[AMERICAN JOURNAL OF SCIENCE, VOL. 288, NOVEMBER, 1988, P. 953-967]

THE AMPHIBOLITIC BASEMENT COMPLEX IN THE BLUE RIDGE PROVINCE OF WESTERN NORTH CAROLINA, PROTO-IAPETUS?

ROGER C. BREWER* and NICHOLAS B. WOODWARD
Department of Geological Sciences, University of Tennessee, Knoxville, Tennessee 37996

ABSTRACT. Present tectonic models of the Blue Ridge Province of western North Carolina correlate the contact between the Amphibolitic Basement Complex and the structurally underlying Cranberry Granitic Basement Complex with a hypothesized Ordovician-Devonian-age "Hayesville-Fries Fault/Suture" separating cratonic rocks from accreted oceanic material. This report involves a structural and petrographic study of these basement complexes and the nature of the contact separating them. The principal study area is located just east of the Hot Springs Window, central western North Carolina.

The Cranberry Complex consists predominantly of biotite granitic gneisses and schists intruded by small bodies of granodiorite to quartz diorite. Other lithologies less typical of the complex include biotite hornblende granitic gneiss, calcsilicate rock, and metapyroxenite. The Amphibolitic Basement Complex consists of locally migmatitic, biotite-hornblende granitic gneisses intruded by and complexly intermixed with amphibolite. Other lithologies less typical of the complex include weakly foliated granitic rock, talc-rich ultramafic rock, metapyroxenite, garnet-chlorite schist, feldspar augen schist, porphyritic metabasalt, diopsidic marble, and calcsilicate rock. Geochemical analyses suggest that the bulk of the amphibolites represent tholeiitic, continental basalts.

The Cranberry Granitic Basement Complex is interpreted to represent a Grenville-age granitic-cratonic complex once attached to the eastern edge of the North American Craton/Canadian Shield. The Amphibolitic Basement Complex is interpreted to represent an intensely disrupted, melange-like complex composed chiefly of transitional crustal material. Both are highly deformed and mylonitized. The contact between the two complexes is interpreted to be a fault, based on truncations of mappable subunits in each complex. Granitic and gabbroic rocks tentatively correlated here with the late Proterozoic Crossnore and Bakersville plutonic suites intrude both the Cranberry and Amphibolitic basement complexes, suggesting a minimum age of late Proterozoic for major movement along the fault separating the complexes.

Contrary to previous interpretations, the contact between the Amphibolitic Basement Complex and the Cranberry Granitic Basement Complex is no younger than late Proterozoic, based on the suggested Crossnore and Bakersville correlations, and therefore cannot be correlated with the hypothesized Ordovician-Devonian-age Hayesville-Fries Fault. The Amphibolitic Basement complex cannot be lithologically or tectonically correlated with the structurally over-

* Present address: Department of Geology, University of Alabama, Tuscaloosa, Alabama 35486

lying Ashe Metamorphic Suite if that suite is of late Proterozoic age (post Crossnore and Bakersville intrusion) as presently interpreted.

INTRODUCTION

In most of lower eastern North America the Archean- to Proterozoic-age core of the Canadian Shield is not exposed, and very little is known about the early geologic history of the shield in this area. However, deep-seated thrust sheets within the Appalachian Orogenic Belt provide small glimpses of allochthonous pieces of the Canadian Shield (fig. 1). Several large thrust sheets containing by old or "Grenville-age" basement rocks are exposed in the Blue Ridge Province of western North Carolina. These represent some of the southernmost exposures of Grenville-age basement in the eastern United States.

At least two groups of Grenville-age basement rocks are exposed in the Blue Ridge Province of North Carolina (fig. 2): (1) cratonic massifs composed predominantly of granitic gneisses and schists, and (2) an elongate belt of amphibolite and ultramafic bearing granitic gneisses and schists referred to by Brewer (ms) as the "Amphibolitic Basement Complex." In addition to the areas denoted in figure 2, a small exposure of amphibolite bearing basement rock is exposed with granitic gneisses in the Ela Dome (Hadley and Goldsmith, 1963; Hadley and Nelson, 1971). Although extensive in area, detailed mapping of the complex is limited to Brewer (ms) and Merschat (1977). This study focuses on describing the lithologic nature and probable age of the Amphibolitic Basement Complex and its tectonic relationship to the structurally underlying granitic basement massifs. New constraints which should be considered for developing regional geologic models of the Blue Ridge Province are introduced. Special reference is made to the hypothesized "Hayesville-Fries Fault," which in past models has been extrapolated to include the contact between the two basement complexes (Hatcher and Odom, 1980; Wehr and Glover, 1985).

REGIONAL GEOLOGY

Geologic setting.—Rankin (1975) and Hatcher (1978) divided the Blue Ridge Province in western North Carolina into two separate terrains (see fig. 2):

1. a western "continental" terrain composed of: (A) Grenville-age granitic basement intruded by Late Proterozoic granites and gabbros of the Crossnore and Bakersville plutonic suites and (B) Late Proterozoic metasedimentary and less common metavolcanic rocks (Ocoee, Grandfather Mountain, and Mount Rogers suites);
2. an eastern "oceanic" terrain composed of intensely deformed Late Proterozoic (?) mixed metasedimentary, metavolcanic, and meta-ultramafic rocks (Ashe, Alligator Back, Tallulah Falls, and Coweeta Suites).

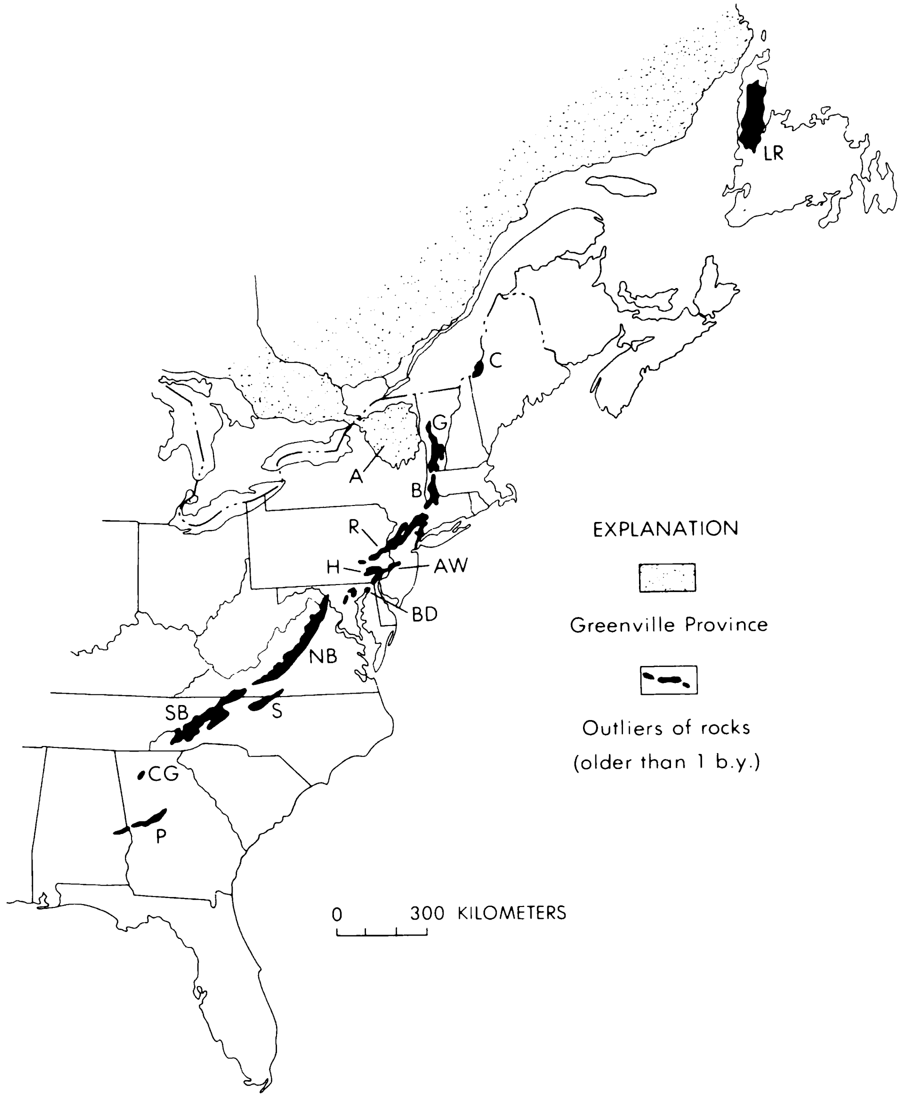


Fig. 1. Exposures of Grenville-age rocks in the Appalachian Orogenic Belt: LR, Long Range; C, Chain Lakes Massif; A, Adirondack Mountains; G, Green Mountains, B, Berkshire Massif; R, Reading Prong; H, Honey Brook Upland; AW, Avondale-West Chester Massif; BD, Baltimore gneiss; NB, Northern Blue Ridge; SB, Southern Blue Ridge; S, Sauratown Mountains; CG, Corbin Granite; and P, Pine Mountain belt. From Drake (1984).

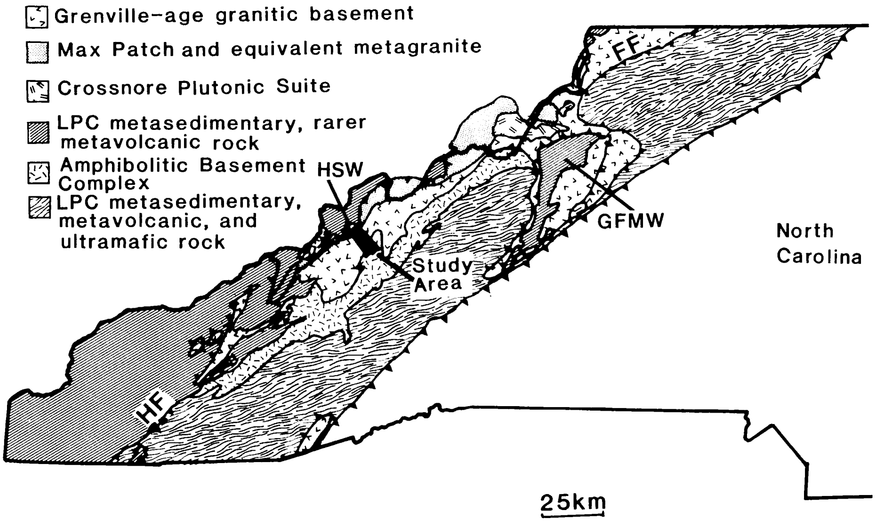


Fig. 2. Generalized geologic map of western North Carolina Blue Ridge Province showing major lithogic packages, major structures, and main study area. HF-Hayesville Fault; FF-Fries Fault; HSW-Hot Springs Window; GFMW-Grandfather Mountain Window. Modified from Brown and others (1985).

As discussed below, the Amphibolitic Basement Complex has at various times been inferred to be most closely related to either the eastern or the western Blue Ridge terrains (Rankin, 1970, 1975; Hatcher and Odom, 1980). The allochthonous eastern Blue Ridge terrain, previously described, structurally overlies the basement complexes. The terrain has been interpreted to represent, in part, the remnants of a Proto-Atlantic or "Iapetus" Ocean that opened during the Late Proterozoic and closed by the Middle to Late Paleozoic (Rankin, 1975; Hatcher, 1978; Abbott and Raymond, 1984). The sedimentary and volcanic rocks of the western Blue Ridge terrain have been interpreted to represent the continental rift equivalents of the eastern Blue Ridge terrain (Rankin, 1975; Hatcher, 1978).

Hayesville-Fries Fault.—The nature of the boundary separating the eastern and western Blue Ridge terrains has been the object of considerable debate over the past two decades. Work in the northwestern portion of the Blue Ridge Province in North Carolina suggests that the contact between the Ashe/Alligator Back Metamorphic Suite and the structurally underlying granitic basement is a major Devonian-age fault (see fig. 2) (Dietrich and others, 1969; Abbott and Raymond, 1984). The fault is commonly referred to as the "Fries Fault," although there is some debate over the use of this name (see Bartholomew and Lewis, 1984). At Fries, Va. the Fries fault carries basement over Chilhowee Group strata (Rankin, 1970). In the southwestern Blue Ridge, Hatcher

(1978) interpreted an Ordovician-age fault at the contact between the Tallulah Falls/Coweeta suites and the structurally underlying, generally volcanic-free, Ocoee metasedimentary rocks and local granitic basement. Hatcher referred to this fault as the "Hayesville Fault."

Recent regional models attempt to correlate the Hayesville and Fries faults as a single, Ordovician-Devonian-age structure collectively referred to as the "Hayesville-Fries Fault" or "suture" (Hatcher 1978; Hatcher and Odom, 1980; Wehr and Glover, 1985). The fault was interpreted to separate a western Blue Ridge Terrain of continental affinity from an eastern terrain of "oceanic" affinity.

The Amphibolitic Basement Complex is exposed southwest of the Grandfather Mountain Window (see fig. 2). Early models of the Blue Ridge grouped the Amphibolitic Basement Complex with the granitic basement complexes of the western terrain (Rankin, 1975), although with quite a different interpretation to ours. In the only previously published detailed mapping involving these rocks, however, Merschat (1977) described widespread amphibolite and ultramafic rock in the complex. Subsequent regional models of the Blue Ridge included the Amphibolitic Basement Complex with the "oceanic" Eastern Blue Ridge Terrain and correlated the Amphibolitic Basement Complex/Granitic Basement contact with the hypothosized Hayesville-Fries Fault (see fig. 2) (Hatcher and Odom, 1980; Wehr and Glover, 1985).

Brewer (1986a) mapped the contact between the Amphibolitic Basement Complex and the Granitic Basement in an area just east of the Hot Springs Window, North Carolina (fig. 2). A generalized geologic map of this area is shown in figure 3. The northwestern portion of the study area is bounded by the Rector Branch Fault, a well exposed ductile shear zone placing Cranberry granitic basement over Late Proterozoic metasedimentary rocks of the Ocoee Series (Oriel, 1951). Structurally overlying the Cranberry Basement Complex and across the hypothesized Hayesville-Fries suture is the Amphibolitic Basement Complex.

CRANBERRY GRANITIC BASEMENT COMPLEX

Detailed mapping of the granitic basement exposures west and northwest of the Grandfather Mountain Window show the unit to represent a heterogeneous basement complex composed of Grenville- or pre-Grenville-age gneisses and schists intruded by slightly younger and less deformed Grenville-age granitic plutons (Bryant and Reed, 1970; Bartholomew and Lewis, 1984). Bartholomew restricts the name "Cranberry" to a specific layered granitic gneiss complex in northwestern North Carolina and assigns this complex to the more regional scale "Elk River Massif." Detailed mapping of the basement southwest of the Grandfather mountain Window is too incomplete to subdivide what Keith (1904) originally termed "Cranberry" into specific massifs. The name "Cranberry" is therefore retained in this study for all exposures of a granitic complex lying structurally below the Amphibolitic Basement Complex. Bryant and Reed (1970) described exposures of the Cran-

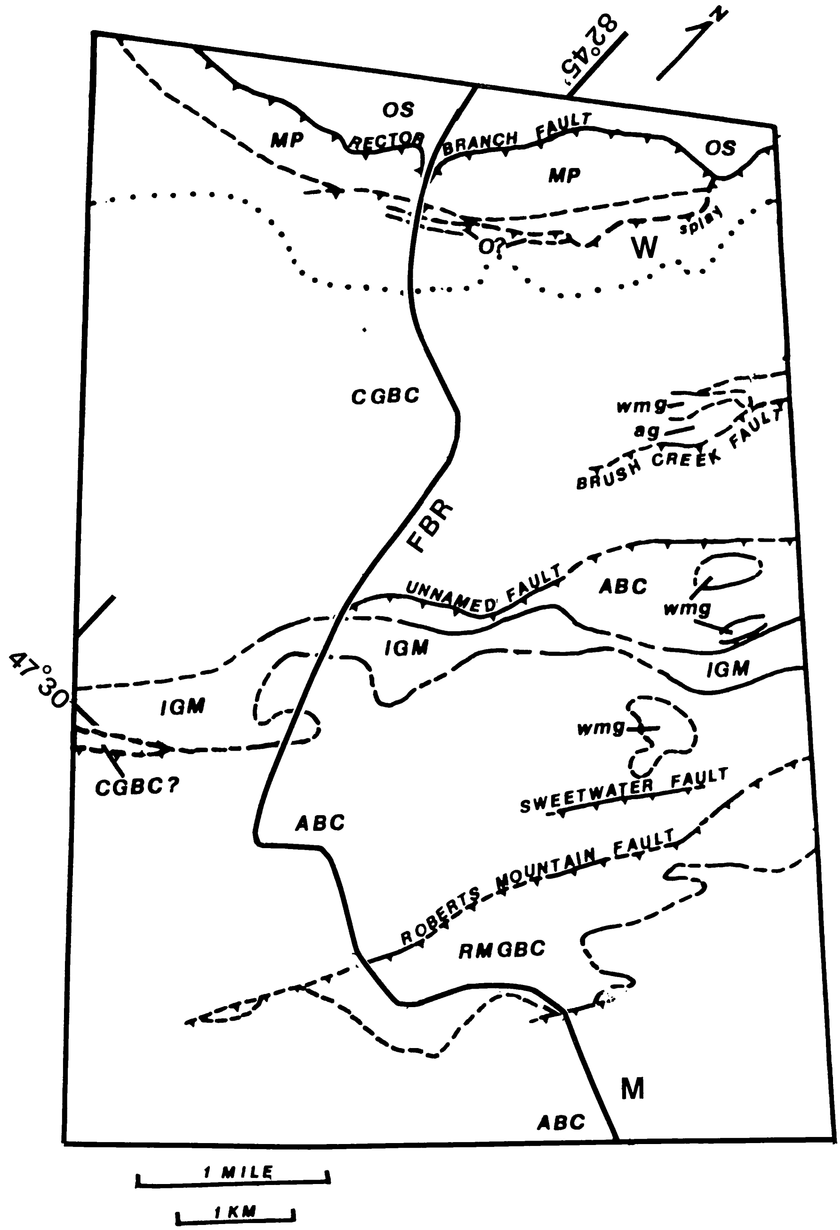


Fig. 3. Generalized geologic map of the study area. OS, Sandsuck Formation-Ocoee Series; 0?, Ocoee ? (isolated fault horses); MP, Max Patch Granite; CGBC, Cranberry Granitic Basement Complex; ABC, Amphibolitic Basement Complex; RMGBC, Roberts Mountain Granitic Basement Complex (upthrown Cranberry equivalent); IGM, Indian Grave Metagranite; ag, amphibolitic gneiss; wmg, white mica granite. W–Walnut, NC; M–Marshall, NC; FBR–French Broad River. Dotted line represents hangingwall extent of major mylonite zone associated with Rector Branch ductile shear zone. From Brewer (ms).

berry Basement north of the study area in the vicinity of the Grandfather Mountain Window. Their descriptions are comparable with the gneissic-plutonic complex exposed in the study area. Published radiometric ages of the Cranberry Complex from exposures to the north of the study area range from 1.8 by to 870 my (Fullagar and Odom, 1978; Monrad and Gulley, 1983; Bartholomew and Lewis, 1984). The most prevalent age is about 1.1 by.

Study area.—In the study area, the Cranberry Complex is composed chiefly of biotite granitic gneisses and schists intruded by small, scattered bodies of weakly foliated granodiorite to diorite (fig. 3). Other lithologies less typical of the complex include biotite hornblende granitic gneiss, calc-silicate rock, and possibly intrusive metapyroxenite. In the study area, as well as throughout the Blue Ridge, the western margin of the complex is marked by the presence of an epidote-rich granite correlated herein with the Late Proterozoic Max Patch Metagranite (Sherkarchi, ms). The Max Patch is deformed concordantly with the Cranberry complex.

AMPHIBOLITIC BASEMENT COMPLEX

The name "Amphibolitic Basement Complex" was introduced by Brewer (ms) to denote the distinctive amphibolitic character and apparent Grenville-age of the complex. Keith (1904) separated "Roan Gneiss" (hornblende gneiss and diorite) from Cranberry "granite" in the Asheville folio, although the name Roan Gneiss has now been dropped by the U. S. Geological Survey. Hadley and Nelson (1971) separated the Amphibolitic Basement Complex from the structurally overlying and underlying units and referred to the complex as an amphibolite bearing "layered gneiss and migmatite," in contrast to the less amphibolitic, granitic gneisses of the Cranberry Complex.

Bryant and Reed (1970) described a correlative "mixed rock unit" southwest of the Grandfather Mountain Window that they described as a transitional lithology between the structurally overlying Ashe Metamorphic Suite and the structurally underlying Cranberry granitic gneisses. The lithologic description and structural position of their "mixed rock unit" are identical to the Ampibolitic Basement Complex delineated in this study.

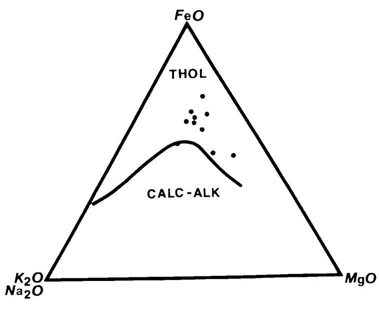
Merschat (1977) completed the only detailed (1:24,000) mapping within the Amphibolitic Basement Complex prior to this study. He referred to the complex as a "light brownish to pinkish grey, massive to well-foliated, biotite hornblende migmatite" in the Mars Hill quadrangle, which is just east of this study area. . . . As did Bryant and Reed (1970), Merschat specifically mapped the unit as separate from the Cranberry and Ashe complexes. Merschat's map units are very similar to those described by Brewer (1986a) and discussed in this paper.

Lithologic description.—In the area just east of the Hot Springs Window, roughly three-fourths of the Amphibolitic Basement Complex is composed of locally migmatitic biotite hornblende granitic gneiss and biotite granitic gneiss (Brewer, ms). The gneisses are intruded by and complexly interfolded with amphibolite. Amphibolite lenses, interlayers, and pods generally compose no more than 20 percent of an exposure. Occurrences of amphibolite range from centimeter-size pods to near mappable lenses (see also Merschat, 1977). Other intermixed lithologies typical of the complex include talc-rich ultramafic bodies (high in Cr and Ni), metapyroxenite, garnet chlorite schist, feldspar augen schist, porphyritic metabasalt, diopsidic marble, calcsilicate rock, and rare kyanite-bearing aluminous metasediments. Small bodies of nonfoliated granodiorite to diorite locally intrude the complex. No consistent stratigraphic order was developed for the complex. Contacts of lithologies other than local amphibolites are generally indistinct or pervasively tectonized. Reconnaissance studies and comparison with other studies suggest that the described lithologic make-up of the complex in the main study area is typical of the complex as a whole.

Amphibolite geochemistry.—Geochemical analyses of amphibolites can be potentially useful in interpreting the protolith of the Amphibolitic Basement Complex. A similar, more extensive geochemical study of amphibolites from the Ashe Metamorphic Suite was conducted by Conte (1986). The data presented here (from Brewer, 1986a) are restricted to the main study area discussed in this report and are not necessarily meant to characterize the complex on a regional scale.

Geochemically, amphibolites from the study area are tholeiitic (fig. 4A). The discriminant diagram plotting Ti/100-Zr-Y*3, developed by Pearce and Cann (1973), suggests that seven of ten amphibolites analyzed may represent within plate basalts (and/or their intrusive equivalents) (fig. 4B). The validity of using this and other discrimination diagrams in metamorphic terrains has yet to be established. However, the locally observed intrusive nature of amphibolites with enclosing

A.



B.

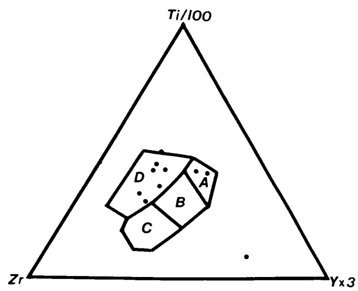


Fig. 4 (A) AFM plot denoting tholeiitic nature of amphibolites. THOL, tholeiitic basalts; CALC-ALK, calc-alkaline basalts. Tholeiite–calc-alkaline boundary after Irvine and Barager (1971). (B) Ti/100–Zr–Y* 3 discrimination diagram (after Pearce and Cann, 1973) showing distribution of amphibolite samples from study area. (A) low potassium tholeiites (volcanic arc basalts); (B) ocean floor and volcanic arc basalts; (C) calc-alkaline basalts (volcanic arc basalts); (D) within plate basalts (ocean island or continental basalts).

biotite granitic gneiss and the general abundance of probably Grenville-age granitic country rock within the Amphibolitic Basement Complex additionally supports a continental setting for the tholeiitic, basaltic rocks.

Age.—Radiometric dating and intrusive relationships bracket the age of the Amphibolitic Basement Complex between ≥ 1.2 by (Grenville-age) and no younger than Late Proterozoic. Hadley and Nelson (1971) inferred a Proterozoic age for their "layered gneiss and migmatite." Rankin (1970, 1975) similarly grouped what this study refers to as the Amphibolitic Basement Complex with the Grenville-age granitic basement terrain structurally underlying the complex and considered these layered gneisses possibly to represent the country rock into which the Cranberry was intruded. Rb/Sr whole-rock dating of a granitic gneiss from exposures of the complex just east of the study area yielded an age of 1.2 by, similarly suggesting a Grenville-age for at least the widespread granitic gneisses of the complex (Fullagar and others, 1979).

Regionally, several Late Proterozoic granitic and gabbroic suites have intruded both basement complexes. Rankin (1970, 1975) reported on the nature and probable origin of the Crossnore Plutonic/Volcanic suite of granitic rocks which intrude the Cranberry Complex in northwestern North Carolina. Goldberg and others (1986) describe the Bakesville Suite of tholeiitic dikes in the northwestern North Carolina Blue Ridge.

Bakersville gabbro has been mapped previously as intruding both complexes just southwest of the Grandfather Mountain Window and just east of the study area (Bryant and Reed, 1970; Merschat, 1977; Goldberg, Butler, and Fullagar, 1986). The age of the Bakersville intrusives has recently been established at 734 my (Goldberg, Butler, and Fullagar, 1986). In the study area, metagabbro dikes locally crosscut the dominant structural trends of both complexes and are mesoscopically similar to the Bakersville suite. These dikes, although deformed, can be easily distinguished from the much more deformed amphibolites of the basement complexes.

A distinct, coarse, pink metagranite, locally named the Indian Grave Metagranite (Brewer, ms), also appears to have intruded across the contact between the two basement complexes in the main study area (fig. 3). The late mylonitic overprint which affects all units in the study area including the dikes and metagranite makes any detailed interpretation of contact relationships difficult. However, the absence of increased mylonitization at the margins of the metagranite and the occurrence of xenoliths of Amphibolitic Basement-like lithologies within the metagranite support an intrusive rather than a tectonic emplacement interpretation for the unit. The granite is texturally and petrographically identical to a very distinct suite of 700 my alkaline granite associated with the Crossnore Plutonic Suite (Rankin, 1970; Odom and Fullagar, 1984) and is therefore correlated with the Crossnore suite in our interpretation. Crossnore granites are known to intrude the Cranberry

Granitic Basement Complex north of the study area but, prior to this study, had not been reported as intruding the Amphibolitic Basement Complex (see Bryant and Reed, 1970; Bartholomew and Lewis, 1984). Unfortunately, exposures of the Indian Cave Grave Metagranite in the main field area were too weathered to use for radiometric dating.

CONTACT RELATIONSHIPS

The contact separating the Amphibolitic Basement Complex and the structurally underlying Cranberry Granitic Basement Complex is marked by a distinctive, widespread, southeastward appearance of complexly interlayered and intermixed amphibolite, scattered ultramafic bodies (although some ultramafic bodies may be present in the granitic basement complexes), and other lithologies described above as characteristic of the Amphibolitic Basement Complex (see Bryant and Reed, 1970; Hadley and Nelson, 1971; Merschat, 1977; Brewer, ms). Merschat (1977) shows amphibolite lenses and mylonite zones truncated at the same contact. On the basis of these relationships and the general restriction of widespread amphibolite and ultramafic rock to the Amphibolitic Basement Complex, the contact is interpreted to be a fault. The intrusion of the Indian Grave Metagranite and Metagabbro dikes into both complexes across the major contact constrains the timing of major movement along the fault to the Late Proterozic if they are correctly correlated with the Crossnore and Bakersville suites.

DISCUSSION

At least four major series of deformational events and possibly two late minor events are interpreted to have led to the present-day configuration of the Amphibolitic Basement and Cranberry Basement Complexes (table 1; Brewer, ms; Brewer, 1986; Brewer and Woodward,

TABLE 1

Sequence of deformational events

Event	Folds	Foliation	Complex	Complex
MIDDLE TO LATE PROTEROZOIC				
D1/M1*		S1	foliation	foliation
D2	F1		folded S1	folded S1
D3			granitic intrusions (prior to ABC D3 ?)	rifting, mafic intrusion
D4/M2		S2		foliation
D5	F2		Cranberry Complex not affected ?	deformation of rift complex
D6				migmatization
D7				quartz veins
D8	F3	S3	dominant foliation, accretion of two complexes, late quartz veins	
734mg-690my				
D9			intrusion of gabbro, granite (Bakersville and Crossnore suites)	

*M = metamorphic foliation.

1986). The sequence of deformation is based on cross-cutting field relationships and correlations with published radiometric dates. This report discusses only the first two series of events: (1) Middle to Late Proterozoic, and (2) Late Proterozoic, or those events occurring up to the initiation of the Appalachian Orogen as it is presently interpreted (see Hatcher 1978, Hatcher and Odom, 1980; Wehr and Glover, 1985; Abbott and Raymond, 1984).

Middle to Late Proterozoic–Protoliths.—The Cranberry Granitic Basement Complex is interpreted to represent a Middle Proterozoic (Grenville-age) granitic cratonic complex (Rankin, 1970, 1975; Bartholomew and Lewis, 1984). Small bodies of granodiorite to diorite intruded the gneissic country rock at some time during this period.

The protolith of the Amphibolitic Basement Complex is inferred here to have developed at some distance from the Cranberry Gneiss with which it is presently in contact. It is interpreted to have been a dominantly plutonic and possibly volcanic complex developed during Middle to Late Proterozoic incipient rifting of Grenville-age granitic crust (D1–D3) (fig. 5A–F) (Brewer, 1986). During this rifting event, gneissic granitic country rock similar to the Cranberry Granitic Basement Complex was intruded by continental, tholeiitic, basaltic magmas now represented by widespread amphibolite. Continued rifting eventually developed some type of transitional crust and may have led to the opening of a "Proto-Iapetus" Ocean of unknown extent. During this period and/or during the closure of the basin, carbonate and terrigenous sediments, now seen as calc-silicate and schist pods, were deposited.

Middle to Late Proterozoic-Closure.—Closure of this basin during the Middle to Late Proterozoic resulted in the intense deformation of the transitional crust and the ultimate accretion of portions of the complex (representing the developing Amphibolitic Basement Complex) to the granitic, cratonic basement massifs of the Canadian Shield (D4–D8) (fig. 6C-D). Blocks of upper mantle peridotite now represented by dunite to altered talc-rich ultramific bodies, dolomitic carbonates now represented by diopsidic marble, and apparently very rare aluminous sedimentary rock now represented by kyanite-bearing metaquartzites were tectonically incorporated into the complex during closure of the basin. Ductile faulting juxtaposing the two complexes and amphibolite to higher facies metamorphism of the basement complexes probably occurred sometime during this event (Brewer, ms). Merschat (1977) recorded the presence of granulite facies minerals in the Amphibolitic Basement Complex in the adjacent Mars Hill quadrangle. Overall, the Amphibolitic Basement Complex now exposed in the Blue Ridge is interpreted to represent a melange-like accretionary terrain recording this Late Proterozoic closure event.

Late Proterozoic.—During the Late Proterozoic (approx 700 my BP), the granitic basement complex and the structurally overlying Amphibolitic Basement Complex were intruded by granitic and gabbroic magmas of the Crossnore and Bakersville plutonic suites (D9). The

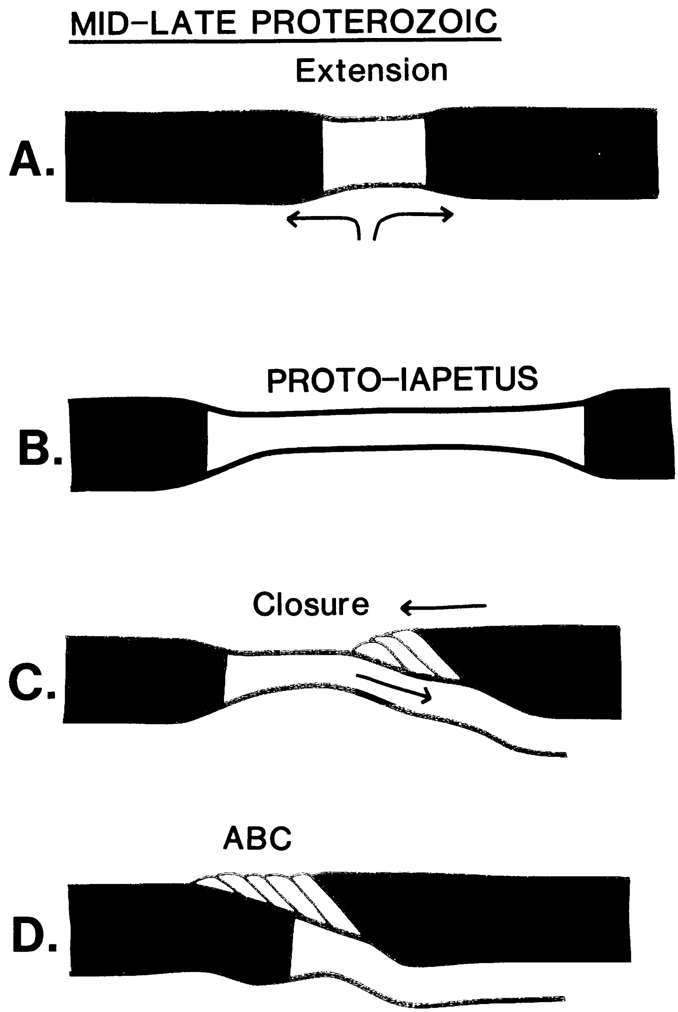


Fig. 5. Proterozoic development of Amphibolite Basement Complex. (A-B) Middle to Late Proterozoic extension of granitic cratonic margin (equivalent to Cranberry Basement Complex) and development of Proto-Iapetus ocean or transitional crustal material; (C-D) Middle–Late Proterozoic closure of Proto-Iapetus Ocean and subsequent accretion of Amphibolitic Basement Complex to Cranberry Basement.

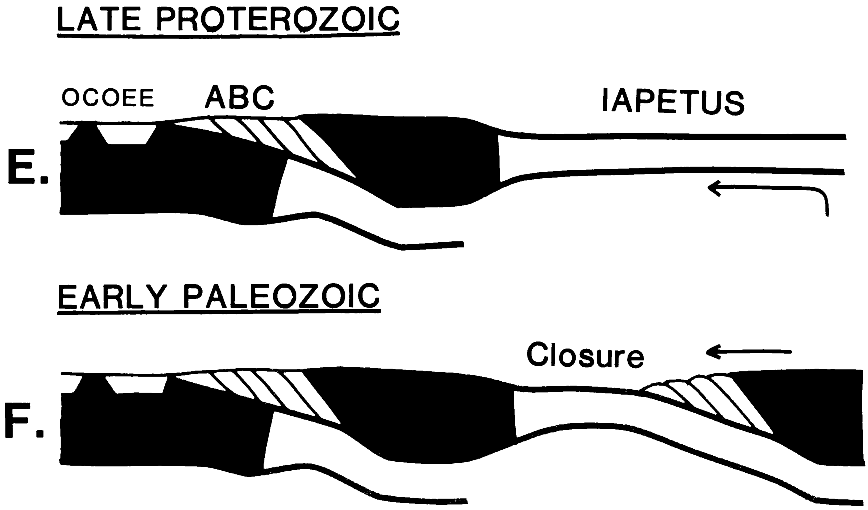


Fig. 5 (continued) (E) Late Proterozoic development of Iapetus Ocean and continental rift strata of the Ocoee, Grandfather Mountain, Mount Rogers and equivalent series. Cranberry and Amphibolitic Basement complexes intruded by Bakersville and Crossnore plutonic suites; (F) Early Paleozoic initiation of the closure of the Iapetus ocean.

intrusion of these magmas is interpreted by Rankin (1975) to reflect Late Proterozoic crustal thinning associated with the opening of a Proto-Atlantic or "Iapetus" Ocean (fig. 5E).

If we accept this Late Proterozoic timing for the opening of the Iapetus Ocean, the Amphibolitic Basement Complex must represent an intrusion, deformation, and metamorphism sequence unrelated to Paleozoic Appalachian orogenesis. It may represent the opening and closing of an older "Proto-Iapetus" Ocean. During the Middle to Late Paleozoic, closure of the younger Iapetus Ocean led to the accretion of the eastern Blue Ridge terrain to the eastern margin of North America, including the already emplaced Amphibolitic Basement Complex (fig. 5F) (see Hatcher, 1978; Hatcher and Odom, 1980; Abbott and Raymond, 1985).

CONCLUSIONS

The Amphibolitic Basement Complex exposed in the Blue Ridge Province of western North Carolina is interpreted to represent at least locally a melange-like accretionary complex recording the Middle to Late Proterozoic opening and closing of a previously unrecognized "Proto-Iapetus" Ocean. The intrusion of rocks correlated here with both the Late Proterozoic Bakersville metagabbro and Crossnore Granite into both the Amphibolitic Basement Complex and the structurally underlying Granitic Basement complexes suggests a Middle to Late Proterozoic age for the fault contact separating the two complexes.

The contact separating the basement complexes cannot be directly related to the hypothosized Ordovician-Devonian-age "Hayesville-Fries Fault" as previously interpreted (Hatcher, 1978; Hatcher and Odom, 1980; Wehr and Glover, 1985). In turn, the Amphibolitic Basement Complex probably cannot be tectonically or lithologically related to the structurally overlying Ashe/Alligator Back, Tallulah Falls/Coweeta suites if these suites are interpreted to have developed after the intrusion of the Bakersville and Crossnore plutonic suites (younger than 700 my BP) (Rankin, 1975; Brewer, 1986). If a single, continuous, Ordovician-Devonian "Hayesville-Fries Fault" can be drawn separating a western Blue Ridge terrain displaying "continental" affinities from an eastern terrain displaying "oceanic" affinities, results from this study suggest that the boundary must lie no farther west than the upper or eastern contact of the Amphiboiltic Basement Complex.

ACKNOWLEDGMENTS

Appreciation is expressed to Carl E. Merschat, Leonard S. Wiener, Loren A. Raymond, Richard N. Abbott, Harry Y. McSween, Jr., Theodore C. Labotka, and the students at the University of Tennessee all of whom provided invaluable discussions throughout the study. Otto C. Kopp assisted with XRF analysis. This study was partially funded by grants from the University of Tennessee Department of Geological Sciences Discretionary Fund, Sigma Xi, and the Geological Society of America-Southeastern Section.

REFERENCES

Abbott, R., and Raymond, L., 1984, The Ashe Metamorphic Suite, northwest North Carolina: Metamorphism and observations on geologic history: Am. Jour. Sci., v. 284, p. 350–375.

Bartholomew, M., and Lewis, S., 1984, Evolution of the Grenville massifs in the Blue Ridge geological province, southern and central Appalachians: *in* Bartholomew, M., and others, eds., The Grenville event in the Appalachians and related topics: Geol. Soc. America Spec. Paper 194, p. 235–267.

Brewer, R., ms, 1986, Structure and petrography of the basement complexes east of the Hot Springs Window, Blue Ridge Province, western North Carolina: M.S. dissert., Knoxville, Univ. Tennessee, 196 p.

———— 1986, Proto-Iapetus? The Amphibolitic Basement Complex in the Blue Ridge Province of western North Carolina [abs.]: Geol. Soc. America Abs. with Programs, v. 18, p. 550.

Brewer, R., and Woodward, N., 1986, Structure and petrology across the "Hayesville-Fries Boundary", Blue Ridge Province, North Carolina: Geol. Soc. America Abs. with Programs, v. 18, p. 213.

Brown, P., and others, 1985, Geologic Map of North Carolina: North Carolina Div. Land Resources, scale 1:500,000.

Bryant, Bruce, and Reed, J., 1970, Geology of the Grandfather Mountain Window and vicinity, North Carolina and Tennessee: U.S. Geol. Survey Prof. Paper 615, 190 p.

Conte, J., ms 1986, Geochemistry and tectonic significance of amphibolite within the Precambrian Ashe Formation, Northwestern North Carolina: Knoxville, Univ. Tennessee, 122 p.

Dietrich, R., Fullagar, P., and Bottino, M., 1969, K/Ar and Rb/Sr dating of tectonic events in the southern Appalachian of southwestern Virginia: Geol. Soc. America Bull., v. 80, p. 307–314.

Drake, A., 1984, The Reading Prong of New Jersey and eastern Pennsylvania: An appraisal of rock relations and chemistry of a major Proterozoic terrane in the Appalachians, *in* Bartholomew, M., and others, eds., The Grenville event in the Appalachians and related topics: Geol. Soc. America Spec. Paper 194, p. 75–109.

Fullagar, P. D., Hatcher, R. D., Jr. and Merschat, C. E. 1979, 1200 my-old gneisses in the Blue Ridge Province of North and South Carolina: Southeastern Geology, v. 20, p. 69–77.

Fullagar, P., and Odom, A., 1973, Geochronology of Precambrian gneisses in the Blue Ridge province of northwestern North Carolina and adjacent parts of Virginia and Tennessee: Geol. Soc. America Bull., v. 84, p. 3065–3080.

Goldberg, S., Butler, R., and Fullagar, P., 1986, The Bakersville dike swarm: Geochronology and petrogenesis of Late Proterozoic basaltic magmatism in the southern Appalachian Blue Ridge: Am. Jour. Sci., v. 286, p. 403–430.

Hadley, J., and Nelson, A., 1971, Geologic map of the Knoxville quadrangle, North Carolina, Tennessee, and South Carolina: U.S. Geol. Survey Misc. Geol. Inv. Map I-654, scale 1:250,000.

Hatcher, R. D., 1978, Tectonics of the western Piedmont and Blue Ridge, southern Appalachians, USA: Review and speculation: Am. Jour. Sci., v. 278, p. 276–304.

Hatcher R. D. Jr., and Odom, P., 1980, Timing of thrusting in the southern Appalachians, USA: model for orogeny?: Geol. Soc. London Jour., v. 137, p. 321–327.

Irvine, T., and Barager, W., 1971, A guide for the chemical classification of common volcanic rocks: Canadian Jour. Earth Sci., v. 8, p. 523-548.

Keith, A., 1904, Description of the Ashville quadrangle (North Carolina-Tennessee): U.S. Geol. Survey Atlas, Ashville folio (no. 116), 10 p.

Merschat, C., 1977, Geologic map and mineral resources summary of the Mars Hill quadrangle, North Carolina: North Carolina Office Earth Resources GM 191-SE and MRS 191SE, scale 1:24,000.

Monrad, J., and Gulley, G., 1983, Age and P-T conditions during metamorphism of granulite-facies gneisses, Roan Mountain, NC-TN, *in* Lewis, S., ed., Geological investigations in the Blue Ridge of northwestern North Carolina: 1983 Guidebook for the Carolina Geological Society, North Carolina Division of Land Resources, Article 4, 29 p.

Odom, A., and Fullagar, P., 1984, Rb/Sr whole rock and inherited zircon ages of the plutonic suite of the Crossnore Complex, southern Appalachians, and their implications regarding the time of opening of the Iapetus Ocean, *in* Bartholomew, M., and others, eds., The Grenville event in the Appalachians and related topics: Geol. Soc. America Spec. Paper 194, p. 255–261.

Oriel, S., 1951, Structure of the Hot Springs Window, Madison County, North Carolina: Am. Jour. Sci., v. 249, p. 1–30.

Pearce, J., and Cann, J., 1973, Tectonic setting of basic volcanic rocks determined using trace element analyses: Earth and Planetary Sci. Letters, v. 19, p. 290–300.

Rankin, D. W., 1970, Stratigraphy and structure of Precambrian rocks in northwestern North Carolina, *in* Fisher, G. W. and others, eds., Studies of Appalachian Geology, Central and Southern: New York, John Wiley & Sons, p. 227–245.

———— 1975, The continental margin of eastern North America in the southern Appalachians: The opening and closing of the proto-Atlantic Ocean: Am. Jour. Sci., v. 275-A, p. 298–336.

Shekarchi, E., ms, 1959, The geology of the Flag Pond quadrangle, Tennessee-North Carolina: Ph. D. dissert, Knoxville, Univ. Tennessee, 140 p.

Wehr, F., and Glover, L., 1985, Stratigraphy and tectonics of the Virginia-North Carolina Blue Ridge: Evolution of a late Proterozoic-early Paleozoic hinge zone: Geol. Soc. America Bull., v. 96, p. 285–295.