned near Big Branch Fault.

The Rich Mountain syncline plunges to the northeast from the heights of Bald Mountain in the western edge of the area. The width of the syncline differs from 17,000 feet in the center of the area to 2,200 feet on the northeastern section. Except for the Erwin formation all other formations of the Ocoee series and the Chilhowee group have been seen in the flanks of the syncline. The syncline is bounded on both flanks, southeast as well as northwest, by thrust faults of the Buffalo Mountain Fault. It is difficult to estimate the length of the syncline, since it extends in both directions, northeast and southwest, out of the Flag Pond Quadrangle; however, its length in the area is approximately 44,000 feet.

Big Branch Fault. The Big Branch Fault was named for exposures of the fault behind Big Branch Church in a road cut parallel to Big Branch Creek. Other exposures of the fault showing brecciation and contortion of material in the fault zone can be seen along a jeep road parallel to Long Branch (Figure 32), 500 feet northeast of the Appalachian Trail at the headwaters of Blockstand Creek, Edwards Branch, and North Higgins Creek.

Big Branch Fault is a high angle thrust fault that extends from near South Higgins Creek on the east side of the area to the northern slopes of Green Ridge Knob in the west edge of the area.

Both horizontal displacement and stratigraphic displacement have been produced by the Big Branch Fault. Horizontal displacement has been recognized in the Rocky Fork Creek area by displaced contacts. It differs from 1,500 to 2,000 feet. The stratigraphic displacement, as can be seen in the cross sections in Plate III, is at least 800 feet.

Big Branch Fault appears to displace the Buffalo Mountain Fault in the Flag Pond Quadrangle. If this interpretation is correct, then it is younger than the Buffalo Mountain Fault. It should be noted that the word younger does not refer to a younger period of thrusting, but it is believed that the Big Branch Fault is the later pulse of the Buffalo Mountain thrust sheet.

Transverse-gravity fault. Only one minor fault was identified in the clastic section of the area. The best exposure of the fault is along a jeep road parallel to North Higgins Creek on the south flank of the Rich Mountain syncline. The fault dips 45° to the southeast.

The fault is identified as a transverse fault because the strike of the fault measuring from north 10° east is not parallel to the strike of regional structure (Rich Mountain syncline), but rather cuts it diagonally. It is called a gravity fault because the east block (Chestnut Knob block) has moved down as a hanging wall relative to the foot wall (Bearwallow Gap block).

The relative movement of the fault could be seen along the northern prong of North Higgins Creek, on Chestnut Knob. The displacement appears to be about 200 feet. This fault is considered to be a local dislocation which took place at the end of the major deformation (late Paleozoic).

Holston Mountain Fault. Outcrops of the Holston Mountain Fault were not recognized in the Flag Pond Quadrangle. As may be seen in cross section BB' (Plate III), however, the Holston Mountain Fault is postulated to be replaced by the Buffalo Mountain Fault. A similar replacement of the Holston Mountain Fault by Buffalo Mountain Fault was indicated by Rodgers in the area of the Flag Pond Quadrangle (Figure 53).

The Holston Mountain Fault was named by Stose and Jonas (1938, p. 23) for the outcrop of the fault on the base of Holston Mountain. Accordingly, it may be traced for miles in Northeast Tennessee. It is a low angle thrust fault dipping to the southeast, and has thrusted the sediments of Precambrian and lower Cambrian northwestward over the rocks of the Great Valley.

Minor structural features. Local folding occurs throughout the clastic rocks. It is best preserved on the northern flank of Rich

Mountain syncline (Plate II). These folds are not of great magnitude, but in the field, if one is not familiar with these features, they are very confusing. An example of local folding is seen in Figure 44 where the competent beds of the upper member of the Unicoi formation show an anticline plunging to the NE. Another example may be seen at the head-waters of Clark Creek about two miles SW from the junction of Chigger Branch and Clark Creek.

In Madison County, North Carolina, another thrust fault separating the sediments from the basement complex is found in the deep cut of Mill Creek. The eastern extension of this fault on the southern flank of Flint Ridge is obscured by vegetation. It is presumed that more detailed work should be done on the western boundary of the area before the attitude and extension of this fault could be thoroughly understood. At present it appears that the thrust fault is very steep on the west end (the dip may be as much as 50°), but on the east end where the strike swings to the southeast it becomes more gentle.

Another minor structural feature of the area is the presence of two extensions of the southwest end of the Mountain City Window. These areas were included in the map prepared by Lowry (1948, unpublished Ph.D. thesis) on the east of the Flag Pond Quadrangle. After careful study of the area the present writer was unable to find evidence for two cross faults indicated on Lowry's map. Furthermore, the contact between the granite and the clastic outcrops does not appear to be as outlined by her. This is noted in Plate II. These areas are considerably smaller than those mapped by Lowry. Her identification of the Sandsuck and

Unicoi formations are in accord with the present findings, but no Snowbird formation was found. In the Flag Pond Quadrangle, as was indicated by her, these two clastic bodies are enclosed by mylonite zones and in some places the contact is hard to distinguish because of vegetation.

Cleavage. Both flow and fracture cleavage were seen in the clastic rocks. Flow cleavage was largely developed in the slate and shaley siltstone units of the Chilhowee group. The best exposure of flow cleavage may be seen in outcrops of brown to chocolate slate of the upper Unicoi formation at the junction of Rocky Fork and Fort Davie Creek. Generally the strike of flow cleavage is north 48° east. This strike was found also in the outcrops of the silty sandstone units of both the Hampton and the Erwin formations along Clark and Cassi Creeks.

Fracture cleavage was developed mainly in the quartzite and feldspathic sandstone units of the Ocoee series and the Chilhowee group. The strike of the cleavage planes varies irregularly from north 10° east or west to north 80° east or west. The best exposures of fracture cleavage planes were found in the quartzite units of the lower Snowbird and Erwin formations, along the gorge of Rocky Fork and Cassi Creek. Flow cleavage was more useful in determining the top and bottom of the beds than was fracture cleavage, simply because of higher degree of development.

Primary structural features. Certain structural features such as graded bedding and cross-bedding within individual sedimentary layers or within a sequence of such layers was found useful and reliable as criteria for identification of top and bottom of formation. These features will be discussed in the following section.

Graded bedding. Graded bedding is one of the important primary features of the stratified rocks. In the field it was of great help in determining the top and bottom of the formation in places where the strata was overturned or where exposures were not continuous. Graded bedding occurs in the feldspathic sandstone, sandy siltstone and sandy shale members of the clastic sediments of both the Ocoee series and Chilhowee group.

Graded bedding offers a key to the manner of deposition and the history of the sediments. During the formation of the sedimentary rocks the materials comprising the graded bedding were transported when the depositing currents were swifter than usual. As the velocity subsided, smaller and smaller particles were deposited. The result is the graded bedding as seen today. Since there are many occurrences of graded bedding, one presumes that the sedimentation was sometimes rather irregular.

The best exposures of graded bedding can be seen on the outcrops of clastic rocks in North Higgins Creek, Tennessee Mill Creek, Painter Creek, and along a jeep road parallel to Fort Davie Creek.

Scour and filling. Another primary feature of the clastic rocks in this area is scour and filling. This has been seen in the sandy siltstone and sandy shale units of the Chilhowee group. The lack of lamination, the presence of coarse-grained sand, and in places, small pebbles at the bottom of the trough of these features distinguish scour and filling from cross-bedding. Their distortional features make the use of scour and fill rather difficult for top and bottom determination.

The main value of scour and filling is that these features indicate erosional action which took place during and shortly after the deposition of sediments.

The best examples of scour and filling are to be seen in the sandy shale and sandy siltstone of the Hampton and Erwin formations along Clark Creek, Painter Creek, and the middle fork of Cassi Creek.

History of the stratified rocks. The question of the history of the clastic rocks and their boundary in relation to the basement complex is a controversial one. In some places the Chilhowee group or its equivalent has been seen in the Appalachian region to be deposited unconformably on the basement complex. In other places the Chilhowee group is separated from the basement complex by several thousand feet of clastic sediments of the Ocoee series and by volcanic rocks.

In most cases in the Flag Pond Quadrangle a fault is recognized separating the two distinct groups: the clastics and basement complex. In one place, however, a paraconformity is recognized which indicates that the unconformity between the clastics and basement complex existed.

The sediments of the Ocoee series are differentiated from those of the Chilhowee group by the absence of volcanic flows (amygdaloidal basalts), coarse-grained units, and ferruginous sandstones.

No angular unconformity between the Chilhowee group and Ocoee series has been found in the Flag Pond Quadrangle. It is presumed that sediments of Chilhowee group were deposited unconformably over the Ocoee series. This unconformity, which is represented throughout the area by a conglomerate that is 25-50 feet thick, has been seen on both sides of the Rich Mountain syncline.

The presence of extrusive volcanics in the Chilhowee group indicates a renewal of volcanism at the beginning of the Paleozoic era, although the volume of volcanics is far less than that of Precambrian time.

Apparently sedimentation began in a small shallow trough at the beginning, but with continued deposition the trough was deepened. Sedimentation may have been interrupted locally by volcanic activity. The edges of the trough were probably elevated above sea level when thick conglomerate beds of the lower Unicoi were deposited.

During deposition of the Erwin formation it seems that chemical weathering had prevailed at the source area, when ferruginous sandstones were supplied to the sea. However, this kind of weathering was lacking in early Chilhowee and Ocoee time. Evidence in the basement rocks indicates that the sediments within the Flag Pond area were thrusted from a southeast direction.

Magnitude of horizontal displacement. Billings (1954, p. 192) states that

> Although the net slip along the overthrust in the vicinity of Buffalo Mountain, Tennessee, is approximately 6 miles, the minimum breadth is 12 miles, and this has been erroneously stated by Keith (Roan Mountain folio) to be the net slip.

King (1954, p. 433, unpublished manuscript) states that

> This conclusion appears to be based on inspection of Keith's maps, and an assumption as to matching of beds above and below the thrust. Differences in facies between equivalent formations above and below this thrust and others in the region demonstrates that any such assumptions are unwarranted.

Since in the Flag Pond area there are no key beds of any of the sediments involved in thrusting that could be matched to measure the maximum horizontal displacement, a minimum distance must be given. This minimum distance as measured from cross section BB' (Plate III) is approximately 3,200 feet. A possible maximum distance might be on the order of four times this amount.

Evidence of post fault folding. There seems to be evidence to indicate that in the basement complex folding occurred before the late Paleozoic overthrust sheets were formed. Isoclinal folding and cataclastic foliation of the Precambrian basement complex appear to be cut by late deformations as shown in Figure 53.

In the clastic rocks it is reasonable to suppose that perhaps convection currents in the geosynclinal area initiated subsidence. The weight of thousands of feet of sediments in a narrow through, after counter-balancing the effect of the crust, contributed to subsidence and folding. The gentle warping of the rocks of the Buffalo Mountain sheet in the Flag Pond area and the general parallelism of their strata to the Buffalo Mountain Fault suggest that, prior to thrusting, the rocks had undergone a little deformation. The break in the Flag Pond area lies near the base of the Ocoee series or in the Precambrian rocks just beneath it.

As can be seen in cross section BB' (Plate III) the fault follows single horizons in the overriding block, such as the shaley siltstone unit of the upper member of the Snowbird formation and the shale units of the Hampton and upper Unicoi formations. These horizons are relatively incompetent parts of the sedimentary sequence. The thrust sheets had moved forward over a relatively simple folded area. The rocks above the steeply ascending parts of the break became warped into local foldings as shown in Figure 44. The folding of the rocks did not cease with the initiation of faulting, but continued concomitantly. The individual planes were further folded and warped with the particular formations involved above and below the fault (i.e., the Snowbird formation above and the Hampton formation below the Buffalo Mountain Fault).

CHAPTER V

MINERAL RESOURCES

Introduction

At present there are no active mines in the Flag Pond area. However, barite and crushed stone have been produced in limited quantities. Radioactive minerals, iron minerals, and graphite have been prospected for, but no production has resulted.

Barite

Barite has been produced from two localities. One mine, on the property of K. E. Chandler, is reached by a secondary road parallel to Big Branch. The mine is 1,500 feet up the first trail leading from the road (Plate II). The exact location according to the Tennessee Coordinate System is 622,550 north, 3,021,825 east. The deposit was known as early as 1924, and since then ten railroad car loads have been shipped to market. Figure 54 illustrates the present state of the mine. At present the mineral rights are leased to Mr. Joe Solemn, Wilksboro, Pennsylvania.

The other barite mine, on the E. O. Higgins property, is about a mile west of Chandler's property and separated from it by a low hill. It is easily reached by a road parallel to Rocky Fork about three-fourths of a mile north of the junction of Rocky Fork Road with Tennessee Highway 81 (Plate II). The best access to the mine is by a trail through the Higgins family cemetery. In accord with the Tennessee

Figure 54. Barite mine, Chandler's property. Shaft in foreground is on vein which trends from left to right.

Coordinate System, the exact location is 622,300 north, 3,018,500 east. This mine was opened in 1938, and since then ten tons have been shipped. It is leased until 1962 for fifty dollars a year.

In both localities the barite is found within the Unakite granite group belt and very close to the contact with the clastic rocks. At the Higgins mine the vein could be seen in open pits that vary from one to two feet in width. The vein is concordant with a weathered pegmatite in the Unakite granite group. In Chandler's mine the vein could not be seen, since the shaft was full of water. However, the surface features indicate that this deposit too must be considered as a vein. The direction of the vein at the Chandler mine projects along strike toward the Higgins mine. Since they are both vein deposits with identical strikes it seems reasonable to assume that both mines are simply surface exposures of the same vein.

The associated minerals in the barite veins in the Higgins mine are magnetite, chalcopyrite, sericite and quartz. The barite is white to white gray and of two varieties; one is a crystalline variety which breaks along cleavage; the other is a saccharoidal type.

For the following reasons it is believed that the barite is formed by hydrothermal solutions.

1. Sericite is present in the granite wall rock.
2. Chalcopyrite and magnetite are associated with barite vein.
3. Quartz crystals and masses are present in the veins.

Radioactive Deposits

A great deal of prospecting for radioactive deposits was done in the area in 1954 and 1955. This work was largely by local residents who were looking for uranium. As a result of the prospectors' intensive combing of the ridges, roads and streams, numerous radioactive anomalies were turned up. None of the prospects have been developed to date, and in view of the low grades and tonnages of the deposits it is unlikely that there will be renewed interest in the future.

The radioactive anomalies of interest are confined to the rocks of the basement complex. However, some of the clastic rocks give readings of slightly above normal background. These slight anomalies are believed due largely to radioactive heavy minerals.

The anomalies in the basement rocks are associated with granitic pegmatite. These pegmatites are distinctive. They are conspicuous because of the abundance of pink feldspar (perthite). Quartz, clear to milky, is also common. Mafic minerals, chlorite and biotite are relatively minor constituents. In size the radioactive pegmatites are small, most being a foot or so thick and usually less than 10 feet in length. The dikes are both concordant and discordant; some are offset by faulting. A few have crude zonation with quartz cores.

From an economic viewpoint these pegmatites are of no particular interest, the uranium values being generally less than 0.1 per cent (chemical analysis). Consequently, detailed minerologic studies have not been made of the dikes. It is believed that much of the radioactivity is from resistant thorium-bearing minerals, since the severely weathered portions of the dikes are as radioactive as the fresh portion. Although thorium is present (based on chemical analysis) the mineral containing it has not been identified (G. D. Swingle, personal communication).

Most of the radioactive pegmatites observed occur in the Unakite granite group. There appears to be a genetic relationship between the granite and the dikes in that the distinctive pink perthite crystals of the dikes are common to the granite.

It is doubtful if these pegmatites have any economic potential as uranium or thorium source rocks, because of this limited size, grade, and anticipated refractory nature of the uranium and thorium-bearing minerals.

The radioactive pegmatites are so numerous that two representative prospects are shown on Plate II. One is on Hogskin Branch, 1,000 feet from Roseville School, or according to the Tennessee Coordinate System 606,350 north, 3,013,150 east. The other is 1,000 feet east of Big Branch Church on the property of Thomas Loyde. The exact location according to Tennessee Coordinate System is 624,500 north, 3,020,620 east.

Miscellaneous

There are three abandoned crushed stone quarries in the Flag Pond Quadrangle. One is located on Highway 23, one half mile south of the junction of Tennessee Highways 81 and 23. The second is three-fourths of a mile south of the first location on Murray Branch Road. The third is 2,000 feet northeast of Rocky Fork School on Tennessee Highway 81. Respectively, according to Tennessee Coordinate System, the locations are: (623,050 north, 3,033,050 east), (627,300 north, 3,033,700 east), and (618,350 north, 3,020,700 east). All the quarries operated in the early 1930's as a source of crushed rock for highway construction in the area. However, when limestone became more popular for this purpose these quarries were abandoned. The type of rock in every quarry examined in the area is that of epidote granite and chlorite granite of the Unakite granite group. The quarries are rather small being only 20 to 40 feet in diameter.

A graphite prospect is located 1,000 feet southwest of Coffee Ridge School on a road cut parallel to Slip Creek. The exact location according to the Tennessee Coordinate System is 611,310 north, 3,031,050 east. The graphite occurs as scales and fibers in the granite gneiss of Flag Pond granite group. The scales measure from one to three millimeter in width and up to five millimeters long. The graphite fibers and scales occur as scattered throughout the rock and as accumulations usually mixed with chlorite and other mafic minerals. The origin of graphite is less easy to explain, since there is no indication of limestone near the graphite exposures. It is possible, however, that graphite was formed by the process of reduction in the surrounding rocks.

Three hematitic sandstone layers were found in the Erwin formation mapped in the area. The thickness of the layers varies from 20 to 40 feet, and can be traced for some distance along the strike. Three locations according to the Tennessee Coordinate System are given: 643,900 north, 2,999,400 east; 639,150 north, 3,000,000 east; and

641,100 north, 3,009,950 east. A specimen assayed by the American Zinc Company in Mascot, Tennessee, shows:

Fe_2O_3	29.40 per cent
SiO_2	63.10 per cent
P_2O_3	1.20 per cent

No iron mining has been done in the area; this perhaps is due to inaccessibility and low grade of the iron in the Erwin formation.

Another prospect, which was active during the summer of 1956, is located according to the Tennessee Coordinate System 604,800 north, 2,999,450 east. It is a large shaft 80 feet deep, 10 feet wide. The operator of this excavation believed it was an old silver mine and was reopening it. On several visits to the site the author was unable to find anything but weathered coarse-grained granite of the Flag Pond granite group. The following summer excavations ceased and no other activity was noted.

CHAPTER VI

CONCLUSIONS

After reviewing the information obtained by detailed surface mapping of the Flag Pond Quadrangle and by petrographic analysis of thin sections from representative areas, the writer reached the following conclusions.

1. The rocks of the two-thirds of the Flag Pond Quadrangle which previously had been labeled as Unicoi formation and undivided Ocoee series by Rodgers (1953, Plate 4) should be subdivided into five formations. The suggested classification is in general agreement with that of other workers in the Northeast Tennessee area. The Hampton formation, not previously reported as being present in the Flag Pond area, was found to be present and is included as one of the five formations (Snowbird, Sandsuck, Unicoi, Hampton, and Erwin).

2. Keith (1905, p. 3) and Rodgers (1953, p. 24) have described the boundary between the crystalline complex and the overlying sedimentary rocks as unconformable. Field evidence from the present study shows it to be faulted in most places in the Flag Pond area. In the Rocky Fork area, however, a paraconformity was identified. This zone probably was extensive but has been obliterated by faulting.

3. Since no fossiliferous zone was identified in the Chilhowee group, the base of the Cambrian in the Flag Pond area was placed at the lithologic change between the Unicoi formation and the Sandsuck formation. This contact is usually marked by a zone of conglomerate

that ranges in thickness from 20 to 50 feet.

4. King (1949, p. 634) characterizes the Ocoee series as containing medium- to coarse-grained graywacke with graded-bedding, conglomerate, slate, siltstone, shales, and lenses of limestone. In his 1958 paper, however, he does not include graywacke and limestone units in the Ocoee series. This reclassification by King is similar to that suggested by this author.

5. The basement complex underwent at least two prominent periods of orogeny. The first period is indicated by the presence of isoclinal folds in the Flag Pond granite group probably caused by a low grade regional metamorphism. This was followed by a second regional metamorphism or metasomatism of pre-existing rocks or by assimilation of aluminous sediments. These processes are indicated by the heterogeneity of the units, gradational boundaries between the units, the presence of epidote, vertical and lateral variation within the units, myrmekitic intergrowths, replacement perthite, unzoned feldspar, aluminous hornblende, and other petrographic features.

The second orogeny is characterized by the formation of mylonite and sheared zones. During this orogeny the Buffalo Mountain thrust sheet was probably thrusted toward the northwest into the Flag Pond area.

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UNITED STATES
TENNESSEE VALLEY AUTHORITY
MAPS AND SURVEYS DIVISION

TENNESSEE-NORTH CAROLINA
FLAG POND QUADRANGLE
190-SE

Control by USC&GS, USGS, and TVA.
Topography by Fairchild Aerial Surveys, Inc., by stereophotogrammetric process.
Field examination by Tennessee Valley Authority - 1939
Office inspection and review by the Geological Survey

Maps distributed by the Geological Survey

APPROXIMATE MEAN DECLINATION, 1939

Scale 1/24000

Contour interval 40 feet with 20 foot contours shown by broken line
Datum is mean sea level

x— Location of Samples

Polyconic projection. 1927 North American datum
10,000 foot grid based on Tennessee and North Carolina rectangular coordinate systems

ROUTES USUALLY TRAVELED
HARD IMPERVIOUS SURFACES
OTHER SURFACE IMPROVEMENTS
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GEOLOGIC MAP OF THE FLAG POND QUADRANGLE TENNESSEE–NORTH CAROLINA

Plate II

TENNESSEE–NORTH CAROLINA
FLAG POND QUADRANGLE

EXPLANATION

LOWER CAMBRIAN

Ce — Erwin formation

Ch — Hampton formation

Cuu, Cul — Unicoi formation; Cuu – upper member; Cul – lower member

PCss — Sandsuck formation

PRECAMBRIAN

PCsbu, PCsbl — Snowbird formation; PCsbu – upper member; PCsbl – lower member

Basic dikes

PCug — Unakite granite group

PCfpg — Flag pond granite group

Strike and dip of bed

Generalized strike and dip of beds

Strike and dip of overturned beds

Strike and dip of cleavage

Syncline; showing trace of axial plane, bearing, plunge of axis and dip of limbs

Anticline; showing trace of axial plane, bearing, plunge of axis and dip of limbs

Contact, dashed where approximately located

Indefinite and gradational contact

Thrust faults; dashed where approximately located. T, on upper plate

Probable fault

Transverse, gravity fault; arrows indicate direction of oblique slip movement, (U, upthrown side; D, downthrown side)

Mylonite zone or shear zone showing approximate dip

Probable mylonite or shear zone

Jeep trail

Foot trail and logging road

Barite mine

Crushedstone quarry

Radioactive prospect

Graphite prospect

Iron prospect

Control by USC&GS, USGS, and TVA
Topography by Fairchild Aerial Surveys, Inc.

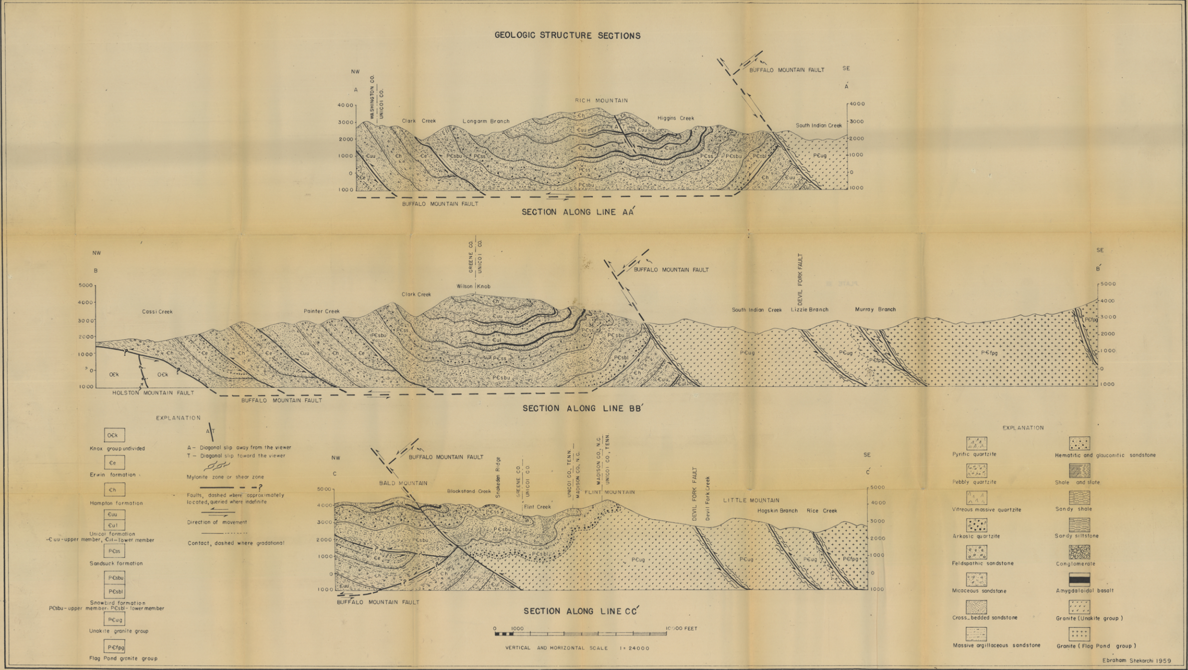
Scale 1:24000

Contour interval 40 feet with 20 foot contours shown by broken line
Datum is mean sea level

APPROXIMATE MEAN DECLINATION, 1959

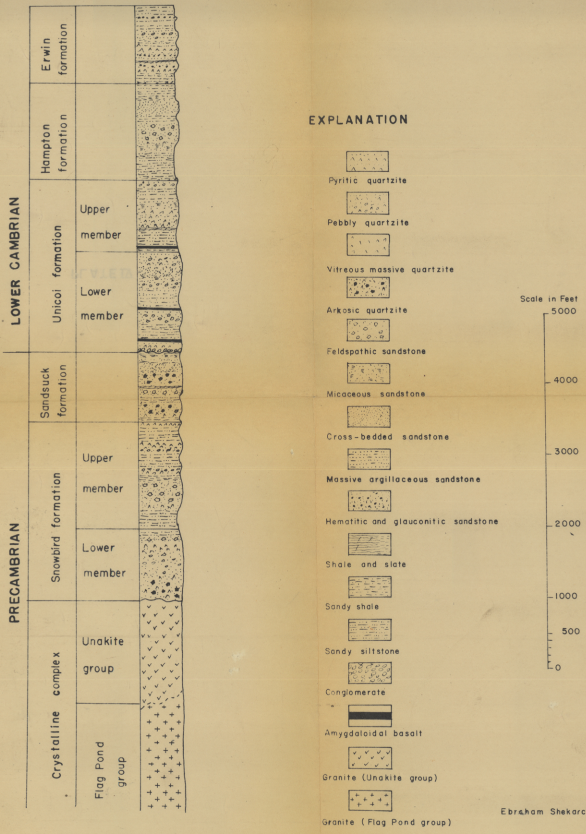
Geology by Ebraham Shekarchi 1959

Plate III


GEOLOGIC STRUCTURE SECTIONS
NW
A
WASHINGTON CO.
UNICOI CO.
Clark Creek
Longarm Branch
RICH MOUNTAIN
Higgins Creek
BUFFALO MOUNTAIN FAULT
SE
A′
South Indian Creek
BUFFALO MOUNTAIN FAULT
SECTION ALONG LINE AA′
NW
B
GREENE CO.
UNICOI CO.
Wilson Knob
Clark Creek
Cassi Creek
Painter Creek
BUFFALO MOUNTAIN FAULT
DEVIL FORK FAULT
South Indian Creek
Lizzie Branch
Murray Branch
SE
B′
HOLSTON MOUNTAIN FAULT
BUFFALO MOUNTAIN FAULT
SECTION ALONG LINE BB′
EXPLANATION
O€k
Knox group undivided
€e
Erwin formation
€h
Hampton formation
€uu
€ul
Unicoi formation
-€uu-upper member, €ul-lower member
P€ss
Sandsuck formation
P€sbu
P€sbl
Snowbird formation
P€sbu-upper member, P€sbl-lower member
P€ug
Unakite granite group
P€fpg
Flag Pond granite group
A– Diagonal slip away from the viewer
T – Diagonal slip toward the viewer
Mylonite zone or shear zone
Faults, dashed where approximately located, queried where indefinite
Direction of movement
Contact, dashed where gradational
NW
C
BUFFALO MOUNTAIN FAULT
BALD MOUNTAIN
Blockstand Creek
Snakeden Ridge
GREENE CO.
UNICOI CO.
Flint Creek
UNICOI CO., TENN.
MADISON CO., N.C.
MADISON CO., N.C.
UNICOI CO., TENN.
FLINT MOUNTAIN
DEVIL FORK FAULT
Devil Fork Creek
LITTLE MOUNTAIN
Hogskin Branch
Rice Creek
SE
C′
BUFFALO MOUNTAIN FAULT
SECTION ALONG LINE CC′
0 1000 10000 FEET
VERTICAL AND HORIZONTAL SCALE 1:24000
EXPLANATION
Pyritic quartzite
Pebbly quartzite
Vitreous massive quartzite
Arkosic quartzite
Feldspathic sandstone
Micaceous sandstone
Cross-bedded sandstone
Massive argillaceous sandstone
Hematitic and glauconitic sandstone
Shale and slate
Sandy shale
Sandy siltstone
Conglomerate
Amygdaloidal basalt
Granite (Unakite group)
Granite (Flag Pond group)
Ebraham Shekarchi 1959

COMPOSITE STRATIGRAPHIC SECTION

Plate IV



Ebraham Shekarchi, 1959