The Volcanogenic Mount Rogers Formation and the Overlying Glaciogenic Konnarock Formation—Two Late Proterozoic Units in Southwestern Virginia

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The Volcanogenic Mount Rogers Formation and the Overlying Glaciogenic Konnarock Formation—Two Late Proterozoic Units in Southwestern Virginia

By DOUGLAS W. RANKIN

The Mount Rogers Formation, largely continental rift-facies volcanic rocks, is redefined, and the name Konnarock Formation is introduced for the overlying glaciogenic deposits of diamictite, arkose, and laminite. Four rhyolite members of the Mount Rogers are named and described

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CONVERSION FACTORS

Measurements in this report are given in metric units except that elevations are given in feet for ease in referring to U.S. Geological Survey topographic maps of the 7.5-minute quadrangles. Conversion factors are provided below.

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
millimeter (mm)	.03937	inch (in.)
centimeter (cm)	.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	.6214	mile (mi)
cubic kilometer (km^3)	.2399	cubic mile (mi^3)

The Volcanogenic Mount Rogers Formation and the Overlying Glaciogenic Konnarock Formation—Two Late Proterozoic Units in Southwestern Virginia

By Douglas W. Rankin

Abstract

In the Mt. Rogers area of southwestern Virginia and adjacent North Carolina and Tennessee, the billion-year-old Grenvillian basement of the Blue Ridge anticlinorium is nonconformably overlain on the northwest limb by a stratified cover sequence that is disconformably overlain by the Lower Cambrian Unicoi Formation. This cover sequence is here divided into two formations. The older, dominantly volcanic unit is called the Mount Rogers Formation (revised name). The younger, which overlies the Mount Rogers, is the glaciogenic Konnarock Formation (new name).

The volcanic rocks of the Mount Rogers Formation are a bimodal suite of basalt and rhyolite in which the younger rhyolites have peralkaline affinity. The rhyolites are concentrated in thick masses thought to have been volcanic centers. The erosion of the volcanic edifices of older centers, which may or may not be partially preserved in the area, produced extensive volcanic conglomerates that make up much of the lower part of the Mount Rogers Formation in the type area. The Fees Rhyolite Member (new name), near the base of the Mount Rogers Formation, was probably erupted from one of these earlier centers, and clasts of the Fees are recognizable in the conglomerates. Rhyolites of the Mt. Rogers volcanic center constitute the upper part of the Mount Rogers Formation in the type area. These include the Buzzard Rock Member (new name) which is lava, the Whitetop Rhyolite Member (new name), also largely lava, and the climactic, zoned, welded ash-flow sheet of the Wilburn Rhyolite Member (new name). The rhyolites of the Mt. Rogers volcanic center erupted about 760 Ma and are thought to be related to an early aborted episode of Iapetan continental rifting.

The Konnarock Formation consists of maroon massive diamictite (tillite), bedded diamictite, varvelike rhythmite that contains dropstones in places, and pink arkose. The Konnarock is mostly structurally isolated from the Mount Rogers Formation but in three areas is seen to be stratigraphically above it. In one of these areas, the contact appears to be unconformable; in the second, concordant; and, in the third, the nature of the contact is indeterminate but is probably concordant. The deformation that caused the unconformity could be synvolcanic or postvolcanic block faulting, which is common in volcanic terranes.

Manuscript approved for publication April 3, 1992.

INTRODUCTION

The rocks described in this report are exposed in the Mt. Rogers area in southwestern Virginia and adjacent North Carolina and Tennessee (fig. 1). The Mount Rogers Formation, as used by Rankin (1970) for rocks in this area, consists of interlayered and interfingering bimodal volcanic and clastic sedimentary rocks, all metamorphosed under low to moderate greenschist-facies conditions. The prefix "meta" is omitted in the following discussion but should be assumed for these rocks. The strata nonconformably overlie Middle Proterozoic Laurentian basement, are overlain with apparent conformity by the basal Cambrian clastic sequence of the Chilhowee Group, and are interpreted to be of Late Proterozoic age. The strata crop out in three major thrust sheets and two or more areally restricted slices. Rankin (1967, 1970) noted that these strata could be roughly divided into three parts: the lower part is interbedded clastic sedimentary rock, greenstone, and rhyolite; the middle is dominantly rhyolite; and the upper part is sedimentary and includes extensive glaciogenic deposits. The lower two parts form continuous sequences in more than one thrust sheet but are generally separated by thrust faults from the upper part, which is stratigraphically beneath the Chilhowee Group. Those relations were not understood in 1970.

The purpose of this paper is to redefine the Mount Rogers Formation to exclude the upper sedimentary part, to introduce the name Konnarock Formation for that upper sedimentary part, to briefly delineate the stratigraphic and structural setting of the Konnarock and redefined Mount Rogers Formations, and to introduce several names for volcanic members of the Mount Rogers.

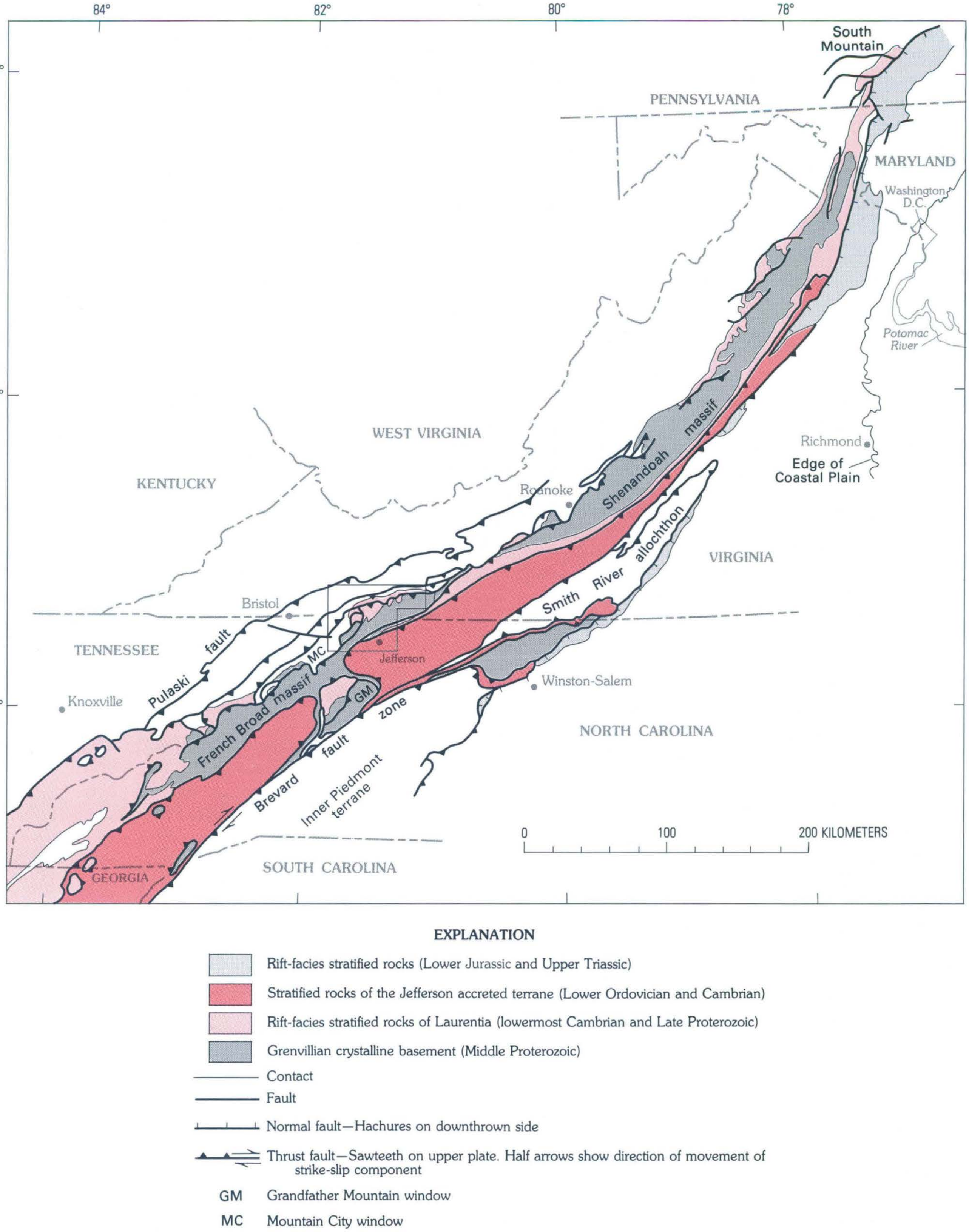


Figure 1. Generalized geology of parts of the central and southern Appalachian orogen. Box outlines Mt. Rogers area shown in figure 2. Significant geographic features are labeled.

Acknowledgments

Over a period of many years, I have discussed the geology of the Mt. Rogers area with many colleagues, most of whom have visited the field area with me. Those with whom discussions have been particularly helpful include R.L. Smith, J.M.G. Miller, J.C. Crowell, and the late D.W. Elliott, D.R. Wones, and M.D. Crittenden, Jr. For most field seasons in the Mt. Rogers area, I was assisted on an almost daily basis by my wife Mary Louise. Her help is gratefully acknowledged. The manuscript was improved by reviews by W.C. Burton and P.T. Lyttle.

PREVIOUS WORK

Interbedded volcanic and sedimentary rocks in southwestern Virginia were named the Mount Rogers series by Stose and Stose (1944) after exposures on Mt. Rogers, the highest mountain in Virginia.[1] The name was modified to Mount Rogers Volcanic Group by Rodgers (1953), and that usage was followed by King and Ferguson (1960). Because the unit is relatively restricted geographically to parts of ten 7.5-minute quadrangles (see fig. 2 for locations of the seven most important quadrangles) and because rock types intertongue locally and are repeated throughout the unit, Rankin (1970) reduced the name to formation status as the Mount Rogers Formation. Although volcanogenic deposits constitute more than 50 percent of the unit, the modifier "volcanic" was dropped because of a large component of nonvolcanic strata in the unit.

Most early reports on the geology of the Mt. Rogers area make no mention of volcanic rocks, probably because ancient volcanic rocks were generally not recognized by early American geologists (see Williams, 1894). As recently as 1916, the geologic map of Virginia included rocks of the Mount Rogers Formation in "crystalline schists and gneisses, chiefly micaceous, intruded with granite and basic igneous materials" (Watson, 1916). As early as 1869, however, Safford recognized a sequence of rocks in northeastern Tennessee (now including the Mount Rogers) that were intermediate in stratigraphic position and degree of metamorphism between the crystalline basement and the Chilhowee Group. In fact, Safford (1869) even suggested "referring them to" (including these rocks in) his Ocoee Group. The observation of intermediate degree of metamorphism between the Chilhowee and basement is generally correct and is because the Chilhowee Group generally crops out northwest of the Mount Rogers and the grade of Paleozoic metamorphism increases to the southeast.

About 60 km south of Mr. Rogers, Keith (1903) mapped metamorphosed basalt and rhyolite in what is now called the Grandfather Mountain Formation (Bryant and Reed, 1970). He also delineated a belt of "metarhyolite" at the northern border of the Cranberry 30-minute quadrangle about 4 km east of Payne Gap (fig. 2). He interpreted this body of metarhyolite to be thin sheets and dikes intrusive into his Cranberry Granite (later modified as Cranberry Gneiss). That body of metarhyolite is here interpreted to be part of the stratified sequence of the Mount Rogers Formation above a thrust fault. Hence, Keith should be credited with the first recognition of a volcanic or hypabyssal component of the Mount Rogers.

The first major study of the Mount Rogers Formation was by A.J. and G.W. Stose for the Virginia Geological Survey (Jonas and Stose, 1939). Their most extensive discussion of the unit is contained in the report on the Gossan Lead district and includes a detailed map of the eastern part of the Mount Rogers outcrop area (Stose and Stose, 1957). Stose and Stose (1957) subdivided their Mount Rogers Volcanic Group into a lower Flat Ridge Formation (with its Cinnamon Ridge Member and Cornett Basalt Member) and an upper unnamed rhyolite unit. These units were poorly defined and not useful as map units for the present study. The Flat Ridge and its members were abandoned by Rankin (1970).

In their comprehensive report on the geology of northeasternmost Tennessee, King and Ferguson (1960) included several important observations concerning the Mount Rogers Formation, but their study of the formation was largely incidental to mapping the northeast end of the Mountain City window. Carrington (1961) reported rhythmically layered sedimentary rocks (herein called the Konnarock Formation but at that time included within the upper part of the Mount Rogers Volcanic Group) that contain large, scattered, well-rounded to subrounded granitoid clasts as much as 1.25 m across. He concluded that the rhythmites were deposited in quiet water and reflected volcanic cycles, not glaciation. Rankin (1967, 1969) suggested a glacial origin for the laminated pebbly mudstones and associated muddy-matrix conglomerates (diamictites), a conclusion supported by Blondeau and Lowe (1972), Schwab (1976), and Miller (1986, 1989a).

The present study of the Mt. Rogers area began in 1962 with geologic mapping at a scale of 1:24,000. The project followed logically from the work of King and Ferguson (1960) in northeasternmost Tennessee and overlapped in time the end of the study of the Grandfather Mountain area, North Carolina, by Bryant and Reed (1970). The detailed Mt. Rogers study was suspended for several years in 1965 in favor of reconnaissance mapping of the Winston-Salem 1°×2° quadrangle, which contains the Mt. Rogers area. The regional study provided a broader per-

[1] Mt. Rogers, elevation 5,729 ft, formerly called Balsam Mountain, was named for William Barton Rogers, the first State Geologist of Virginia (1835), later founder and first president of the Massachusetts Institute of Technology (1862) and third president of the National Academy of Sciences (1879) (Roberts, 1936). Elevations in this report are given in feet for ease in referring to U.S. Geological Survey topographic maps of the 7.5-minute quadrangles.

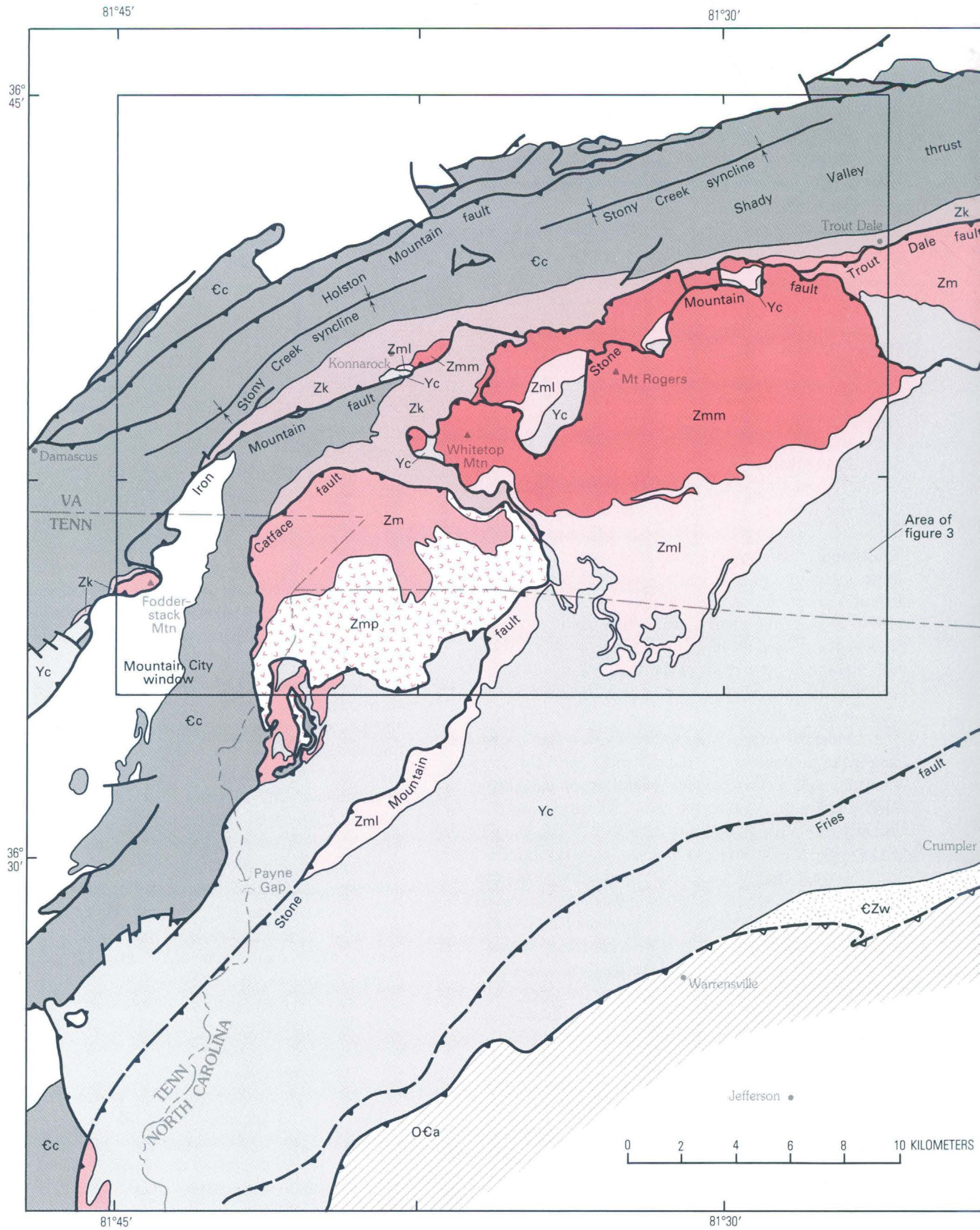
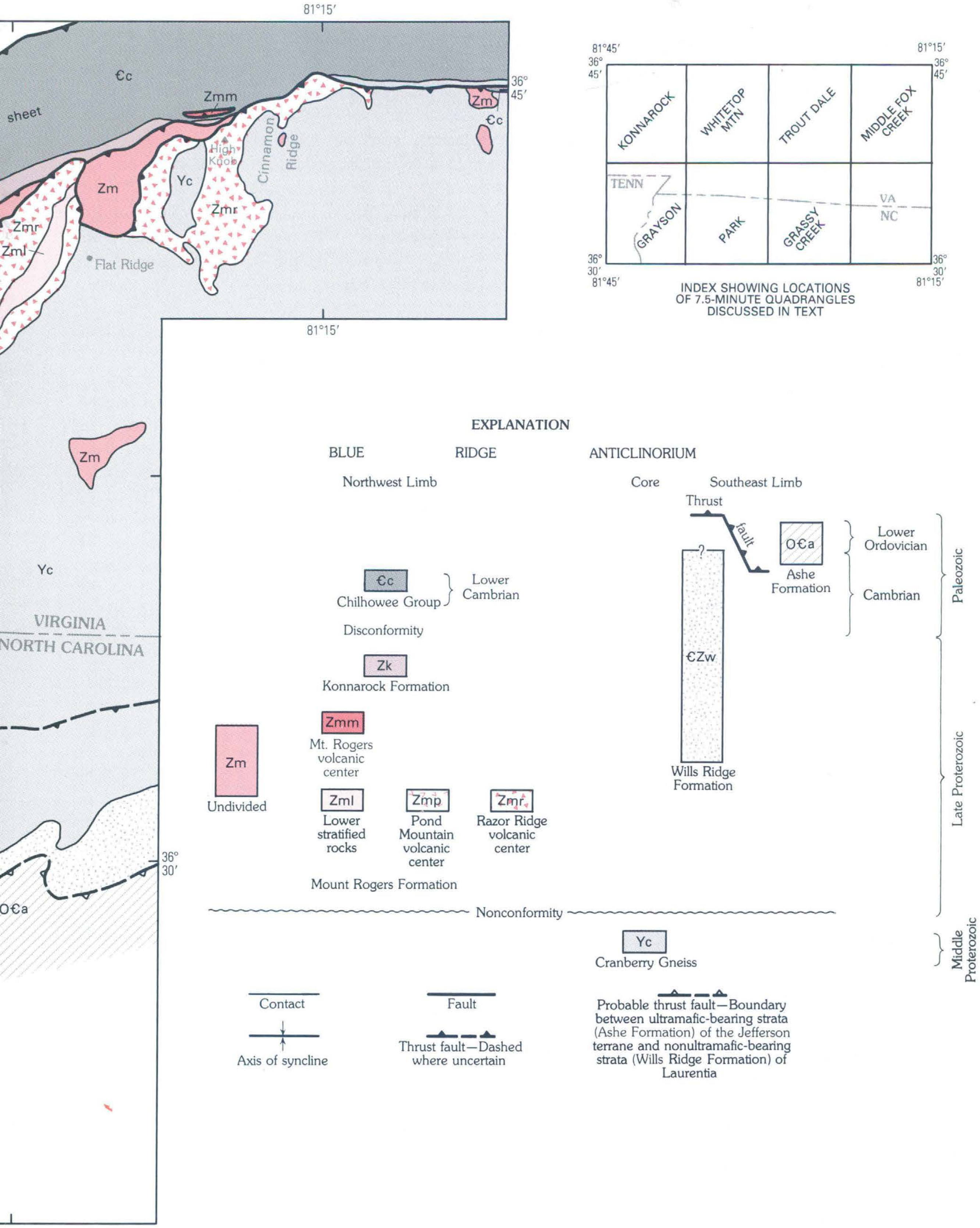


Figure 2. Geology of the Blue Ridge tectonic province in southwestern Virginia and adjacent North Carolina area mapped in figure 3.



and Tennessee. Map shows thrust faults, Late Proterozoic volcanic centers, and location of the Mt. Rogers spective in which to complete the field work in the Mt. Rogers area in 1973 and 1974 (Rankin, 1970, 1975, 1976).

Detailed maps of the Mt. Rogers area have not yet been published, but the distribution of rock types and the regional setting are shown on the west half of the Winston Salem 1°×2° quadrangle at a scale of 1:250,000 (Rankin and others, 1972). The impetus for this paper is the recent documentation of two episodes of continental rifting near the end of the Proterozoic separated by as much as 200 m.y. (Aleinikoff and others, 1991). The older of the two episodes is represented by rhyolites of the Mount Rogers Formation, which are dated at about 760 Ma. Thus, roughly 200 m.y. elapsed between eruption of the Mount Rogers rhyolites and the deposition of the siliciclastic rocks of the basal Cambrian Chilhowee Group. A reevaluation of the field data indicates that the glaciogenic deposits stratigraphically beneath the Chilhowee can be interpreted to be separated from the rhyolites by thrust faults or, in a few places, to be stratigraphically above them. Because of the long time interval between the rhyolites and the Chilhowee, the permissiveness of the field relations, and the current interest in Late Proterozoic glaciation, it seems wise to define a new stratigraphic unit for the glaciogenic deposits rather than to continue to include them as part of the Mount Rogers Formation. In order to demonstrate the need for a new formation as well as to provide stratigraphic names for map units within the redefined Mount Rogers Formation, the stratigraphy of the Mount Rogers will be discussed first after a review of the regional and structural setting of the Mt. Rogers area.

REGIONAL AND STRUCTURAL SETTING

The thrust sheets or slices that carry the Mount Rogers and Konnarock Formations are along the leading or northwestern edge of the composite Blue Ridge crystalline thrust sheet. The composite sheet experienced its last major movement (Alleghanian) in the late Paleozoic. The sole thrust, which has different local names along strike, carries Middle Proterozoic crystalline basement and its Late Proterozoic stratigraphic cover over little-metamorphosed to nonmetamorphosed Paleozoic strata as young as Mississippian of the Valley and Ridge province. In the Mt. Rogers area, the sole thrust is traditionally thought to be the Holston Mountain-Iron Mountain fault, which is the sole thrust of the Shady Valley thrust sheet and at its leading edge carries the Lower Cambrian Chilhowee Group over rocks as young as the Middle Ordovician clastic sequence (see Rankin, Drake, and Ratcliffe, 1989). In the interpretation of Rankin and others (1991), however, the fault that carries rocks exposed in the Mountain City window (probably the Pulaski fault) also cuts into the basement (fig. 1).

The crystalline basement is mostly gneissic granite and augen gneiss included within the Cranberry Gneiss (roughly 1.2 to 1.0 Ga). These rocks are interpreted to be part of the Grenville province of Laurentia exposed in an outlier within the Appalachian orogen. The outlier, called the French Broad massif, is one of several external massifs of Grenvillian rocks exposed along the western margin of the Appalachian internides between Georgia and Newfoundland. The Mount Rogers and Konnarock Formations are the basal part of the cover sequence on the northwest flank of the French Broad massif, and the Wills Ridge Formation is interpreted to be the basal part of the cover sequence locally exposed on the southeast flank of the massif (Rankin and others, in press) (fig. 2). Hence, although the basement and cover are part of an imbricate thrust stack, the term "Blue Ridge anticlinorium" is still applicable.

The Wills Ridge Formation was recently defined by Rankin and others (in press) as a new formation free of ultramafic rocks. The rocks of the Wills Ridge were formerly included in the Ashe Formation at its structural base. The juxtaposition of the Wills Ridge and Ashe Formations is thought to be along a thrust fault. The age of the Wills Ridge Formation is poorly constrained. It is bracketed between the Middle Proterozoic formation of Grenvillian basement and the Ordovician Taconian closing of the Iapetus Ocean. Whisonant and Tso (1992) concluded from a field and petrographic study of the Wills Ridge Formation (their "lower Ashe Formation") that it was deposited in subaqueous parts of fan or braid deltas that prograded into relatively deep water on Laurentian crust. Whether the absence of ultramafic bodies in the Wills Ridge is because the depositional site was on the Laurentian margin or because the age of the deposits is predrift is not known. The Wills Ridge Formation, therefore, is here assigned a Late Proterozoic to Cambrian age. Note that on figure 2, the Ashe Formation is indicated as being Lower Ordovician and Cambrian in agreement with the interpretation of Rankin and others (in press) that the Ashe formed as an accretionary wedge during subduction of Iapetan oceanic crust. Hence the age of the Ashe Formation is bracketed between the opening of Iapetus, roughly at the beginning of the Cambrian, and the Taconian closing of Iapetus.

Figures 2 and 3 are generalized tectonic and geologic maps of the Mt. Rogers and surrounding areas that show the present interpretation of the configuration of thrust faults and their relation to the stratigraphic units under discussion. The interpretation differs in important ways from that portrayed in Rankin (1967, 1970) and Rankin and others (1972). Details of those differences will have to await publication of the detailed maps, but differences important for this report are noted briefly here.

1. The east-northeast-trending thrust on the south side of Whitetop Laurel Creek separates glaciogenic deposits on the north in the Shady Valley thrust sheet from rocks of the Chilhowee Group on Chestnut and Lost Mountain to the south and dips steeply north where exposed by

digging along Virginia Highway 859 (lat 36°38.85′N., long 81°40.05′W.) (fig. 3). It is reinterpreted to be the northeastern continuation of the Iron Mountain fault rather than the Catface fault of earlier interpretations. The reinterpretation for this particular segment of the fault is the same as that shown by King and Ferguson (1960). The reinterpretation puts this southern block of Chilhowee and the stratigraphically underlying glaciogenic deposits along Green Cove Creek (see Rankin, 1967) within the Mountain City window.

2. The Catface fault is now interpreted to go through McQueen Gap and separate the glaciogenic deposits of the Konnarock Formation to the north along Green Cove Creek from the sheared felsites and sedimentary rocks of the Mount Rogers Formation to the south. The sharp transition from little-sheared glaciogenic deposits to strongly sheared volcanogenic rocks in outcrops along the Norfolk and Western (abandoned) railroad cuts was noted by Rankin (1967). To the east in the Park quadrangle, the Catface fault swings south and is overridden by the Stone Mountain fault, which carries the main body of the French Broad massif as well as the best studied and most complete section of the Mount Rogers Formation as here redefined. The trace of the Stone Mountain fault to the south to meet the well-defined position of the Stone Mountain fault southwest of U.S. Highway 421 (23 km south of the Virginia State line) has been determined by a combination of field mapping and the trace of a conspicuous aeromagnetic gradient (the high magnetic values are in the Stone Mountain thrust sheet) (U.S. Geological Survey, unpub. data).
3. The previously unnamed thrust along the lower north slopes of Mt. Rogers that carries rhyolite of the Mount Rogers Formation over glaciogenic deposits of the Konnarock-Trout Dale valley continues eastward into the Middle Fox Creek quadrangle and carries clastic and volcanic sedimentary rocks of the Mount Rogers Formation over the eastward continuation of the glaciogenic deposits. This fault is here named the Trout Dale fault. To the west, the Trout Dale fault overrides the Iron Mountain fault east of Konnarock and is in turn overridden on the north slope of Whitetop Mountain by the Stone Mountain fault. Thus, it forms the northeast termination of the Mountain City window (here an eyelid window) and is an out-of-sequence thrust. The Stone Mountain fault must also be an out-of-sequence thrust because of relations described in point 2 as well as here.

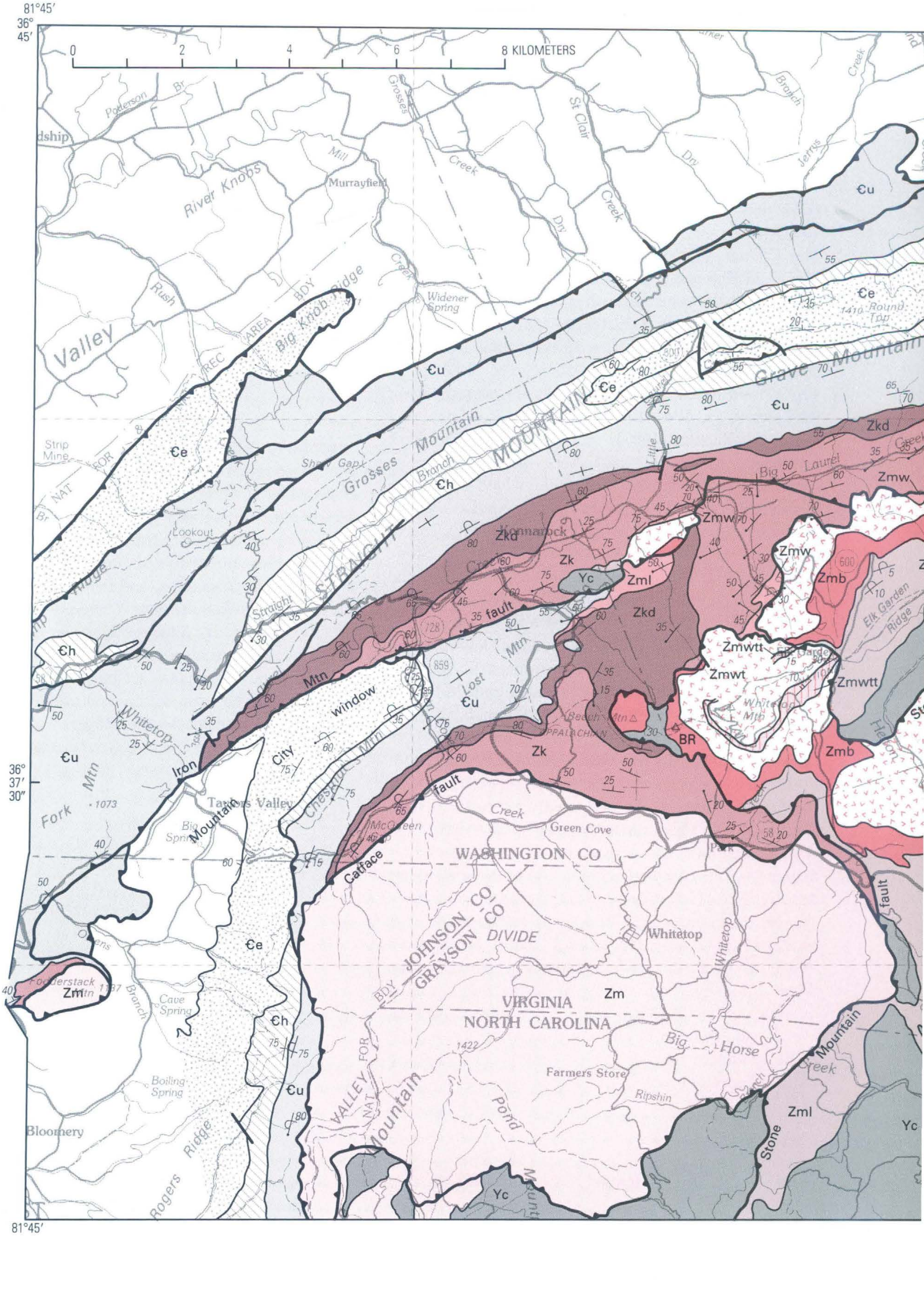
MOUNT ROGERS FORMATION (REVISED NAME)

The most studied and best understood area of the redefined Mount Rogers Formation is in the Stone Mountain thrust sheet. In that sheet, the lower two parts of the tripartite division of the formation as formerly used are exposed in continuous section (this does not imply continuous outcrop!) from the nonconformity above the Middle Proterozoic (Grenvillian) Cranberry Gneiss up to the Wilburn Rhyolite Member (named below), the youngest known rhyolite. The triangular area in the Stone Mountain thrust sheet from Whitetop Mountain to Pine Mountain in Virginia south to Nella, N.C., is designated as the type area of the Mount Rogers Formation (fig. 3). This type area includes the summit of Mt. Rogers. No stratigraphic unit younger than the Wilburn Rhyolite Member is preserved in the type area, and thus the top of the Mount Rogers is not preserved in the type area or, in fact, in the Stone Mountain thrust sheet. The glaciogenic deposits underlying the Unicoi Formation (the lowest of the three formations constituting the Chilhowee Group in the Mt. Rogers area) are nowhere preserved in the Stone Mountain thrust sheet and are herewith excluded from the Mount Rogers Formation. The Mount Rogers in the type area is on the order of 3,000 m thick, although structural complexities in the lower part of the formation make this estimate a crude one.

The lower part of the Mount Rogers Formation consists of complexly folded graywacke, phyllite, conglomerate, arkose, greenstone, and rhyolite; only a major rhyolite has been broken out here. The clastic sedimentary rocks are about twice as abundant as the volcanic rocks. Most conglomerates are clast-supported volcanic conglomerates in which most of the clasts are porphyritic felsite. These are probably derived from the erosion of a volcanic edifice or edifices that predate the Mt. Rogers volcanic center (see below). Locally, basement clasts predominate. Where the conglomerates are deformed, the felsite clasts tend to be more flattened and elongated than the granitic basement clasts, suggesting that the felsites may have been pumiceous. The greenstone is in part nonporphyritic and in part plagioclase-phyric. The latter commonly has a crudely aligned to turkey-track (fig. 4) arrangement of the plagioclase. Some greenstones are amygdaloidal. In the type area, the major felsite in the lower part of the Mount Rogers is at or near the base of the formation; it is described in the next section.

Metamorphic minerals in the matrix of the graywacke include biotite and stilpnomelane. In some of the arkose, detrital plagioclase has been replaced by epidote and quartz, and the basement-derived microcline is reddish orange. The resulting rock looks much like unakite, locally developed by similar metamorphic reactions in the underlying Cranberry Gneiss. The greenstone has typical greenschist-facies assemblages (albite-epidote-actinolite-chlorite, mostly with sphene and with or without quartz).

Deformation is locally intense. Folding is polyphase, and clasts in the conglomerates, even up to boulder size, are flattened and elongated. Where shearing is intense, it is commonly difficult to distinguish between arkose and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Zmwtt
Zmb
Big Laurel
Elk Garden Ridge
Whitetop Mtn
Beech Mtn
BR
fault
Lost Mtn
window
Iron Mountain
City
Taylors Valley
Chestnut Mtn
Catface
Green Cove
WASHINGTON CO
JOHNSON CO
GRAYSON CO
DIVIDE
Whitetop
VIRGINIA
NORTH CAROLINA
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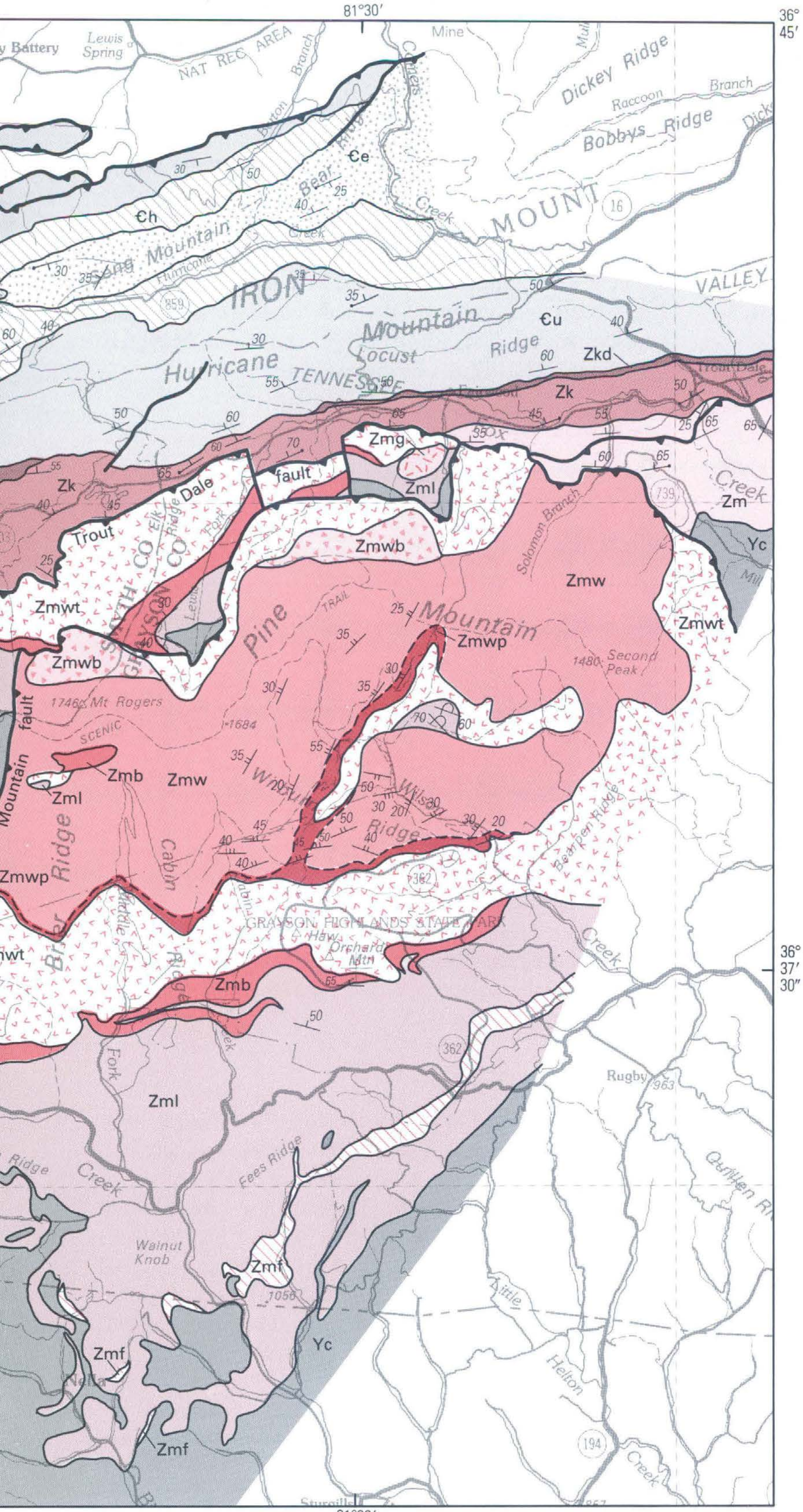


Figure 3*A*. Geology of the Mt. Rogers area. Geology mapped in 1962–74. Base modified from U.S. Geological Survey 1:100,000-scale map of the Wytheville 30′×60′ quadrangle, Virginia, North Carolina, and Tennessee, 1982. See figure 3*B* for explanation and index of 7.5-minute quadrangles.

graywacke of the Mount Rogers and granitic gneiss of the Cranberry. A microscopic aid in identifying the cover rocks and thus confirming the location of a field contact is the presence in the cover rocks of clasts of highly perthitic alkali feldspar derived from phenocrysts in the rhyolites. Enough of this volcanic perthite texture survives the shearing to be distinguishable from the basement microcline perthite.

The Mount Rogers Formation is intruded by diabase (greenstone) dikes, rhyolite dikes, and a body of granophyre. The diabase and rhyolite dikes are not shown in figure 3. The diabase dikes intrude rocks as young as the Wilburn Rhyolite Member. Several dikes crop out on Wilburn Ridge, are roughly vertical, trend northeast, and are as much as 10 m thick. They could be feeder dikes for the metabasalts in the Unicoi Formation but have not been observed to intrude either the Konnarock or Unicoi Formation. The granophyre is poorly exposed and deeply weathered near the western border of the Trout Dale quadrangle about 1 km south of Fairwood (fig. 3). The mapped area, about 0.4×0.8 km, is determined largely from float. Phenocrysts of perthite as large as 13 mm, quartz as large as 4 mm, and equant opaque minerals as large as 1 mm are set in a reddish aphanitic groundmass that in places is micrographic. Because the granophyre appears to intrude the Whitetop Rhyolite Member (named below) (fig. 3) and because it has a phenocryst assemblage similar to that in the Wilburn Rhyolite Member, it is interpreted to be the intrusive equivalent of the Wilburn.

Volcanic Centers

Rhyolite makes up 50 to 60 percent of the Mount Rogers Formation. Where analyzed, it is mostly high-silica rhyolite, but some low-silica rhyolite is present. The rhyolites are metaluminous and have high concentrations of Nb, Y, and rare earth elements and low contents of Ba and Sr. Some rhyolite is thought to have been peralkaline at the time of eruption. Mafic phenocrysts are sparse, and fluorite is a common accessory mineral. Most of the rhyolite is concentrated in three thick masses interpreted to be the sites of volcanic centers that erupted 500 to 1,000 km^3 of rhyolite. From east to west, these centers are here named Razor Ridge, Mt. Rogers, and Pond Mountain volcanic centers (fig. 2).

Rhyolites of the Mt. Rogers volcanic center constitute the upper part of the redefined Mount Rogers Formation in the Stone Mountain thrust sheet and will be discussed more fully below. Rhyolites of the Mt. Rogers center also crop out in at least two other and probably four other thrust sheets or slices. In the current interpretation, the Razor Ridge volcanic center is east of the Mt. Rogers center in the Stone Mountain thrust sheet and may crop out only in that thrust sheet. Because the rhyolite of that center is petrographically similar to the Fees Rhyolite Member, named below, in the lower part of the Mount Rogers Formation in the type area, the Razor Ridge center is probably older than the Mt. Rogers center. The Pond Mountain center is in the Catface thrust sheet southwest of and structurally below the Stone Mountain thrust sheet. Rhyolite of the Pond Mountain center has the same phenocryst assemblage as the Fees Rhyolite Member, but the phenocrysts constitute as much as 40 percent of the rock, and feldspar phenocrysts are commonly a centimeter and may be as much as 3 cm across. These coarsely porphyritic rhyolites could be hypabyssal intrusive rocks. The Razor Ridge and Pond Mountain volcanic centers will not be discussed further here.

Fees Rhyolite Member (New Name)

A prominent porphyritic rhyolite near the base of the Mount Rogers Formation in the type area is here named the Fees Rhyolite Member for exposures on the southern extension of Fees Ridge in the northeastern part of the Park quadrangle (fig. 3). The Fees is characterized by a phenocryst assemblage of quartz, perthite, and plagioclase. Plagioclase constitutes a variable, commonly small percentage of the phenocryst assemblage, but its presence with quartz phenocrysts distinguishes the Fees from the rhyolites of the overlying Mt. Rogers volcanic center. The groundmass is aphanitic and typically has a grayish-purple or maroon tinge as do most rhyolites of the Mount Rogers Formation. The rock is highly sheared. Phenocrysts typically make up 35 percent of the rock, and the feldspars are about 5 mm across. Mapping of float is interpreted to indicate that locally the Fees is in contact with the Cranberry Gneiss. Elsewhere the Fees is within the lower part of the Mount Rogers. These relations suggest that the basement topography was uneven. The Fees Rhyolite Member is on the order of 100 m thick.

Mt. Rogers Volcanic Center

The upper part of the Mount Rogers Formation in the type area in the Stone Mountain thrust sheet consists of a thick mass of extrusive rhyolites interpreted to be the site of a volcanic center called the Mt. Rogers volcanic center. The rhyolites have been mapped as three units, which are here named as members of the Mount Rogers Formation. From oldest to youngest, these are the Buzzard Rock Member (formerly unit C of Rankin, 1967, and Rankin and others, 1974), Whitetop Rhyolite Member (formerly unit B), and Wilburn Rhyolite Member (formerly unit A). The Buzzard Rock and Whitetop consist mostly of lava flows, and the upper or Wilburn Rhyolite Member is a welded ash-flow sheet.

The relatively simple structure of the rhyolites of this center contrasts with the polyphase tight folding observed toward the base of the formation. No major structural discordance was observed between the rhyolites

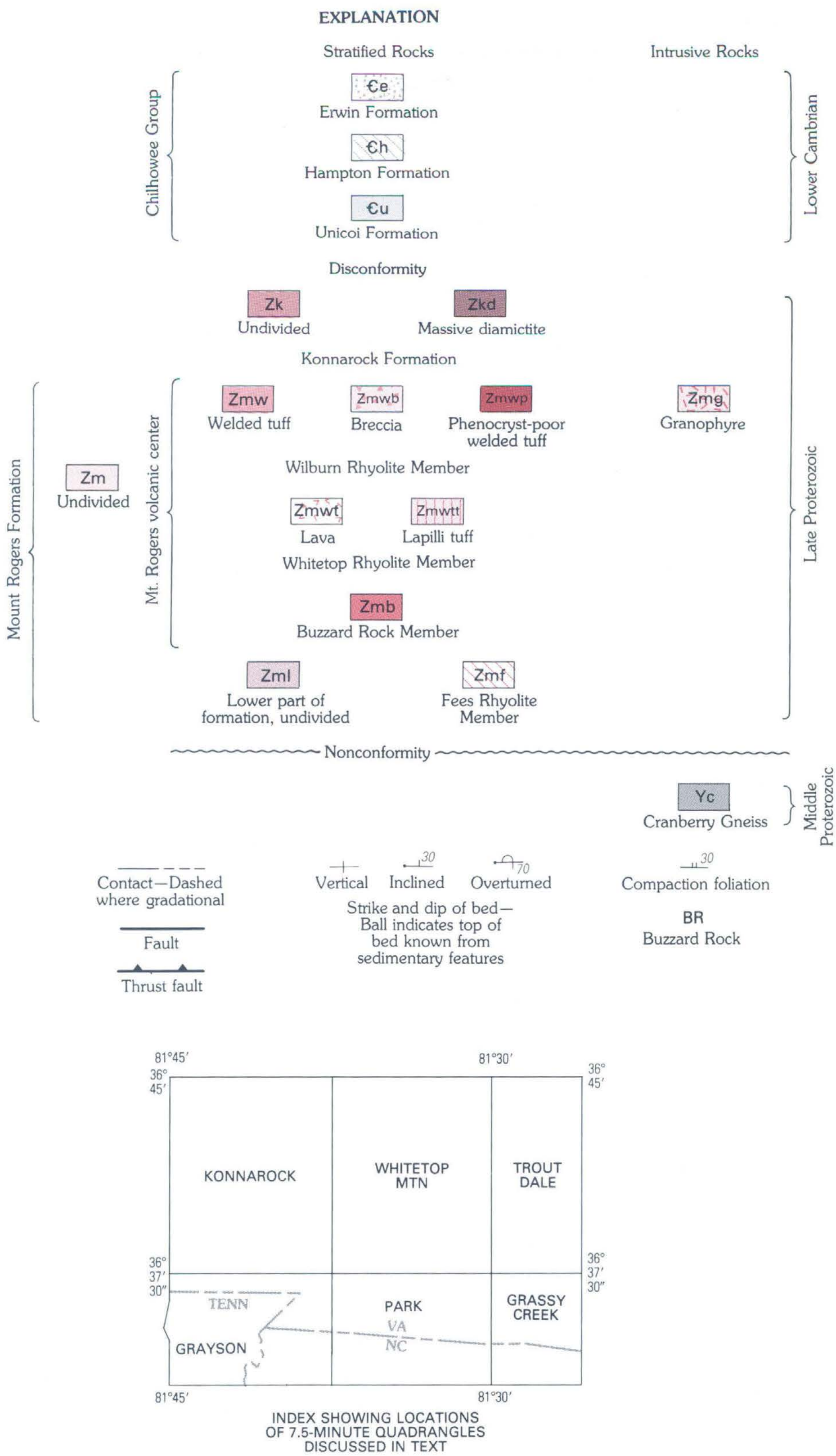


Figure 3*B*. Explanation for figure 3*A* and index of 7.5-minute quadrangles discussed in text.

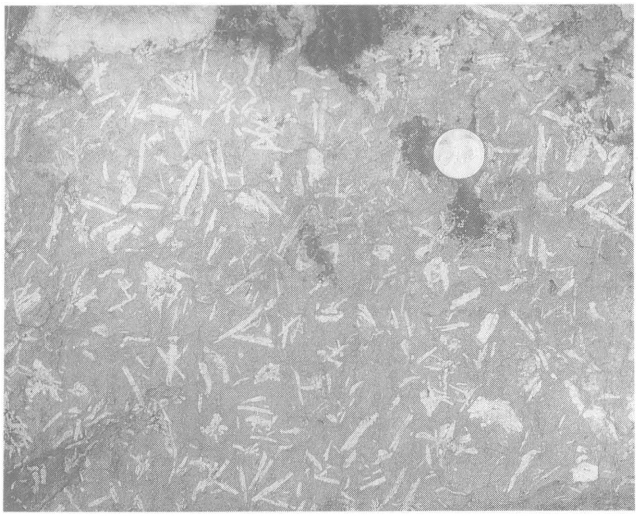


Figure 4. Greenstone with turkey-track arrangement of plagioclase phenocrysts from lower part of the Mount Rogers Formation. Float block located along Appalachian Trail on northwest side of Elk Garden Ridge about 1 km northeast of the height of land on Virginia Highway 600, Whitetop Mountain quadrangle (fig. 3). U.S. penny for scale.

and the underlying greenstone and sedimentary package. The Buzzard Rock Member is discontinuous beneath the Whitetop Rhyolite Member, but at present there is no evidence that this discontinuity is structural. Indeed the Buzzard Rock Member interfingers with both the greenstone and sedimentary and tuffaceous rocks along the southern slopes of Mt. Rogers and Haw Orchard Mountain. The contrast in structural style is probably the result of the massiveness of the rhyolite pile relative to the inhomogeneous nature of the lower part of the Mount Rogers Formation. The massive rhyolite, however, is penetratively deformed as evidenced by foliation of variably developed intensity, deformed phenocrysts and spherulites, and compaction foliation (eutaxitic texture) in welded tuffs systematically oblique to the axes of columnar joints.

Buzzard Rock Member (New Name)

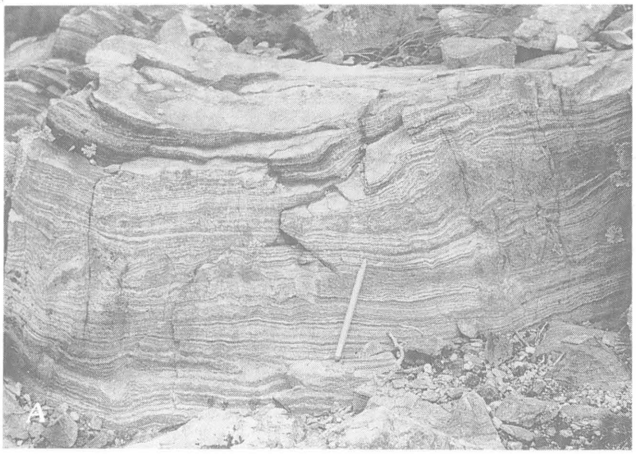
The Buzzard Rock Member is named for exposures on Buzzard Rock, a shoulder of Whitetop Mountain, in the southwest corner of the Whitetop Mountain quadrangle (fig. 3). It is the lowest and thinnest of the three rhyolite units of the Mount Rogers Formation in the Mt. Rogers volcanic center. The rock is characterized by an aphanitic, commonly grayish-purple or maroon groundmass containing 5 to 20 percent phenocrysts of perthitic alkali feldspar and plagioclase in subequal amounts. The phenocrysts are typically 2 to 4 mm across. Growth aggregates of the two feldspar species are common; monomineralic aggregates of plagioclase are particularly common. The reddish perthite and greenish-white plagioclase phenocrysts give the rock a distinctive appearance easily recognized in mapping outcrop or float.

Scattered observations of flow layering indicate that the unit consists of lava flows. Flow layering is not obvious at the type locality on Buzzard Rock but is conspicuous in roadcuts between the elevations of 4,760 and 4,880 ft on the Grayson Highlands State Park Road on the west side of Haw Orchard Mountain (fig. 3). In one large float block along this stretch of road, the flow layering and folding are brought out by layered concentrations of purple-fluorite-filled amygdules a few millimeters long. The amygdules, which also contain quartz, albite, epidote, and sphene, make up about 25 percent of the rock, which may be the scoriaceous margin of a flow. The weathered surface of the rhyolite is commonly mottled with whitish spots; in some thin sections it can be seen that the spots are poorly preserved spherulites. The alkali feldspar phenocrysts are highly perthitic mesoperthite in which the two phases tend to be in coarse patches, a feature shared with the alkali feldspar phenocrysts in the two overlying rhyolite members. The Buzzard Rock Member is a low-silica rhyolite. The normalized volatile-free silica content of four samples ranges from 68.9 to 70.5 percent, which is distinctly lower than that of the two overlying high-silica rhyolites (Rankin, unpub. data, 1975).

On the southwest side of Haw Orchard Mountain, the Buzzard Rock Member is about 300 m thick and consists of at least two flows separated by maroon arkose. In the thrust slice above the Trout Dale fault, the Buzzard Rock Member is about 350 m thick on the east side of Elk Ridge.

Whitetop Rhyolite Member (New Name)

Phenocryst-poor rhyolite that crops out on the summit of Whitetop Mountain (about 5,530 ft and the second highest mountain in Virginia) in the southwestern corner of the Whitetop Mountain quadrangle is here named the Whitetop Rhyolite Member of the Mount Rogers Formation (fig. 3). The rhyolite is characterized by an aphanitic groundmass, commonly grayish purple or maroon, containing 0 to 10 percent phenocrysts of quartz and perthite in varying proportions. Commonly quartz is more abundant than perthite. The phenocrysts are typically small (less than 2 mm across) and inconspicuous. Some samples are aphyric on the scale of a thin section. Some of the quartz phenocrysts are embayed, and the perthite is a mesoperthite in which the two phases tend to be in patches. Locally, in the upper drainage basin of Wilson Creek, lava of the Whitetop contains microphenocrysts of arfvedsonite. These arfvedsonite-bearing lavas are directly overlain by arfvedsonite-bearing, phenocryst-poor welded tuff at the base of the Wilburn Rhyolite Member. This stratigraphy suggests that, toward the end of the Whitetop lava cycle, a period of relative quiescence ensued long enough for some upper parts of the magma chamber to evolve peralkaline



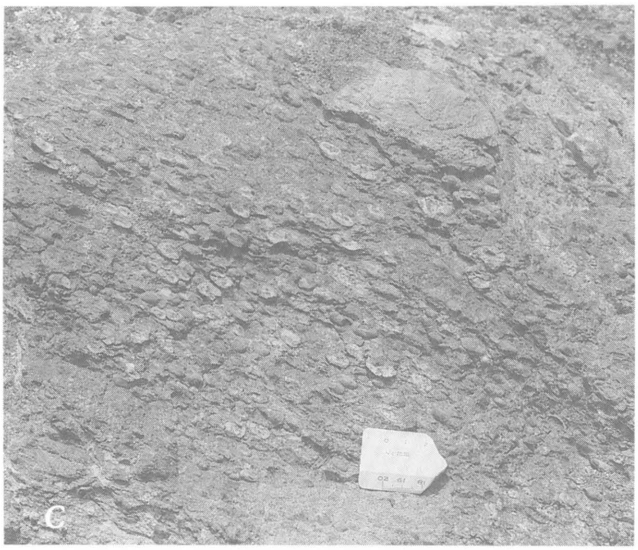


Figure 5. Whitetop Rhyolite Member of the Mount Rogers Formation. *A*, Flow-layered lava. Outcrop, north peak Haw Orchard Mountain, Whitetop Mountain quadrangle (fig. 3). Pencil for scale. *B*, Flow breccia. Outcrop in pasture in 5,170-ft saddle between Brier Ridge and Mt. Rogers, Whitetop Mountain quadrangle (fig. 3). Pencil for scale. *C*, Multishelled lithophysae in lava. Outcrop at elevation of about 4,800 ft on ridge extending south from Wilburn Ridge toward Haw Orchard Mountain (lat 36°37.25′N., long 81°30.90′W.), Whitetop Mountain quadrangle (fig. 3). Scale shows centimeters.

liquids and to build up enough volatile components to produce the climactic ash-flow eruption of the Wilburn Rhyolite Member. The Whitetop is a high-silica rhyolite. Six samples of lava have silica contents ranging from 76.72 to 78.47 percent, normalized volatile free.

Many outcrops or parts of outcrops are massive and provide no diagnostic textures indicative of the eruptive mechanism. Furthermore, in numerous outcrops or parts of outcrops, the rhyolite is bleached white (silicified), and in some areas the rhyolite contains significant pyrite. Textures are best seen on weathered outcrop surfaces and weathered joint surfaces. Flow layering, commonly chaotic, is observed in many outcrops (fig. 5*A*) and indicates that most of the unit consists of lava flows. Flow breccias are also observed (fig. 5*B*). Flow layering is commonly emphasized by the concentration in layers of relict spherulites. Relict, thin-walled, multishelled lithophysae have also been observed at several localities. Two of the best of these are (1) at an elevation of about 5,220 ft on the road up Whitetop Mountain and (2) at an elevation of about 4,800 ft on the ridge extending south from Wilburn Ridge (fig. 5*C*). At the Whitetop Mountain locality, the lithophysae are as much as 5 cm across and contain up to 40 shells. Both spherulites and lithophysae may be deformed so that the long axes of the ellipsoids plunge southeast at moderate angles.

The Whitetop Rhyolite Member also includes a variety of pyroclastic rocks. Typically these occur as isolated outcrops and are difficult to relate to a regional pattern with two exceptions. A tuff breccia (not shown on fig. 3) at the base of the Whitetop on the northwest side of the saddle between Buzzard Rock and Whitetop Mountain contains unsorted clasts as much as 30 cm across in an aphanitic phenocryst-poor matrix. The clasts include pieces of the Buzzard Rock Member, pieces of the Whitetop Rhyolite Member, and sparse clasts of basement gneissic granite. In thin section, scattered fragments of quartz, perthite, microcline, and plagioclase are xenocrysts in the matrix. A strong foliation has destroyed any primary structure in the matrix. The tuff breccia may be the initial air-fall deposit of the

Whitetop Rhyolite Member deposited on the underlying Buzzard Rock Member. A pyroclastic unit of phenocryst-poor rhyolite several meters thick has been mapped much of the way, but not all of the way, around the upper part of Whitetop Mountain (fig. 3). Some of this material is composed of lithic lapilli tuff breccia in which the fragments are sorted by size; some is probably welded tuff, and some was suggested by R.L. Smith (U.S. Geological Survey, oral commun., 1973) to be near-vent agglutinate. The last crops out in a series of ledges at an elevation of about 5,000 ft on the east shoulder of Whitetop Mountain (lat 36°38.50′N., long 81°35.45′W.) and is characterized by flattened lapilli for which the compaction foliation is wavy, not planar. Tuff breccia in the lower part of this unit on the north side of the saddle through which the road to the summit of Whitetop Mountain passes, at an elevation of more than 4,800 ft, contains clasts of lava from the Whitetop Rhyolite Member and clasts of the Buzzard Rock Member, porphyritic rhyolite resembling the Fees Rhyolite Member, greenstone, and gneissic granite. Most of the clasts are pebble to granule size, but pieces of the Whitetop are as much as 30 cm across.

As determined from the map pattern and attitudes of flow layering and compaction foliation, the Whitetop Rhyolite Member on Whitetop Mountain has an estimated minimum thickness of about 500 m (fig. 3). The top of the Whitetop is not preserved in this section. The Whitetop Rhyolite Member between the Buzzard Rock Member on Haw Orchard Mountain and the Wilburn Rhyolite Member is estimated to be about 750 m thick.

Wilburn Rhyolite Member (New Name)

Porphyritic rhyolite on Wilburn Ridge[2] in the southeastern part of the Whitetop Mountain quadrangle is here named the Wilburn Rhyolite Member of the Mount Rogers Formation (fig. 3). The rock is characterized by an aphanitic groundmass, commonly grayish purple or maroon, containing about 30 percent quartz and perthite phenocrysts in the main body of the unit. The phenocrysts are mostly 2 to 3 mm across; some perthite phenocrysts are as large as 6 mm. Quartz phenocrysts are commonly embayed, and the perthite, as in the Buzzard Rock Member, is a mesoperthite in which the two phases are present as patches within the phenocryst outline. Typically, perthite is more abundant than quartz in a ratio of about 3:2, but in many rocks they are present in subequal amounts. The lower few tens of meters of the Wilburn Rhyolite Member contain fewer and smaller phenocrysts, typically about 10 percent quartz and perthite in subequal amounts.

The Wilburn is a welded ash-flow sheet interpreted to have been emplaced by the culminating eruptions from the Mt. Rogers volcanic center, which probably led to a caldera collapse. It is thought to have been erupted and emplaced subaerially. Diagnostic features of welded ash-flow tuffs such as columnar joints and fiamme (flattened pumice lumps) (fig. 6*A*) are present throughout the member. The columnar joints have been modified by Paleozoic tectonism but are still convincing (fig. 6*B*). Devitrified and flattened shards are visible in numerous thin sections (fig. 6*C*). Irregularly shaped, calcite-filled vugs arranged in crudely columnar zones perpendicular to the compaction foliation may be fossil fumaroles (R.L. Smith, oral commun., 1973). The main body of the ash-flow sheet is highly compacted. Fiamme range in length from 1 or 2 cm to a maximum of about 20 cm and have a flattening ratio of about 10:1. No variation in flattening ratio through the main body of the sheet was observed. In many thin sections, the spherulitic centers and axiolitic borders of the fiamme are preserved. In most thin sections, however, the fiamme are simply coarser grained mosaics of quartz and feldspar than the rest of the groundmass. In numerous thin sections as well as numerous outcrops, no fiamme are visible, presumably because the rocks are recrystallized.

In 1973 a suite of samples was collected from two sections through the Wilburn Rhyolite Member on Wilburn Ridge. Both of these sections started at the basal contact with the Whitetop Rhyolite Member and extended stratigraphically upward through the Wilburn as high as unequivocal compaction foliation indicated a consistent direction of dip. The stratigraphic thickness of the thicker section as thus determined is 760 m. Topographic profiles of each section combined with the attitude of compaction foliation near each sample site determined the stratigraphic position of each sample in the ash-flow sheet. Petrography and chemistry of these samples indicate that the Wilburn Rhyolite Member is a zoned ash-flow sheet. Preliminary results of this study were presented by Novak and Rankin (1980).

The basal 30 m of the Wilburn, in addition to having only about 10 percent quartz and perthite phenocrysts, is characterized by microphenocrysts of zincian arfvedsonite and sparse acmite. Weathered outcrops in this zone show a mottling of small (millimeter-size) black spots or lenses that are aggregates of microphenocrystic arfvedsonite. The acmite is restricted to the basal zone, but the arfvedsonite persists upward in decreasing amounts. In the top third of the studied sections, minor biotite is the sole Fe-Mg groundmass mineral. In the basal zone, the fiamme are somewhat smaller and more compacted. In fact, some of the eutaxitic texture approaches flow layering, suggesting that parts of the alkalic lower part of the Wilburn flowed during

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[2]Named for Wilburn Waters, a prominent 19th century local figure who is buried on a hill overlooking Big Horse Creek in nearby North Carolina (Park quadrangle). A marker along the stream pointing to his grave reads:

WILBURN WATERS
1812–1878
PREACHER
BEAR HUNTING PIONEER
KILLED 120 BEARS

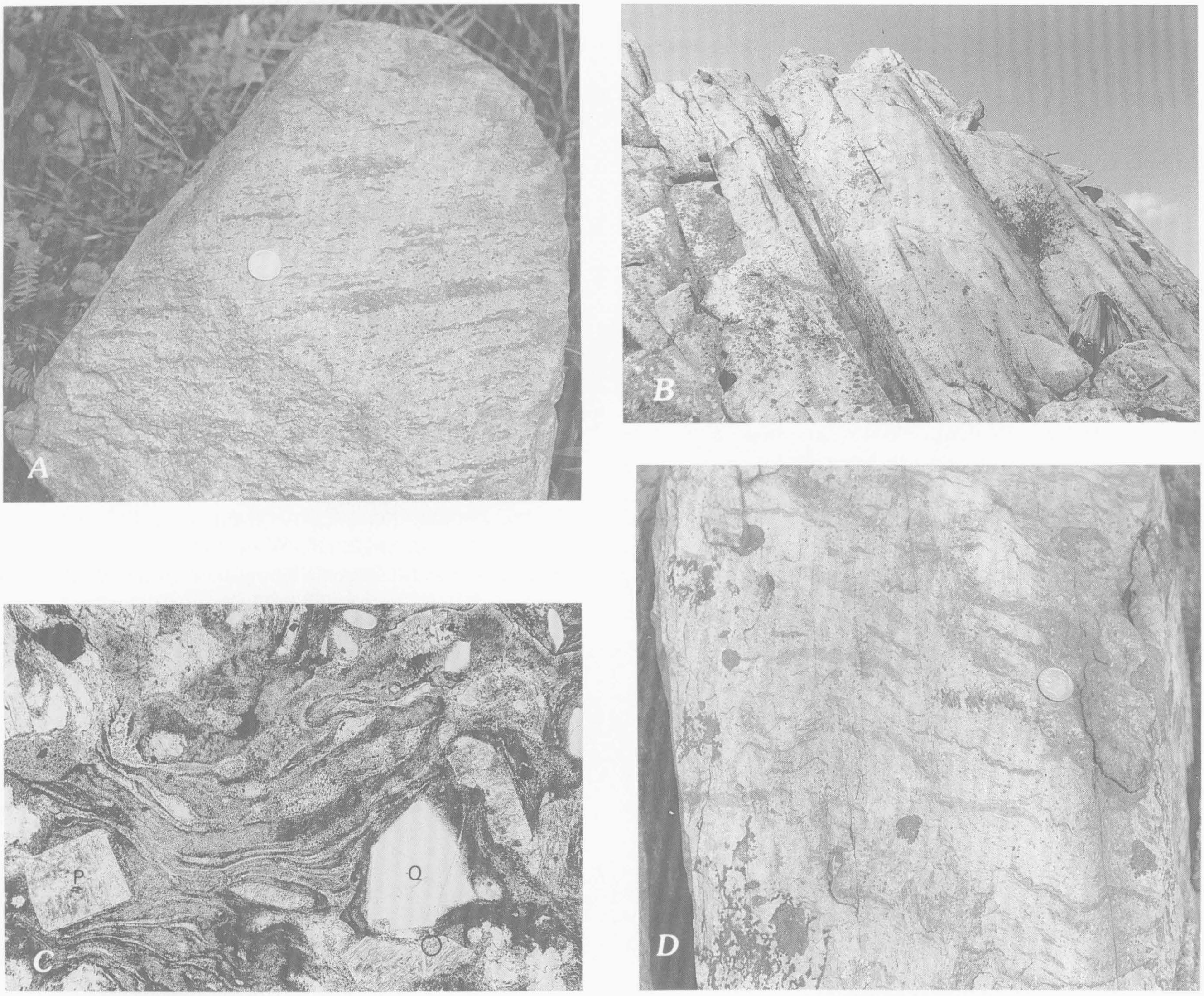

Figure 6. Welded tuff, Wilburn Rhyolite Member of the Mount Rogers Formation. *A*, Fiamme (collapsed pumice lumps) in welded tuff. Float boulder, at elevation of about 3,480 ft about 0.6 km south of Fairwood, Trout Dale quadrangle (fig. 3). Dime for scale. *B*, Columnar jointing in outcrop at elevation of about 5,000 ft on ridge extending south from Wilburn Ridge, Whitetop Mountain quadrangle (fig. 3). Backpack is about 0.5 m tall. *C*, Photomicrograph showing phenocrysts of perthite (P) and quartz (Q) in welded tuff. Devitrified and flattened shards are visible in the groundmass. Plane-polarized light. Thin section is of sample R–TC2–14, one of two samples of rhyolite from the Mount Rogers Formation dated by T.W. Stern (Rankin and others, 1969). Sample is from elevation at about 3,620 ft on ridge northwest of Solomon Branch on the north slope of Stone Mountain (Pine Mountain on fig. 3), Trout Dale quadrangle (lat 36°41.46′N., long 81°27.75′W.). Horizontal field of view about 3 mm. *D*, Fiamme deformed by steeply dipping regional cleavage. Cleavage surfaces are poorly defined here, but they regionally strike northeast and dip moderately southeast. Outcrop is basal, phenocryst-poor, arfvedsonite-bearing welded tuff at elevation of about 4,960 ft on ridge extending south from Wilburn Ridge, Whitetop Mountain quadrangle (fig. 3). Dime for scale.

or after compaction. Lithic inclusions are common in the basal zone and are found scattered well up into the main body of the Wilburn. In places, lithic fragments in the basal 10 m or so of the Wilburn constitute almost 50 percent of the rock in which deformed fiamme may be seen between the lithic fragments. Excellent exposures of the fragment-rich, basal ash-flow tuff are at an elevation of about 4,900 ft on the southern extension of Wilburn Ridge in the Whitetop Mountain quadrangle (lat 36°38.19′N., long 81°30.94′W.) and are at about 4,500 ft on the south side of Wilburn Ridge in the Trout Dale quadrangle a short distance above the Grayson Highlands State Park Road (lat 36°38.27′N., long 81°29.80′W.) (fig. 3). Lithic clasts include Whitetop Rhyolite Member, Buzzard Rock

Member, arfvedsonite-bearing Wilburn Rhyolite Member, coarsely porphyritic rhyolite, granite, and gneissic granite. At the exposure in the Trout Dale quadrangle, nearly 75 percent of the fragments are of the Whitetop Rhyolite Member (as large as 35×50 cm), and most of the rest are granite. Clearly the basal Wilburn ash flows overran a rubbly surface of Whitetop Rhyolite Member but carried with them fragments of older units including basement, probably derived from the vent walls. Zones rich in lithic fragments higher up in the Wilburn probably mark distinct flow units. These zones were not traced in mapping.

Analyses of 18 samples from the two sections show that the Wilburn Rhyolite Member is a high-silica rhyolite having a mean SiO_2 content of 76.0±1.7 weight percent dry (Novak and Rankin, 1980). The mineralogic and chemical zonation through the ash-flow sheet reflects a magma chamber in which TiO_2 decreased upward, whereas F, the differentiation index, the molecular (Na+K)/Al ratio, and the Fe/(Fe+Mg) ratio increased upward. The basal zone representing the upper part of the magma chamber, although containing peralkaline minerals (acmite and arfvedsonite), is not now peralkaline (molecular (Na+K)/Al>1) but probably was prior to regional metamorphism.

Breccia cropping out over areas as large as 2×0.8 km has been mapped at the base of the Wilburn Rhyolite Member on the north slopes of Mt. Rogers and Pine Mountain (Whitetop Mountain and Trout Dale quadrangles, respectively, fig. 3). The matrix of the breccia is quartz- and perthite-phyric tuff of the Wilburn. Devitrified shards can be seen in some thin sections. No sodic amphibole or acmite microphenocrysts have been observed. The breccia fragments include lava and flow breccia of the Whitetop Rhyolite Member in fragments up to several meters across, welded tuff of the Wilburn, and rare granite. In most outcrops, the Whitetop blocks are the dominant clasts and may constitute 75 to 80 percent of the rock. At first appearance, these outcrops look like flow breccia of the Whitetop Rhyolite Member unless the matrix, of which there may not be much, is examined carefully. Perhaps these matrix-poor breccias of the Wilburn Rhyolite Member are parts of the collapsed caldera wall infiltrated with ash of the Wilburn. The breccias crop out at or near the leading edge of the Stone Mountain thrust sheet and only in that thrust sheet. Hence, other direct evidence for the caldera is not preserved.

Much of the Wilburn has been penetratively deformed. Phenocrysts, particularly the quartz, have been sheared. The sheared quartz typically has "ribbon" extinction. Regional foliation has produced a crinkling of fiamme in places (fig. 6*D*) and an alignment of microlites (opaque minerals or arfvedsonite commonly) in the groundmass. In most outcrops, the compaction foliation is at a high angle, but not at right angles to the axes of columnar joints.

Lower Contact

The Mount Rogers Formation nonconformably overlies the Middle Proterozoic (Grenvillian) Cranberry Gneiss. The actual contact is rarely exposed. Recognizable clasts up to boulder size of granite and gneissic granite of the Cranberry Gneiss are scattered throughout the Mount Rogers Formation in both sedimentary and volcanic rocks. Their presence indicates that the Grenvillian basement granite had been uplifted and was exposed to erosion at the time of deposition of the Mount Rogers. Four localities illustrating features observed at or near the contact are described below. At the first locality, the contact is a fault; at the other localities, the contact is stratigraphic.

First area providing data on lower contact.—A saprolite roadcut at an elevation of about 3,200 ft a little more than 1 km north of Flat Ridge in the northwestern part of the Middle Fox Creek quadrangle (fig. 2, lat 36°42.53′N., long 81°20.95′W.) exposes a fault contact between the Mount Rogers Formation to the north and the Cranberry Gneiss to the south. The fault strikes N. 70° W. and is vertical. A zone of blastomylonite about a meter wide separates light-greenish-gray, quartz-pebble-bearing conglomerate saprolite from orange saprolite of gneissic granite. This fault is interpreted to be the Stone Mountain fault, but it is also possible that the structure here is more complicated than deduced from reconnaissance mapping in 1965. Early movement on this fault could be related to Iapetan continental rifting.

Second area providing data on lower contact.—In the northeastern part of the Middle Fox Creek quadrangle (fig. 2, lat 36°44.55′N., long 81°16.35′W.; elevation about 3,100 ft), a residual regolith separates the Cranberry Gneiss (here a little-deformed granite) from the Mount Rogers. This locality was noted by Stose and Stose (1957) and shown on their plate 60. They considered the regolith to be a conglomerate, or perhaps there is a conglomerate along strike that was not visited by me. At the above locality, the regolith is overlain by a few meters of medium- to coarse-grained graywacke with a maroon matrix, then by laminated maroon argillite, which grades through purple tuffaceous rocks into greenstone. About 0.7 km to the southeast, on Cinnamon Ridge (fig. 2), greenstone forms the basal Mount Rogers Formation. The basal part of the greenstone is oxidized (maroon color) and contains abundant little-deformed xenoliths of subangular to subrounded granite (Cranberry Gneiss) as large as 0.7 m (fig. 7). Superficially this rock resembles diamictite of the Konnarock Formation described below, but the hand specimens have noticeably high specific gravity (heft), and the maroon "matrix" contains abundant hematite and abundant, randomly oriented, millimeter-size, white-weathering plagioclase laths. This area has been visited in reconnaissance only, but the oxidized basal zone appears to grade up into green amygdaloidal greenstone without granite clasts.

Figure 7. Basal oxidized zone of maroon greenstone at base of the Mount Rogers Formation. Xenoliths of billion-year-old Cranberry Gneiss probably picked up from underlying regolith. Note that xenoliths are little-deformed granite. They were incorporated into the basalt prior to Paleozoic deformation that profoundly affected the main body of the Cranberry Gneiss farther southeast. Float block on Cinnamon Ridge in northeast corner of Middle Fox Creek quadrangle (fig. 2). Scale shows centimeters.

Third area providing data on lower contact.—A large poison-ivy-covered greenstone outcrop near the eastern border of the Park quadrangle about 260 m north of the North Carolina State line is interpreted to be the basal outcrop of the Mount Rogers Formation. The outcrop, about 10 m high, is above the road on the east side of a stream (fig. 3, lat 36°34.93′N., long 81°30.30′W.). In the upper part of the outcrop, the greenstone is free of basement clasts, but these become increasingly abundant in the greenstone toward the bottom of the outcrop, where they constitute about 50 percent of the rock. The basement clasts are gneissic granite, granite, and quartz in rounded and stretched pebbles to boulders. The largest clast observed is 35 cm across perpendicular to the stretching. Basement is present in float across the stream and in nearby exposures of this structurally complex area. The actual contact was not observed.

Fourth area providing data on lower contact.—Finally, basement-cover relations may be studied near Buzzard Rock, southwestern Whitetop Mountain quadrangle (fig. 3). This area was described by Rankin (1967). Buzzard Rock is about 5,120 ft in elevation. At an elevation of 4,980 ft on the south side of Buzzard Rock, ledges of Cranberry Gneiss are as close as 3 m horizontally and less than 1 m vertically from ledges of the Buzzard Rock Member of the Mount Rogers Formation. The Cranberry here is a medium-grained mylonitic gneiss with a strong subhorizontal foliation. In addition to sheared and fragmented quartz, microcline, and plagioclase, the rock contains chlorite, epidote, abundant sericite, and minor stilpnomelane. Although the foliation in the Cranberry Gneiss is pronounced, lineation is not obvious. The Cranberry is overlain by about 20 m of strongly sheared tuffaceous material. Although the shearing partially obscures the lithologies, the tuff is a mixture of basement granitic rocks and disaggregated granite (quartz and orange basement microcline fragments are easily visible), and Buzzard Rock Member rhyolite in an aphanitic felsic matrix. The tuff may be water-reworked air-fall material of the Buzzard Rock and basement debris. The percentage of recognizable basement material in the tuff decreases upward, and, at an elevation of about 5,040 ft, outcrops are of sheared rhyolite of the Buzzard Rock Member. The strong deformation of this rock is probably because the nonconformity here is only about 90 m above the Stone Mountain fault (fig. 3).

About 300 m around to the northwest, on the Buzzard Rock side of the saddle between Buzzard Rock and Beech Mountain, the highest Cranberry Gneiss outcrops contain pieces of the Buzzard Rock Member. These outcrops are interpreted to be an admixture of regolith of the Cranberry Gneiss and pieces of rhyolite of the Buzzard Rock Member. Apparently shearing has obscured the fragmental nature of the Cranberry. No tuffaceous interval is present here between the Cranberry and homogeneous Buzzard Rock.

In summary, for the three localities where the contact is stratigraphic, the Mount Rogers Formation is nonconformably above the Cranberry Gneiss. Mount Rogers units in contact with the Cranberry include a variety of sedimentary rocks, greenstone, and the Fees Rhyolite Member of the lower part of the formation and the Buzzard Rock Member of the Mt. Rogers volcanic center. My earlier statements that at one place or another nearly every unit from the bottom to the top of the formation is in contact with the Cranberry (Rankin, 1967; Rankin, Drake, and others, 1989) need to be revised in accordance with removing the glaciogenic deposits from the Mount Rogers Formation. However, the stratigraphic range of Mount Rogers units that are in contact with the Cranberry Gneiss, as well as the coarseness of many conglomeratic units, does indicate that the Mount Rogers was deposited on a basement topography of considerable relief such as one might find in continental rifts.

Upper Contact

As noted above, the upper contact of the Mount Rogers Formation is not preserved in the Stone Mountain thrust sheet. The upper contact is interpreted to be preserved in three areas in underlying thrust sheets or slices.

First area providing data on upper contact.—Near the community of Konnarock astride the border of the Konnarock and Whitetop Mountain quadrangles, a much thinned and geographically restricted section of the Mount Rogers is preserved above an inlier of Cranberry Gneiss (fig. 3). These rocks are interpreted to be in the Shady Valley thrust sheet immediately above the Iron Mountain fault (fig. 2) and stratigraphically below maroon clastic sedimentary rocks here included in the Konnarock Formation. In this area, the Mount Rogers includes a very thin section of greenstone and sedimentary rocks of the lower part of the formation as well as all rhyolite members of the Mt. Rogers volcanic center in their proper stratigraphic order (that is, Buzzard Rock, Whitetop, and Wilburn). Mapping of float suggests that both greenstone and lower sedimentary rocks are in stratigraphic contact with the Cranberry Gneiss basement.

The contact between the Wilburn Rhyolite Member and maroon sedimentary rocks of the Konnarock Formation is exposed in a roadcut along Virginia Highway 603 just west of the highway bridge over Big Laurel Creek and about 400 m east of the Konnarock-Whitetop Mountain quadrangle boundary (fig. 3). On the west side of this outcrop, arkose overlies the Wilburn and is separated from it by 2 to 4 cm of sheared rock. Above the shear zone, the arkose appears undeformed and is overlain by maroon rhythmites (graded sets of siltstone or sandstone and mudstone). The contact strikes N. 40° E. and dips 45° N. On the east side of the outcrop is a volcanic conglomerate in steep contact with the Wilburn and beneath the projection of the bedding in the now-eroded arkose. The conglomerate is composed dominantly of clasts of the Wilburn, but it also contains clasts of the Whitetop Rhyolite Member and rhythmite. A thin section of the matrix of this rock contains basement microcline. The Wilburn Rhyolite Member in the outcrop is much fractured, and many surfaces are slickensided. The contact has been exposed by digging in a road bank on its strike projection to the southwest across Big Laurel Creek. There the contact is sharp and vertical and strikes N. 75° E. The basal arkose of the Konnarock is again overlain by maroon rhythmite.

On the basis of evidence from both sides of Big Laurel Creek, the contact between the Wilburn Rhyolite Member and the Konnarock Formation is interpreted to be a stratigraphic one in which the Konnarock covered an irregular surface marked by rubble-filled pockets. Contacts between the Konnarock and other units of the Mount Rogers are not exposed. Outcrops are generally poor, and much of the mapping is based upon float. The resulting map pattern, however, is interpreted to delineate an unconformity beneath the Konnarock Formation along which maroon rhythmite or arkose of the Konnarock is in contact with and stratigraphically above all units from the Cranberry Gneiss to the Wilburn Rhyolite Member. If the above interpretation is correct, at least some deformation, even if it was simply warping or faulting related to the volcanism, must have occurred between the Mount Rogers eruptions and deposition of the Konnarock. In addition, the Mount Rogers in the inlier near Konnarock must have been distal to the main body of the formation.

Second area providing data on upper contact.—The upper contact of the Mount Rogers may be preserved on the north slope of Whitetop Mountain in rocks that are interpreted to be in the Mountain City window (fig. 3). Field relations are equivocal, but bedding in maroon arkose and rhythmite immediately north of an outcrop of the Wilburn Rhyolite Member dips northwest away from the rhyolite. The sedimentary rocks are not unusually deformed, although the rhythmites do have a cleavage. In roadcuts near an elevation of 3,700 ft along Virginia Highway 600 to Elk Garden, arkose, grit, and mudstone are interlayered in the Wilburn. Channeling of grit in the mudstone indicates that tops are to the northwest and that the beds are overturned (bedding dips 30° to the southeast). An alternate interpretation, not favored, is that this thin section of the Wilburn including the interlayered sedimentary rocks is at the top of the more or less complete section of the Mount Rogers Formation that appears to be overturned and stratigraphically attached to the Cranberry Gneiss southeast of Elk Garden. That interpretation would require the fault framing the Mountain City window to be either between the Wilburn Rhyolite Member and rocks to the northwest here included in the Konnarock Formation or farther northwest within the Konnarock. The last possibility would, of course, still make the Wilburn-Konnarock contact here a stratigraphic one.

Third area providing data on upper contact.— Conglomerate, grit, and siltstone closely resembling those in the lower part of the Mount Rogers Formation crop out structurally beneath diamictite, arkose, and rhythmite here included in the Konnarock Formation along and south of Fox Creek between Fairwood and Trout Dale (fig. 3), in the west-central part of the Trout Dale quadrangle. Bedding in both suites dips moderately north, and graded bedding in the laminites close to the conglomerate, grit, and siltstone indicates that beds young to the north. The conglomerate, grit, and siltstone are thought to be in stratigraphic contact with and beneath the diamictite, arkose, and rhythmite. The conglomerate contains far less argillaceous matrix than the diamictite, and clasts in the conglomerate are more rounded and dominantly rhyolite as opposed to granite. The conglomerate, grit, and siltstone are here considered to be part of the Mount Rogers Formation. J.M.G. Miller (Vanderbilt University, written commun., 1989) reported a concordant contact, which I have since visited with her, between bedded diamictite (Konnarock Formation) and conglomerate (Mount Rogers Formation) on the west side of Virginia Highway 739 along Solomon Branch south of the junction with Virginia Highway 603 (lat 36°41.85′N., long 81°27.55′W.). The suites of rocks described above are in the Shady Valley thrust sheet. Field relations here are again equivocal, but the map pattern suggests that this relatively thin section of the Mount Rogers Formation is overridden from the south by phenocryst-poor rhyolite lava resembling the Whitetop Rhyolite Member, grit, siltstone, and phyllite, all of the Mount Rogers Formation.

A second exposure in this general area (lat 36°41.81′N., long 81°28′W.) is in a brush-covered roadcut on the south side of Virginia Highway 603 about 0.8 km west of the intersection with Virginia Highway 739. This exposure was also shown to me by J.M.G. Miller. Diamictite of the Konnarock Formation overlies volcanic conglomerate of the Mount Rogers; the contact is sharp and dips steeply to the north. Although this outcrop is near the concordant contact just described on Virginia Highway 739, bedding is not visible in this outcrop. Excellent exposures of the volcanic conglomerate may be seen in the adjacent roadcut to the west and in outcrops along Fox Creek below that roadcut.

KONNAROCK FORMATION (NEW NAME)

Name, Type Area, and Thickness

Maroon diamictite, rhythmite, and pink arkose in the vicinity of Konnarock, Va., in the Konnarock quadrangle, are here called the Konnarock Formation (fig. 3). These rocks were formerly considered to be the upper part of the Mount Rogers Formation. They are here defined as a new formation because, as discussed in the previous sections, they could be significantly younger than the Mount Rogers Formation and are locally unconformably above the Mount Rogers; the rocks are largely glaciogenic and nonvolcanic, whereas the Mount Rogers, as redefined, is largely volcanic; the unit is stratigraphically overlain by the Lower Cambrian Unicoi Formation; and, except locally, it is structurally isolated from the Mount Rogers Formation. Typical exposures are along Whitetop Laurel Creek and adjacent roadcuts and railroad (now abandoned) cuts from northwest of the end of Virginia Highway 728 at Creek Junction (lat 36°39.08′N., long 81°40.81′W.) to Konnarock (fig. 3). The Konnarock Formation is on the order of a kilometer thick.

Description

Lithologies in the Konnarock include massive and bedded diamictite, rhythmite, rhythmite containing dropstones, massive argillite, arkose, and minor conglomerate. Aspects of these rocks have been described in publications by Carrington (1961), Rankin (1967), Blondeau and Lowe (1972), Schwab (1976), and Miller (1989a,b) and in three Master's theses by Blondeau (1975), Rexroad (1978), and Whithington (1986). Most rocks are maroon with the exception of gray or greenish sandy or silty bases to the graded sets in the rhythmites and the pink or greenish-gray arkose.

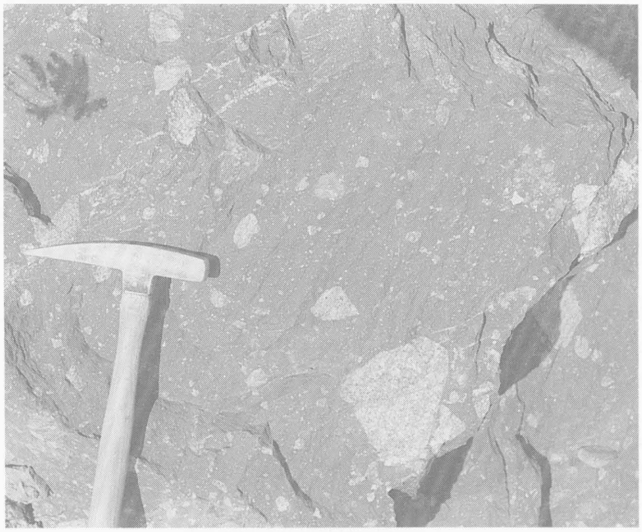

Figure 8. Massive diamictite (tillite) in Konnarock Formation. Outcrop along Whitetop Laurel Creek about 250 m northwest of end of Virginia Highway 728 at Creek Junction at lat 36°39.08′N., long 81°40.81′W. (fig. 3, note that Creek Junction is not shown).

The massive diamictite (fig. 8) is a matrix-supported conglomerate or conglomeratic mudstone in the terminology of Blondeau and Lowe (1972). Grain size ranges continuously from clay to boulders more than a meter across, although, as noted by Schwab (1976), clay and silt account for up to 80 percent of the rock. From 70 to 83 percent of the clasts are basement rocks, mostly granite and porphyritic granite. Very few clasts are recognizable metamorphic rocks (gneiss, schist, amphibolite). The balance of the clasts are from the Mount Rogers Formation and include rhyolite, basalt, arkose, and argillite (the last two types could also be material from the Konnarock Formation). The matrix of the diamictite is typically reduced (greenish) adjacent to basalt clasts. Rhyolite, including both porphyritic and phenocryst-poor types, generally does not constitute more than 10 percent of the clasts. The clasts were incorporated in the diamictite as unweathered rock. The massive diamictite is nonbedded and occurs in layers 3 to 30 m thick (Schwab, 1976). Massive diamictite is particularly common toward the top of the formation, and a unit that is dominantly massive diamictite has been mapped as a more or less continuous unit, as thick as 400 m (Miller, 1989a), for a strike distance of nearly 40 km in the Shady Valley thrust sheet (figs. 2 and 3). The massive diamictite also forms a thick unit here interpreted to be in the Mountain City window on the slopes of Beech Mountain.

Rankin (1967) suggested that the massive diamictite is a tillite and later (Rankin, 1969) suggested that the tillite might have been the result of alpine glaciation related to volcanic edifices. As discussed below, that latter idea no longer seems reasonable. Miller (1986, 1989a,b) proposed that the diamictite is a lodgment tillite that was deposited from ice that advanced across a glacial lake. Schwab (1976) reported very rare striated clasts in the diamictite; I observed none. Both Rankin (1969) and Schwab (1976) noted the absence of a striated pavement, but pointed out that the diamictite everywhere rests on coeval subaqueous sediments (also implied in the lodgment till interpretation).

Rhythmite, rhythmite containing dropstones (laminated pebbly mudstone), and bedded diamictite are variants of units deposited by turbidity currents and grade into one another. Rhythmites are repetitions of graded sets or couplets of gray-green siltstone or fine-grained sandstone bases and maroon mudstone tops. Typically the siltstone part of the couplet is thinner than the mudstone. In many outcrops, the cleavage is refracted across the repeated graded beds so that the cleavage surface has the superficial appearance of ripple marks. Typically the couplets range in thickness from a few millimeters to a few centimeters (fig. 9).

The couplets may be simple, consisting of a single graded set, or complex, where a generally fining upward cycle is composed of a series of thinner couplets. Carrington (1961) described and illustrated sets of microrhythmites (as thin as 0.1 mm) within rhythmites. He also described thicker cycles that he called megarhythmites that had periodicities of 0.5 to 3.5 m.

Even relatively thin couplets are remarkably continuous laterally. In an old, small quarry on the north side of Virginia Highway 603 about 3.8 km east of Virginia Highway 600 (lat 36°41.81′N., long 81°34.15′W.), couplets as thin as 1 cm are continuous for 6 m and show no variation in thickness. Sandy bottoms may show load casts in the underlying mudstone (fig. 10). Mudstone rip-ups are common, as are slump structures and penecontemporaneous small-scale faulting. Locally the mudstone is greenish along bedding planes or in irregular patches as a result of reduction. The rhythmites were probably deposited by glaciolacustrine turbidity currents and may in fact be varves (Rankin, 1967; Blondeau and Lowe, 1972; Schwab, 1976; Miller, 1986, 1989a).

In several extensive exposures (fig. 3), the rhythmites contain outsized angular to subangular clasts interpreted to be ice-rafted dropstones. Places where these may be seen include the railroad cut on the north side of the trestle over Whitetop Laurel Creek at the junction with Green Cove Creek (fig. 11*A*); a small quarry on the northeast side of the intersection of Virginia Highways 600 and 603, Whitetop Mountain quadrangle; pavement exposures in Big Laurel Creek about 1.2 km east of the junction of Virginia Highways 600 and 603, Whitetop Mountain quadrangle (Rankin, 1975, plate 1B; the caption to that plate erroneously gives the locality west of the road junction); pavement outcrops in Big Laurel Creek about 3 km east of the intersection of Virginia Highways 600 and 603, Whitetop Mountain quadrangle (fig. 11*B*); and artificial pavement exposures east of the junction of Virginia Highways 603 and 16, Trout Dale, Va. No statistical study has been made of the dropstones, but as with the clasts in the massive diamictite, most of them are basement granitoids. Most dropstones range in size from granules to cobbles. One boulder 1 m across was observed in the rhythmite at an elevation of about 3,760 ft on the west slope of Beech Mountain, Konnarock quadrangle (lat 36°38.65′N., long 81°38.17′W.). The boulder is exposed on the wall of an open pit in saprolite of the rhythmite (a manganese prospect pit?).

Figure 9. Rhythmite in Konnarock Formation. Bedding strikes N. 25° E. and dips 55° N. Beds are right side up and are younger toward the northwest (toward the hammer head). Weathered outcrop in road gutter at elevation of about 3,180 ft on east side of Virginia Highway 600 about 0.7 km southeast of junction with Virginia Highway 603, Whitetop Mountain quadrangle (fig. 3). Photograph taken in 1965. Gutter is now lined with concrete; no outcrop is visible.

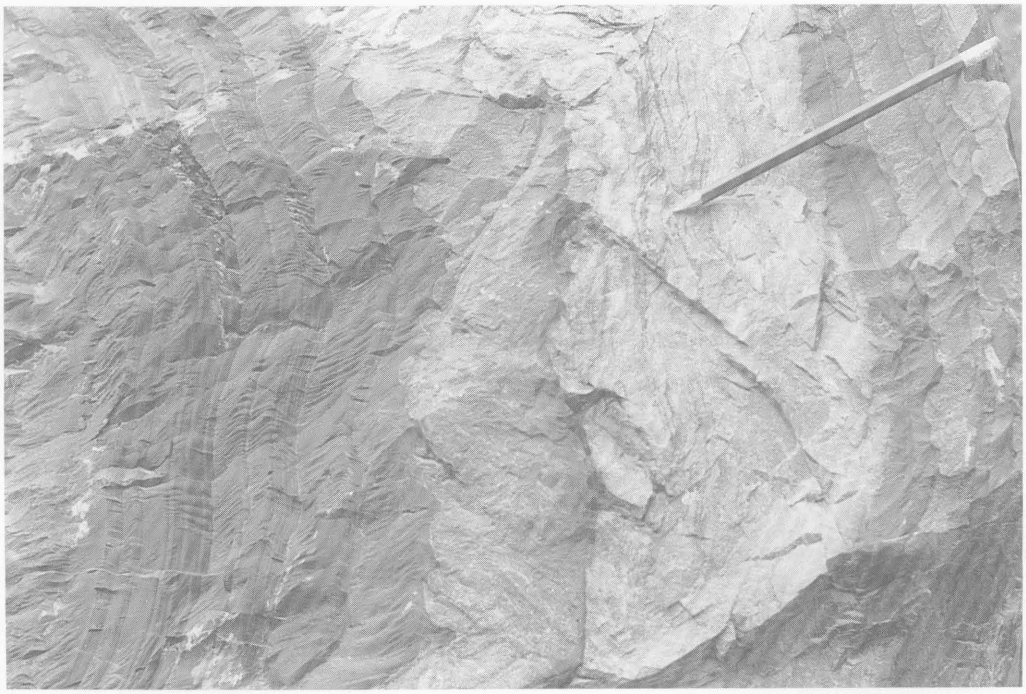

Figure 10. Rhythmite and interlayered arkose bed, which is about 20 cm thick, in Konnarock Formation. Sandy bottoms of arkose bed and successive couplets show load casts accentuated by regional cleavage (which strikes N. 60° W. and dips 25° S.). Cleavage is refracted through couplets. Beds are younger to the right. Photograph taken looking north along steep east limb of asymmetrical east-verging anticline to which cleavage is axial planar. Fold axis trends N. 85° E. and plunges 15° W. Roadcut on north side of Virginia Highway 603 about 0.5 km south of intersection with Virginia Highway 16, Trout Dale quadrangle (fig. 3).

Figure 11. Rhythmite containing dropstones (laminated pebbly mudstone) in Konnarock Formation. *A*, Subangular granitoid dropstone in rhythmite. Right (south) side of outcrop is bedded diamictite. Bedding strikes N. 65° E. and dips 60° N. Photograph taken looking east; beds are younger to left. Railroad cut on north side of trestle over Whitetop Laurel Creek at junction with Green Cove Creek, Konnarock quadrangle (fig. 3). Quarter for scale. *B*, Several granitoid dropstones in rhythmite. Bedding strikes N. 55° E. and dips 35° N. Beds are younger in direction of pencil eraser. Weathered pavement outcrop along Big Laurel Creek about 3 km east of junction of Virginia Highways 600 and 603 (180 m west of Bethel Church), Whitetop Mountain quadrangle (fig. 3).

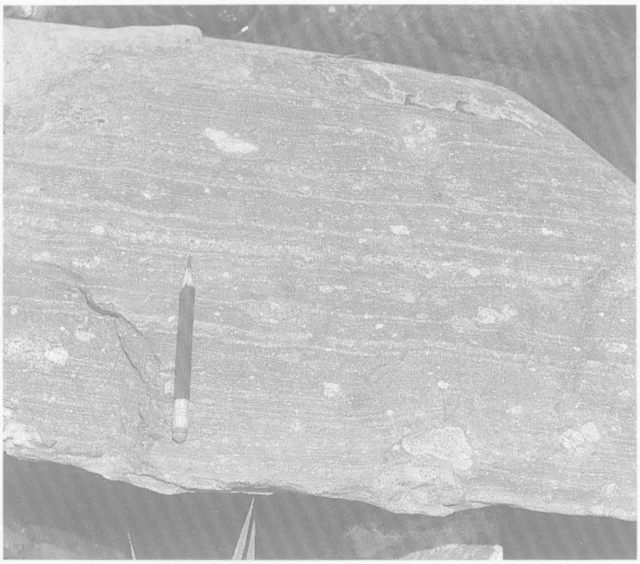

Figure 12. Bedded diamictite in Konnarock Formation. Float block along Big Laurel Creek 1.2 km east of junction of Virginia Highways 600 and 603, Whitetop Mountain quadrangle (fig. 3).

In places, thin beds of grit alternate with mudstone or sandy mudstone. Grading may or may not be obvious. Outsized clasts are scattered throughout, but some may be associated with specific grit beds. Mudstone rip-ups and slump structures are common. These are the bedded diamictites of Miller (1989a) (fig. 12).

Bedded pink or greenish-gray arkose is scattered throughout the Konnarock Formation. The beds may be several centimeters thick, interlayered repeatedly in the rhythmites and somehow part of the periodicity, or in more massive beds as thick as 6 m that are probably part of the fluvial lithofacies of Schwab (1976).

Blondeau and Lowe (1972) and Miller (1989a) presented generalized stratigraphic columns for the rocks now called the Konnarock Formation. The section of Blondeau and Lowe (1972) includes quartz-pebble conglomerate within the Konnarock. Blondeau (1975, p. 14) placed the top of the upper division of the Mount Rogers Formation (here the Konnarock Formation) at the base of a "regionally extensive basalt unit" above the quartz-pebble conglomerates because of the absence of orthoquartzite (characteristic of parts of the Chilhowee Group) beneath the basalt and the presence of maroon mudstone interlayered with both the quartz-pebble conglomerate and the diamictite.

King and Ferguson (1960) did include quartz-pebble conglomerate exposed on Big Hill (about 1.5 km due south of Konnarock) along U.S. Highway 58 and along Green Cove Creek in the Mount Rogers Formation. These areas were at the very northeastern limit of their very large map area, however, and were peripheral to their main study. King and Ferguson (1960, p. 31) noted the similarity of those rocks to the lower division (usage of King and Ferguson, 1960) of the Unicoi Formation. The stratigraphy established by King and Ferguson (1960) for their large map area includes most of the basalt in the lower division of the Unicoi. Typically the uppermost basalt is at the top of the lower division of the Unicoi.

In my mapping, I extended this stratigraphy into the Mt. Rogers area. I used the uppermost basalt to define the top of the lower division of the Unicoi and mapped the quartz-pebble conglomerate as the lower division of the Unicoi (Rankin, 1967). My mapping demonstrated that the quartz-pebble conglomerates on Big Hill and along Green Cove Creek are stratigraphically beneath basalt (Rankin, 1967), a relation not discovered by King and Ferguson (1960). Because of the continuity of the stratigraphy of the Mt. Rogers area with that in northeasternmost Tennessee and because of striking contrast between the quartz-pebble conglomerate and the diamictite (see below), the placement of the lower contact of the Unicoi Formation above the quartz-pebble conglomerate as suggested by Blondeau (1975) and Blondeau and Lowe (1972) should not be adopted. Furthermore, the maroon mudstone interlayered with quartz-pebble conglomerate is different from that in the Konnarock Formation. The maroon shales in the Unicoi Formation have detrital muscovite on the bedding surfaces. Detrital muscovite is not visible on the bedding surface of pelitic rocks in the Konnarock Formation (Rankin, 1967). This distinction was found to be a useful mapping criterion even in mudstone chips in the soil.

Upper Contact and Age

The contact as here defined between the Konnarock Formation and lower division of the Unicoi Formation in weathered outcrop is exposed on U.S. Highway 58 on Big Hill about 1.5 km due south of Konnarock (figs. 3, 13) and was described by Rankin (1967). At the time of my mapping, this was a fresh roadcut. The lower 15 m of the Unicoi consists mostly of feldspathic grit, but includes a bed 0.5 m thick of quartz-pebble conglomerate at its base. This basal bed of the Unicoi is atypical in that it contains numerous small granite pebbles (most clasts in the conglomerates of the Unicoi lower division are monomineralic: either quartz or microcline). The basal conglomerate bed is in knife-sharp contact with maroon laminated mudstone and arkose of the Konnarock Formation. Beds on both sides of the contact strike N. 80° E. and dip 60° N. The contact in this outcrop appears to be conformable but is probably paraconformable. The laminated mudstone and arkose lack obvious graded bedding and are hence not the typical rhythmite. One graded bed was observed several centimeters below the contact, and its presence confirms that beds are younger toward the north toward the Unicoi. Massive diamictite crops out about 100 m to the south.

Figure 13. Paraconformable contact between laminated mudstone and arkose of the Konnarock Formation on the left and the lower division of the Unicoi Formation; view looking west. Shovel of entrenching tool rests on contact, which strikes N. 80° E. and dips 60° N. Weathered roadcut at elevation of about 3,280 ft on U.S. Highway 58 on Big Hill about 1.5 km south of Konnarock (fig. 3, lat 36°39.58′N., long 81°38.31′W.). Photograph taken in 1969. Roadcut is now vegetated, but contact may be exposed by vigorous digging.

In railroad cuts along Green Cove Creek, 3.5 km southwest of the outcrop described above, the massive diamictite is directly overlain by the Unicoi Formation, lower division (Rankin, 1967) (fig. 3). The actual contact is covered in a steep gully a few meters wide, but bedding in the Unicoi (strike N. 45° E.; dip 70° S.) appears to be parallel to the contact. Crossbedding in the quartz-pebble conglomerate of the Unicoi just north of the contact confirms that, although the beds dip steeply to the southeast, they are younger to the northwest. The diamictite is not bedded. The Green Cove Creek locality is important because, upsection along the creek, Simpson and Sundberg (1987) reported the Early Cambrian (Tommotian?) marine trace fossil *Rusophycus* in the upper division of the Unicoi. The fossil locality is about 400 m stratigraphically above the Konnarock. Rankin (1967) noted the sharp lithologic contrast between the diamictite, in which roughly 75 percent of the clasts are rock fragments, and the quartz-pebble conglomerate, in which roughly 90 percent of the clasts are monomineralic (quartz, microcline, or black chert). This contrast implies a major shift in provenance between the times of deposition of the two units and probably a significant time gap. The Konnarock Formation is, therefore, thought to be of Late Proterozoic age. The Konnarock is stratigraphically above the Mount Rogers Formation, which is dated at roughly 760 Ma, and beneath the Lower Cambrian Unicoi Formation; thus, the Konnarock is in the proper time interval to be part of the global episode of glaciation that, according to Miller (1989b), happened between 700 and 650 Ma.

Plumb and James (1986) noted that there were several episodes of widespread Late Proterozoic continental glaciation in all tectonic regimes and on all continents. They stated that this glaciation reached its widest extent during the interval 800 to 700 Ma and that, in many areas, glaciation continued into the latest Proterozoic. Subsequently, in recognition of the episodes of cold climate, the Subcommission on Precambrian Stratigraphy recommended and the International Union of Geological Sciences adopted the name Cryogenian for a formal period (850 to 650 Ma) within the Neoproterozoic Era (roughly equivalent to the Late Proterozoic but beginning 1000 Ma rather than 900 Ma) (Plumb, 1991). The closest reasonably well dated Late Proterozoic glaciogenic sedimentary rocks to the Mt. Rogers area are the Squantum Member of the Roxbury Conglomerate of the Boston Bay Group in Massachusetts. The Squantum is stratigraphically above the basal Mattapan Volcanic Complex, also of the Boston Bay Group, and is conformably below the fossiliferous Lower Cambrian Weymouth Formation (Socci and Smith, 1990). The Mattapan is dated at 602±3 Ma (Kaye and Zartman, 1980). The Squantum is in the Avalon terrane of proto-Gondwanaland and in Late Proterozoic time was probably far removed from the site of the Konnarock glaciation in Laurentia. It is, thus, not possible at present to better constrain the age of the Konnarock Formation by correlation with other Late Proterozoic glaciogenic deposits.

DISCUSSION AND SUMMARY

In southwestern Virginia and adjacent North Carolina and Tennessee, the billion-year-old Grenvillian basement is overlain by a stratigraphic cover sequence older than the Lower Cambrian Unicoi Formation. This cover sequence is here divided into two formations: an older, dominantly volcanic unit called the Mount Rogers Formation (revised name) is overlain by the glaciogenic Konnarock Formation (new name). The volcanic rocks of the Mount Rogers Formation are a bimodal suite of basalt and rhyolite in which the younger rhyolites have peralkaline affinities. The volcanic rocks and consanguineous plutonic rocks that intrude the Grenvillian basement to the south are part of the Crossnore Complex and are thought to be related to an early aborted phase of Iapetan continental rifting.

The rhyolites are concentrated in thick masses thought to have been volcanic centers. The erosion of the volcanic edifices of older centers, which may or may not be partially preserved, produced extensive volcanic conglomerates that make up much of the lower part of the Mount Rogers Formation in the type area. The Fees Rhyolite Member (new name) near the base of the Mount Rogers Formation was probably erupted from one of these earlier centers, and clasts of the Fees are recognizable in the conglomerates.

Rhyolites of the Mt. Rogers volcanic center constitute the upper part of the Mount Rogers Formation in the type area. These include the basal Buzzard Rock Member (new name), which is lava, the Whitetop Rhyolite Member (new name), also largely lava, and the climactic, zoned, welded ash-flow sheet of the Wilburn Rhyolite Member (new name). The rhyolites of the Mt. Rogers volcanic center are dated at about 760 Ma (Aleinikoff and others, 1991; R.E. Zartman, U.S. Geological Survey, written commun., 1992).

The thin basalts in the Unicoi Formation may correlate with the volcanic rocks, mostly metabasalt, of the Catoctin Formation, which overlies Grenvillian rocks of the Blue Ridge anticlinorium from central Virginia to South Mountain, Pennsylvania (rift-facies stratified rocks of Laurentia on fig. 1). Rhyolite of the Catoctin Formation has recently been dated at about 570 Ma (J.N. Aleinikoff, U.S. Geological Survey, written commun., 1992). The basalts in the Unicoi Formation are about 145 m stratigraphically below the Early Cambrian (Tommotian?) marine trace fossil along Green Cove Creek. Hence the correlation of the basalts in the Unicoi with the Catoctin Formation is at least permissible. The Catoctin volcanism is thought to mark the second and successful episode of continental rifting that led to the opening of the Iapetus Ocean.

A couple of other points should be made in conclusion. Because the Konnarock Formation generally crops out northwest of the Mount Rogers Formation, it is less intensely deformed than much of the Mount Rogers. Granitoid basement clasts in the Konnarock are typically without foliation or have only a crude foliation subparallel to the regional cleavage in the Konnarock. There are no clasts of mylonitic gneiss or augen gneiss such as those that constitute the Cranberry Gneiss beneath the more highly sheared basal units of the Mount Rogers Formation further southeast. The intense deformation of the Grenvillian basement in the Blue Ridge is, therefore, a Phanerozoic event. Many of the granitic clasts in the Konnarock are porphyritic and contain large phenocrysts of microcline. This texture supports the idea that many of the augen gneisses in the Cranberry were derived by shearing and recrystallizing porphyritic granite.

The clast makeup of the Konnarock diamictite is markedly different from that of conglomerates of the Mount Rogers Formation, even where bedded diamictite is in stratigraphic contact with the conglomerate of the Mount Rogers west of Trout Dale. Clasts in the diamictite are dominantly basement granitoids; clasts in conglomerate of the Mount Rogers are dominantly volcanic rocks, mostly rhyolites from the Mount Rogers. This clast distribution argues against the Konnarock glaciation being alpine on volcanic highlands. The glaciers were clearly moving over exposed basement rocks, but basement rocks in the outcrop area of the Konnarock Formation were mostly covered by the Mount Rogers Formation.

The contact between the Konnarock and Unicoi Formations on Big Hill is concordant. The Mount Rogers and Konnarock Formations thin to featheredges both to the northeast and southwest beneath the Unicoi Formation. For reasons not clear, both the Mount Rogers and Konnarock feather out at about the same places. East of the disappearance of the two formations, where the Unicoi Formation is nonconformably above Grenvillian basement, greenstone dikes cutting the basement rocks terminate at the nonconformity, indicating an erosional interval between the time of intrusion of the dikes and the deposition of the Unicoi (Rankin, 1970). Regionally, therefore, the Unicoi Formation is disconformably above the Konnarock Formation. It must be emphasized, however, that no metamorphic episode or folding event is represented by that disconformity.

Rankin (1976) speculated that the rhyolite of the Mount Rogers Formation was generated at a triple junction of three intersecting continental rifts. Apparently this episode of rifting did not proceed to continental separation and the generation of oceanic crust (Aleinikoff and others, 1991). One of these rifts was hypothesized to have extended roughly northwest from the Mt. Rogers area toward the craton. If this rift or failed arm did exist, most of the evidence for it was eroded along with the thrust sheets that project into the air northwest of Mt. Rogers, or the evidence may be buried deeply far to the southeast in autochthonous Laurentian crust. Support for the former existence of this failed arm or aulacogen comes from the great thickness of the Chilhowee Group in the Mt. Rogers area relative to the thickness of that group northeast and southwest of Mt. Rogers (Rankin, 1976). Perhaps the simultaneous thinning and disappearance of both the Mount Rogers and Konnarock Formations to the northeast and southwest can also be attributed to the presence of this northwest-trending trough at the time of their deposition.

Of the three areas in which the Konnarock Formation is interpreted to be in stratigraphic contact with the Mount Rogers Formation, in one, the contact is an unconformity; in another, the contact is concordant; and in the third, the nature of the contact is indeterminate. In the area south of Konnarock where the map pattern suggests an unconformity, block faulting and rotation of blocks, such as one finds near volcanic centers, could produce the map pattern. No orogenic episode is required. In other areas within the Mt. Rogers volcanic center in the Stone Mountain thrust sheet, combinations of normal faulting and volcanic topography could produce the outcrop areas of older volcanic rocks and volcanic conglomerates that show through the veneer of the Wilburn Rhyolite Member. Two such areas are in the Brier Ridge-Mt. Rogers saddle and in the upper basin of Wilson Creek (fig. 3).

Two of the areas of stratigraphic contact between the Konnarock and Mount Rogers Formations are in the Shady Valley thrust sheet (fig. 2). Rocks of the Shady Valley thrust sheet are thought to have always been palinspastically northwest (using modern directions) of those in the Stone Mountain thrust sheet (Rankin, 1970). The thin Mount Rogers section in the inlier south of Konnarock and the presence of volcanic conglomerate at the top of the Mount Rogers west of Trout Dale indicate that the palinspastic position of those outcrops of the Mount Rogers Formation was distal to and north of the Mt. Rogers volcanic center.

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