MAFIC ROCKS OF THE SOUTHERN APPALACHIANS: A REVIEW
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ABSTRACT. Mafic rocks (greenstone, amphibolite, gabbro, meta-
gabbro, metadiabase, metadiorite), ranging in age from late Pre-
cambrian to middle Paleozoic, are widely distributed in the southern
Appalachian lithotectonic belts and provide constraints for tectonic
settings of these belts. Mafic rocks of the Blue Ridge belt, particu-
larly abundant in the Hayesville (-Fries?) thrust sheet, are domi-
nantly subaerially erupted metabasalts of tholeiitic affinity, which
occur as conformable units in late Precambrian stratified sequences
(Catoctin, Lynchburg, Ashe, Ashland, and correlatives). Their in-
trusive equivalents intrude the stratified sequences as well as the
underlying granitic basement complex. The late Precambrian vol-
canism, related to a divergent plate tectonic setting, continued at a
much reduced scale into early Paleozoic time which probably marks
the culmination of the major rifting episode. In contrast, the Devo-
nian Hillabee Greenstone complex (Talladega belt) at the southwest-
ern fringe of the Blue Ridge belt shows tholeiitic and calc-alkaline
affinities suggestive of a volcanic arc or actively developing con-
tinental margin environment.

Metabasalts of tholeiitic affinity and probable late Precambrian
age are also abundant in the Inner Piedmont belt. Some of these
(for example, the Dadeville Complex) are associated with younger
but pre-metamorphic mafic intrusives. Parental magmas for these
mafic rocks were probably generated and emplaced in an island arc
or continental margin environment. Mafic rocks of the Kings Moun-
tain, Charlotte, and Carolina slate belts include metamorphosed late
Precambrian to Cambrian basaltic flows and tuffs deposited in sub-
marine environments and a large number of pre- (or syn-) and
post-metamorphic gabbroic complexes. The metavolcanics, which
show both tholeiitic and calc-alkaline trends, are typical of island-arc
settings; the gabbros, which are particularly concentrated along an
areuate chain in the Charlotte belt, may represent the eroded
plutonic core of a Paleozoic arc. Mafic (-ultramafic) complexes of
likely ophiolitic affinity and mélangé terranes containing fragments
of oceanic crust have been reported from the Blue Ridge and the
Eastern slate belt. The distribution and character of the mafic rocks
in the southern Appalachians is compatible with the concept of
suspect terranes proposed by Williams and Hatcher (1982).

INTRODUCTION

Metamorphic rocks of mafic composition comprise significant parts of
the stratigraphy of the southern Appalachians, and mafic intrusions are
important phases of the major igneous events in this region. Within the
past 20 yrs, there have been numerous studies of individual units or
plutons but no attempts to place all these mafic bodies into a systematic
regional framework. This stems in part from the fact that ideas about

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southern Appalachian tectonics have evolved rapidly over this period but is also due to lack of sufficient field, petrologic, and geochemical data on the mafic rocks themselves. This paper is a review of previous studies of mafic rocks in this region, with emphasis on units for which the most information is available. We expect that the recognized regional patterns of mafic rocks will provide further constraints on tectonic models for this part of the Appalachian orogen.

GEOLoGIC SETTING

Lithotectonic belts of the southern Appalachians.—The southern Appalachians conventionally refer to that portion of the Appalachian orogenic belt extending southwestward from Roanoke, Va., to the Gulf Coastal Plain (Rodgers, 1949). The southern Appalachians can be divided into three contrasting physiographic provinces which approximately coincide with geologic strike belts, differing from each other in certain lithologies, structural styles, and grades of metamorphism (King, 1955). These are: (1) the Valley and Ridge, an area of unmetamorphosed Paleozoic clastic and carbonate rocks; (2) the Blue Ridge, consisting of metasedimentary and metabasaltic rocks of Precambrian-Paleozoic age underlain by a basement complex of Grenville age; and (3) the Piedmont, composed of an assemblage of metamorphic and plutonic igneous rocks of Precambrian-Paleozoic age, bounded on the west by the Brevard Zone, a narrow belt of intensely sheared, lower-grade metamorphic rocks, and on the east and south by the Coastal Plain. Further subdivisions of the Piedmont from northwest to southeast, are (fig. 1): (A) the Inner Piedmont belt, comprising high-grade migmatitic rocks; (B) the Kings Mountain belt, consisting of schists with some quartzite and marble of greenschist and amphibolite facies; (C) the Charlotte belt, characterized by gneisses of amphibolite facies and an abundance of intrusive rocks; (D) the Carolina slate belt, with greenschist facies assemblages of metasedimentary and metavolcanic rocks; (E) the Kiokee and Raleigh belts, high-grade terrains affected by Hcorynian metamorphism and separated from the Carolina slate belt by the Eastern Piedmont fault system; and (F) the Pine Mountain belt in Georgia and Alabama, comprising a sequence of quartzite, marble, and mica schist, which overlies a terrane of Precambrian basement.

Regional distribution of lithologies.—The distributions of Triassic basins, Paleozoic metasediments, late Precambrian metasediments, and Precambrian basement gneisses in the southern Appalachians are shown in figure 1. Original lithologies in the Piedmont are not shown, as most areas represent complex mixtures of metamorphosed sedimentary, pyroclastic, and igneous rocks whose distributions have not been adequately mapped on a regional scale. In the lower right of this figure is an inset for northern Virginia that represents an extension of the northeastern (righthand) section of the map.

Mafic rocks are distributed unevenly throughout the region, as shown in figure 1. Most of the large exposures of mafic rocks are Precambrian metabasalts that occur within the eastern Blue Ridge and Inner Piedmont
belts. Mafic rocks are absent in the Valley and Ridge and are uncommon in the western Blue Ridge, the notable exception being the Paleozoic metavolcanic rocks in Alabama. Mafic rocks in the eastern Piedmont consist of early Paleozoic flows and pyroclastic rocks and several generations of Paleozoic gabbroic intrusions. Rocks of possible ophiolitic affinity occur in several locations of the Blue Ridge and Piedmont. Mesozoic diabase dikes are also scattered throughout the region, but these will not be considered in this paper.

Figure 1 is modified primarily from a similar map by Misra and Keller (1978) and references therein, with additional data from Griffin (1974), Hartley (1973), Kite and Stoddard (1984), Pavlides, Gair, and Cranford (1982), and McElhaney and McSween (1983). Unpublished data obtained through personal communication with R. D. Hatcher, Jr., J. R. Butler, J. F. Conley, and D. J. Milton were also used in this compilation.

BLUE RIDGE BELT

On the basis of lithology, stratigraphy, and age, the Blue Ridge belt may be divided into the following broad units (fig. 1): (1) Grenville-age granitic basement rocks which form the cores of the Blue Ridge anticlinorium (Virginia and North Carolina), the Sauratown Mountain anticlinorium (Virginia), and the Tullulah Falls and Toxaway domes (Georgia), and occur in the structural windows (for example, the Grandfather Mountain window); (2) late Precambrian metasedimentary-metavolcanic sequences, which include the rocks exposed at the flanks of the Blue Ridge anticlinorium (Catotin, Lynchburg, Ashe formations and their equivalents), the Ocoee Supergroup (and its correlatives such as the Tullulah Falls Formation), and the Ashland-Wedowee belt (Georgia-Alabama); and (3) early Paleozoic metasedimentary sequences mainly at the western fringe of the Blue Ridge belt (for example, Chilhowee Group and Talladega belt) but also including the Murphy synclinal belt. The western boundary of the Blue Ridge belt is marked by the Valley and Ridge belt, devoid of volcanics except for thin bentonite beds. Triassic diabase dikes, and minor occurrences of basaltic and andesitic volcanics (Johnson, Milton, and Dennison, 1971). Despite lack of agreement on the nature and significance of the Brevard Zone (Hurst, 1973; Neathery and Reynolds, 1973; Rankin, 1975; Hatcher, 1978), it is generally regarded as the eastern boundary of the Blue Ridge belt from the Coastal Plain overlap in Alabama to about the Smith River Allochthon, Virginia; northeastward in Virginia Blue Ridge rocks rest against the lower Paleozoic Evington Group (James River synclinorium).

Metamorphosed mafic rocks are found in all the three Blue Ridge units, but with marked differences in their form, distribution, and abundance. Mafic rocks are fairly abundant in basement rocks (Cranberry Gneiss), commonly as thin dikes and small intrusions of gabbroic composition. In contrast, in the overlying stratified sequences (late Precambrian-early Paleozoic) they occur predominantly as conformable units of extrusive origin. The mafic rocks form an integral component of almost all late Precambrian stratified sequences and only locally are associated
with significant quantities of felsic volcanic rocks. The mafic bodies (as well as ultramafites) are particularly abundant in, although not restricted to, the Hayesville-(Fries?) thrust sheet (Hatcher, 1978) in the eastern Blue Ridge. The Mount Rogers Formation, the Bakersville Gabbro, and the Catoctin Greenstone are the major exceptions to this generalization. Except for a few dikes and sills of altered diorite, diabase, and amphibolite (for example, Hurst, 1955a), which may be late Precambrian or as young as Middle Paleozoic (Bryant and Reed, 1970a), the Ocoee Super-group does not contain any mafic rocks (Hadley, 1970). However, isolated mafic-ultramafic complexes occur in the Tallulah Falls Formation which is considered to be the high-grade equivalent of the Ocoee (Hatcher, 1973). Continuation of late Precambrian volcanism into early Cambrian (?) time, although at a much reduced scale, is evidenced by the presence of metabasalt flows in the lower to middle part of the Unicoi Formation (lowermost formation of the Chilhowee Group) in Tennessee and Virginia and metabasalts (Slippery Creek greenstone) in the Evington Group in Virginia. Except for scattered Mesozoic diabase dikes, the youngest mafic rocks in the southern Blue Ridge are represented by the Hillabee Greenstone (early to middle Devonian) of the Talladega belt in Alabama (Tull and Stow, 1980).

**Basement Complex.**—Swarms of dikes and irregular plugs of metamorphosed gabbro, diabase, and basalt are widespread in the vicinity of Asheville, N.C. and northeastward into Virginia, and at places make up as much as 30 percent of the Cranberry Gneiss terrane (the Elk Park plutonic group of Rankin, Espenshade, and Shaw, 1973). The dikes, which also cut the overlying late Precambrian metasedimentary sequences, are believed to have served as feeders for the volcanic components of the Ashe and equivalent formations (Bryant and Reed, 1970a). Similar metadiabase dikes in the basement rocks beneath the Catoctin Formation in Virginia have also been considered feeders for the Catoctin flows (Reed, 1955; Bloomer and Werner, 1955). According to Rankin (1970), most of these mafic rocks in the Basement Complex are probably intrusive equivalents of the late Precambrian volcanic rocks, but some may be as young as the basaltic flows of the lower Cambrian (?) Unicoi Formation. However, there may not be any genetic relationship between the mafic dikes in the Cranberry Gneiss and the metabasalts of the Ashe if the Cranberry Gneiss-Ashe contact is a fault as interpreted by Abbott and Raymond (this issue, p. 350-375).

Mafic bodies are particularly abundant west of the Grandfather Mountain window where they are known as the Bakersville Gabbro, grouped as part of the Crossnore plutonic-volcanic group by Rankin, Espenshade, and Shaw (1978). The rocks have been subjected to varying grades of metamorphism (up to amphibolite facies) during Paleozoic regional metamorphism but still preserve a variety of relict igneous textures (porphyritic, diabasic, ophitic). Phenocrysts of relict plagioclase are recognizable, and some of them show pronounced normal zoning (Bryant and Reed, 1970b). From limited chemical analyses, Wilcox and Poldervaart (1958) suggested that the Bakersville mafic rocks represent a differentiated
suite of olivine basalts. Similar mafic dikes and sills which intrude the Wilson Creek Gneiss and rocks of the Grandfather Mountain Formation inside the Grandfather Mountain window are called the Linville Metadiabase. This unit, which may have fed the basalt flows in the Grandfather Mountain Formation, is probably equivalent to the Bakersville Gabbro, although there is no direct evidence of such a correlation (Bryant and Reed, 1970b).

Catoctin Greenstone.—The Catoctin Formation in Virginia (loc. 1, fig. 1) is composed predominantly of flows of mafic composition (greenstones), except at the northern end of the Blue Ridge anticlinorium where felsic rocks (metarhyolite flows with some ash flow tuffs) become the dominant constituent. U-Pb ages of zircons suggest that the Catoctin rhyolite in Pennsylvania, similar in composition to the rhyolite of the Mount Rogers Formation (Rankin, 1976b), has an age of about 820 my (Rankin and others, 1969); an upper Precambrian age for the Catoctin is also suggested by its stratigraphic relationships (Espenshade, 1970). In the southeastern limb of the Blue Ridge anticlinorium, the Catoctin either overlies or interfingers with the Lynchburg Formation (late Precambrian). In the northwestern limb, minor amounts of mafic basaltic rocks in the Swift Run Formation, which underlies the Catoctin and is considered equivalent to the Lynchburg (Brown, 1970), are mineralogically and chemically similar to the Catoctin Greenstone (Bloomer and Werner, 1955). Thus, it is not clear if the Catoctin in the northwestern limb is of the same age or younger than that in the southeastern limb. Recently, Lukert and Clarke (1981) have argued that the Catoctin must be younger than the Robertson River granite (700 my), and Mose (1981) has raised the possibility that it may be as young as Cambrian. In any case, presence of amygdaloidal basalt flows in the Unicoi Formation (Stose and Stose, 1957; Rankin, 1976b) and in the Evington Group (Brown, 1958), similar to those in the Catoctin, suggests that volcanism similar to the Catoctin continued into early Paleozoic time.

Well-preserved amygdaloidal textures in the greenstones attest to their extrusive origin (Bloomer and Werner, 1955; Reed and Morgan, 1971). Columnar joints can be observed at places, but no pillow structures have been observed. Individual flows can be recognized by schistose zones formed in amygdular and breccia flow tops. The greenstones are dominantly basaltic, metamorphosed to greenschist facies, although rocks of andesitic composition have been reported at places (Bloomer and Bloomer, 1947; Bloomer and Werner, 1955; Blackburn and Brown, 1976).

Because of their mineralogy, high Na contents, and association with eugeosynclinal sediments, Bloomer and Werner (1955) and Brown (1958) interpret the metabasalts as eugeosynclinal spilites. On the other hand, field evidence such as the presence of flow-top breccias and columnar jointing and the absence of pillow structure suggests that the basalts were subaerial (Reed, 1955). From detailed chemical studies, Reed (1964) and Reed and Morgan (1971) concluded that the basalts were tholeiitic and have acquired their present high Na due to metamorphic segregation of Na-depleted epidote–quartz masses. However, according to Rankin
the high alkali content of the Catoctin metabasalts reflects an original alkalic composition. Using immobile trace element discriminant diagrams, Blackburn and Brown (1976) and Davis, Blackburn, and Brown (1978) have interpreted the Catoctin greenstones to represent continental tholeiites related to rifting.

**Lynchburg and Ashe Formations.**—The late Precambrian Lynchburg Formation, exposed in the southeastern flank of the Blue Ridge anticlinorium, unconformably overlies the basement rocks (the Virginia Blue Ridge Complex) and conformably underlies the Catoctin Formation (or, the Evington Group where the Catoctin pinches out). The Lynchburg predominantly is a metasedimentary sequence (greenschist to amphibolite facies), but it contains many mafic and ultramafic bodies which may be genetically related (Bloomer and Werner, 1955; Stose and Stose, 1957). Both the ultramafites (chlorite–amphibole schist, serpentinite, soapstone, and partially altered peridotite), particularly numerous in the upper part of the formation, and the mafic rocks (amphibolite and hornblende gneiss) occur as concordant and discordant bodies. According to Brown (1970), the concordant mafic bodies may have been mostly lavas and tuffs, and the discordant bodies feeders to the Catoctin fissure eruptions. The chemistry of the mafic rocks remains to be studied, but the field relations are compatible with this interpretation.

Rankin (1970) proposed the name Ashe Formation for the thick sequence of stratified metasedimentary-metavolcanic rocks (mostly amphibolite facies) in northwestern North Carolina (loc. 2) that lies unconformably above the Cranberry Gneiss. Subsequently, Rankin, Espenshade, and Shaw (1973) subdivided this sequence into two formations—the Ashe (late Precambrian), correlative with the Lynchburg in Virginia, and the Alligator Back (younger Precambrian and/or early Paleozoic), probably correlative with the Evington Group in Virginia. Mafic bodies (amphibolite, hornblende gneiss, greenstone), commonly associated with ultramafic bodies, occur throughout the Ashe Formation and in the layered gneisses and schists of the Spruce Pine area, N.C., (Brobst, 1962), which have been correlated with the Ashe (Rankin, 1970). The individual amphibolite units range in thickness from a few centimeters to hundreds of meters. The amphibolites have been interpreted as metamorphosed basaltic flows and penecontemporaneous shallow intrusives on the basis of the following lines of evidence (Rankin, 1970; Rankin, Espenshade, and Shaw, 1973): (1) some amphibolites are relatively coarse-grained with relict gabbroic textures; (2) finer-grained amphibolites contain tabular phenocrysts of altered plagioclase, closely resembling phenocrysts in the metabasalts of the Mount Rogers Formation; (3) mafic dikes and small gabbro bodies cut the Cranberry Gneiss immediately below the Ashe Formation, suggesting that they were feeders to the Ashe metavolcanics; (4) geochemistry of the amphibolites resembles that of basalt (Bryant and Reed, 1970b); (5) initial $^{87}$Sr/$^{86}$Sr ratios are similar to those of basalts (Bottino, 1971); and (6) a metasedimentary origin is unlikely because at
lower metamorphic grade the Ashe contains greenstones, but dolomitic beds have not been found.

Amphibolite bodies are also scattered within the Alligator Back Formation and appear to be concentrated adjacent to areas of abundant amphibolites in the Ashe Formation. No relict textural features have been observed in the Alligator Back amphibolites, but by analogy with the Ashe they are also regarded as metavolcanic rocks (Rankin, Espenshade, and Shaw, 1973).

A close spatial association between the ultramafic and mafic bodies in the Ashe Formation suggests a genetic relationship, but some of the ultramafic bodies may have been emplaced independently of the amphibolites (Rankin, Espenshade, and Shaw, 1973). Rankin (1975) considered the Ashe (and its equivalents) to represent a marine sequence of volcanics and sediments formed within a rift system. Recently, Swanson and Raymond (1977) and Abbott and Raymond (1982) have interpreted the Ashe as a possible mélangé which, with its ophiolitic mafic and ultramafic rocks, was obducted onto the Grenville basement (Cranberry Gneiss). The plate-tectonic setting of the Ashe is discussed in detail by Abbott and Raymond (this issue).

Mount Rogers and Grandfather Mountain Formations.—The Mount Rogers Formation (loc. 3) in the northwest flank of the Blue Ridge anticlinorium and the Grandfather Mountain Formation (loc. 4) within the Grandfather Mountain window are thick sequences of late Precambrian metasedimentary and metavolcanic rocks, characterized by significant amounts of felsic volcanic rocks in addition to mafic rocks similar to those in the Ashe Formation. According to Rankin (1970), the Mount Rogers and Grandfather Mountain Formations were coeval with, and represent different lithofacies of, the Ashe Formation. Zircons from metarhyolites of these two formations have yielded the same age (about 820 my; Rankin and others, 1969) as those from the Catoctin Formation.

The Mount Rogers Formation may be roughly divided into three parts (Rankin, 1970): a lower heterogeneous unit consisting of interbedded sedimentary rocks, basalt, and rhyolite; a middle unit characterized by thick masses of rhyolitic lava and ash flows; and an upper unit of sedimentary rocks containing minor rhyolite and basaltic pillow lava. The most distinctive feature of this formation is the presence of thick subaerially erupted rhyolite masses around three volcanic centers (Rankin, 1975), some with peralkaline affinity (Rankin, Lopez-Escobar, and Frey, 1974; Novak and Rankin, 1980).

Volcanic rocks are also common in the relatively low-grade Grandfather Mountain Formation, but they form a much smaller proportion compared to the Mount Rogers Formation. The volcanic rocks include minor amounts of rhyolitic flows and tuffs mostly in the basal part of the Formation, local occurrences of mafic flows and tuffs in the lower part, and a prominent greenstone unit (the Montezuma Member) at a higher stratigraphic level. Some of the mafic flows show well-preserved relict porphyritic and amygdaloidal textures; the Montezuma greenstone shows
only indistinct igneous texture, except for prominent amygdaloidal zones. Chemically, the mafic rocks are basalts similar to the Catoctin Greenstone; their somewhat higher Na contents have been attributed to albitionization (Bryant and Reed, 1970b).

**Tallulah Falls Formation.**—Near the Georgia-North Carolina border (loc. 5) occur a number of mafic/ultramafic complexes that are distinct from other mafic occurrences in the Blue Ridge. These units were emplaced into paragneisses of uncertain correlation, probably high-grade representatives of the Tallulah Falls Formation (Hatcher and Butler, 1979), although Kuntz and Hedge (1981) have argued that this is Precambrian basement. The ages of these complexes are not known, and conflicting observations for several complexes suggest emplacement by different mechanisms and at different times relative to Taconic deformation and metamorphism. These units may be extensive sheet-like bodies in the subsurface, as they are exposed primarily in antiforms. This formation also contains scattered amphibolite units similar to those in the Ashe Formation; these have not been studied.

The Lake Chatuge complex, Georgia, is a sill exposed on the flanks of two large antiforms (Hartley, 1973; Hartley and Penley, 1974). This body is concentrically zoned with a dunite center surrounded by troctolite, in turn enclosed by olivine gabbro grading into amphibolite. Foliation within the amphibolite is parallel to that in the host rocks, suggesting that the sill was intruded prior to regional metamorphism. Localized pods of garnet-pyroxene gneiss have been interpreted as eclogite (Dallmeyer, 1974). Initial \(^{87}S/^{86}Sr\) ratios are consistent with a mantle derivation of the parental magma (Jones, Hartley, and Walker, 1973).

The Chunky Gal Mountain complex, North Carolina, consists of a large ultramafic body (Buck Creek) enveloped by amphibolites (McElhaney and McSween, 1983). The complex is partly bounded by a major thrust fault which truncates the amphibolite foliation. The ultramafic body is primarily dunite, partly altered to serpentinite, containing lenses of troctolite and anorthosite (Hadley, 1949; Kuntz, ms). Two distinct amphibolite assemblages occur in different parts of the complex and represent different metamorphic grades (McElhaney and McSween, 1983). All amphibolites have similar chemical compositions and appear to have been derived from a cumulate gabbroic protolith. Adjacent to the Chunky Gal Mountain complex to the east is the Carroll Knob complex. Mapping by Hatcher and others (this issue, p. 484-506) indicates that these highly deformed rocks are similar to those of Chunky Gal Mountain, but the mechanism of emplacement of this complex is unclear.

The possibility that the Chunky Gal Mountain complex is an ophiolite has been suggested by Hatcher and Butler (1979), Kuntz and Hedge (1981), and McElhaney and McSween (1983). Nd and Sr isotopic data for this complex and Lake Chatuge are consistent with the interpretation that both are oceanic crust (Shaw and Wasserburg, this issue, p. 319-349). Geochemical investigations of the Carroll Knob and Laurel Creek, Georgia, complexes (Petty and Hatcher, 1980; Hatcher and others, this issue)
suggest that amphibolites of these complexes represent mafic rocks generated in an ocean floor or arc environment, in contrast to the continental basalt affinity of other amphibolites of the Tallulah Falls Formation. Ophiolitic stratigraphy is not readily recognizable in any of these complexes, but many may be complexly deformed and metamorphosed basal sections of ophiolites.

**Ashland-Wedowee Belt.**—A concentration of mafic bodies occurs in a belt of metamorphic rocks (greenschist to amphibolite facies, Neathery and Reynolds, 1973) that extends from northeast Georgia to central Alabama, previously called the Ashland Schist (Adams, 1926; Crickmay, 1952) and now included in the Ashland Group (Hurst, 1973) or the Ashland Supergroup (Tull, 1978). Stratigraphic correlations across the Alabama-Georgia line have not been established, so that the Ashland Group mapped in Georgia may not represent the same sequence as the Ashland Supergroup mapped in Alabama. The Ashland Group comprises two different rock sequences: an upper sequence characterized by metasedimentary rocks, relatively abundant ultramafic bodies, and extensive amphibolites; and a lower sequence of metasedimentary rocks practically devoid of metavolcanics and ultramafites. The Ashland Group (at least, the upper sequence) is probably correlative with the Ashe Formation in North Carolina and is late Precambrian in age (Hurst, 1973). Metavolcanic rocks, particularly amphibolite, are very scarce in the underlying Wedowee Formation which is dominated by graphitic phyllite or schist. The Sandy Springs sequence, which may be correlative with the Ashland upper sequence, contains thin amphibolites in the lower part. The Ashland Supergroup is divided into two sequences: the upper Poe Bridge Mountain-Higgins Ferry Groups, a metamorphosed volcaniclastic sequence with interlayered amphibolites, and the lower Mad Indian-Hatchet Creek Groups, dominated by feldspathic schists but with rare amphibolites (Tull, 1978).

The upper Ashland amphibolites in Georgia crop out extensively in the Cartersville-Villa Rica area (loc. 6) and have been studied by many workers. The amphibolites are massive to layered, the layering being conformable with the compositional banding in the associated metasediments. Crickmay (1952) considered the amphibolites to be metamorphosed andesites intruded mostly as sills, whereas Kesler (1950) and Kesler and Kesler (1971) concluded that they are metasomatised carbonate sediments. However, features such as the presence of amygdules (not very common) and pillow structures (in various degrees of preservation) in the amphibolite and relict porphyritic texture in interlayered light colored gneiss suggest that these mafic rocks are of volcanic origin (Hurst, 1955b; Hurst and Jones, 1973). Chemical analyses of the amphibolite given by Crickmay (1952) are very similar to those of basalt; the analyses of Kesler and Kesler (1971) show lower Al₂O₃ and higher Fe₂O₃ values compared to usual basalts, but the differences are still within the reported analytical error. Also, the initial ⁸⁷Sr/⁸⁶Sr compositions of these amphibolites (Jones, Hurst, and Walker, 1973b) are very similar to those of the amphibolites
(metabasalts) in the Ashe Formation (Bottino, 1971). Similar amphibolites from the “Alabama Ashland” sequence, described in detail by Stow, Neilson, and Neathery (this issue, p. 416-436), have been interpreted as tholeiitic basalts generated in an oceanic rift system.

**Hillabee Greenstone.**—The Hillabee Greenstone (Hillabee Chlorite Schist) is one of the most extensively studied groups of volcanic rocks in the southern Appalachians (Tull and Stow, 1980, 1982). It represents a sequence of Paleozoic metavolcanic rocks which crops out discontinuously for about 170 km at the stratigraphic as well as structural top of the Talladega slate belt (late Precambrian to Devonian) in Alabama (loc. 7). The upper contact of the sequence is a major thrust boundary, the Hollins Line fault, against the Ashland-Wedowee belt. The lower contact is a conformable stratigraphic contact, gradational with the underlying Jemison Chert, suggesting an early to middle Devonian age for the initiation of Hillabee volcanism.

Hillabee metavolcanic rocks comprise two distinct volcanic suites: mafic rocks (greenstones and mafic phyllites), which constitute over 80 percent of the exposed Hillabee, and felsic units, which are interlayered with the mafic rocks. The greenstones are massive rocks with relict igneous textures (gabbroic, diabasic, porphyritic); the mafic phyllites are well foliated slaty rocks which commonly display compositional layering. The mineralogies of the two are similar and entirely metamorphic (greenschist facies). Lithologies of the felsic units range from slightly foliated gneissic rocks to those with phyllitic textures.

From detailed field, petrographic, and geochemical studies, Tull and Stow (1980, 1982) have offered the following interpretation for the Hillabee sequence. The greenstones represent dominantly basaltic lava flows that were locally intermixed with basaltic pyroclastic rocks and terrigenous sediments; the compositionally similar mafic phyllites probably represent highly deformed greenstones and metapyroclastic material. The alkalis-silica relationship and Y/Nb ratios of relatively unaltered rocks indicate that the pre-metamorphic protolith of the mafic rocks was low-K tholeiite. The tabular nature of the felsic units suggests that they are extrusive rocks (ignimbrites?); their composition is that of quartz dacite with distinct calc-alkaline affinity. An arc, or actively developing continental margin, environment has been inferred for the Hillabee volcanism on the basis of relationships of the Hillabee with the rest of the Talladega belt stratigraphy, geochemical discriminants, and relative abundance of felsic rocks.

**PIEDMONT**

Mafic rocks of the Piedmont exhibit considerably more variability than those of the Blue Ridge. Metavolcanic rocks of the Inner Piedmont are similar to Precambrian rift volcanics of the Blue Ridge. In the Kings Mountain and Carolina slate belts, metavolcanic rocks formed in an Cambrian island arc system. Those in the intervening Charlotte belt probably formed in a similar environment, but their characteristics are obscured by higher grades of metamorphism and by pervasive plutonism. These eastern Piedmont belts also contain numerous Paleozoic gabbroic
intrusions, as well as at least one example of ophiolitic material. Little information is available about the minor mafic rocks of the Kiokee and Raleigh belts.

**Inner Piedmont Belt.**—The upper amphibolite facies grade Inner Piedmont belt contains significant quantities of mafic rocks but is the least studied of all the belts in the southern Appalachians. The Inner Piedmont of South Carolina (loc. 8) has been divided into northeast flank, core, and southeast flank by Griffin (1974). Tightly folded amphibolites interlayered with granitoid gneisses are abundant within the flanks, particularly the northeast flank. The Inner Piedmont core contains fewer amphibolites with greater fold amplitudes. Griffin (1974) suggested that the Inner Piedmont is a sedimentary-volcanic pile that has suffered metamorphism and migmatization. At least one metagabbro body (McConnell and Griffin, 1973) also occurs in the Inner Piedmont core of South Carolina. Textures range from relict igneous to crystalloblastic.

The only other comprehensive studies of Inner Piedmont mafic rocks involve the Dadeville complex of Alabama (loc. 9). Approximately half of this metagneous complex consists of amphibolites of the Ropes Creek, Waverly, and Waresville Formations (Bentley and Neathery, 1970). Rocks of the Waverly Formation are more feldspathic than the other mafic units, and the Waresville amphibolites are interlayered with chlorite-actinolite schists. These amphibolites are suggested to have been derived from mafic tuffs (Bentley and Neathery, 1970) or tholeiitic basalts and their differentiates (Neilson and Stow, 1980). More complete chemical studies that establish the tholeiitic nature of these rocks are presented by Stow, Neilson, and Neathery (this issue).

The Dadeville complex also contains mafic intrusive rocks (orthopyroxenite, norite, and gabbro) that have survived subsequent metamorphism. These have been subdivided by silica saturation into the silica-saturated Doss Mountain type and the undersaturated Slaughters type (Neilson, 1978). These intrusive rocks contain variable amounts of garnet, actinolite, and chlorite and are enclosed by amphibolites of the same chemical compositions as the intrusives (Neilson and Stow, 1980). From trace element geochemistry, Stow and others (1982) have interpreted the Dadeville Complex to represent a deeply eroded portion of an island arc.

The metagneous Dadeville complex is separated from the metasedimentary Opelika complex by the "Stonewall Line," a lithologic discontinuity of unknown origin. These complexes are similar to the rocks of the northeast flank and core of the Inner Piedmont in South Carolina, and Griffin (1971) extrapolated the flank-core boundary, which he interpreted as a tectonic slide, through the Georgia Inner Piedmont to connect with the Stonewall Line in Alabama. However, Hatcher (1978) proposed that the Stonewall Line truncates against the Brevard zone in central Georgia. Additional studies are needed in Georgia and North Carolina to understand the gross stratigraphy of the Inner Piedmont.

Mafic rocks of the Smith River Allocithon within the Inner Piedmont (loc. 10) include a prominent amphibolite unit at the top of the Precambrian Basett Formation (leucocratic gneisses) and the Rich Acres
Formation which intrudes the overlying Fork Mountain Formation (pelitic schists) (Conley and Henika, 1973). Preliminary study (Achaibar, ms) suggests that the amphibolite represents metamorphosed (amphibolite facies) flows of quartz tholeite, probably of continental affiliation. The Rich Acres Formation is a mafic intrusive complex comprising metamorphosed norite, gabbro, and diorite bodies. The norite shows well-preserved ophitic and porphyritic textures and in places contains significant amounts of olivine.

No definitive age determinations are available for the Inner Piedmont rocks. The amphibolite units in the Inner Piedmont belt are probably correlative with the late Precambrian basalts in the Blue Ridge. These may also be correlative with the rocks of the Uchee complex in Alabama, if the Inner Piedmont is allochthonous (Bentley and Neathery, 1970). The mafic intrusions in the Inner Piedmont were emplaced later, but prior to regional metamorphism (Taconic?). The parental magmas for these bodies may have been generated and emplaced below an island arc of continental margin (Neilson and Stow, 1980; Stow, Neilson, and Neathery, this issue).

**Kings Mountain belt and Charlotte belt.**—The boundary between the Charlotte and Kings Mountain belts in many areas is arbitrary, and the lithologic similarities between the two belts suggest that they may be parts of the same terrane (Horton, 1981). Overstreet (1970) suggested that rocks in both these belts might also be parts of the same stratigraphic sequence to which the Carolina slate belt rocks belong. The Charlotte belt is of high metamorphic grade (amphibolite facies); metamorphic grade of the Kings Mountain belt is generally believed to be lower (green schist in places), though sillimanite grade rocks occur locally. The Kings Mountain belt consists in large part of intermediate metavolcanic, pyroclastic, and epiclastic rocks similar in many respects to those of the Carolina slate belt. The sequence shows a gradual upward transition from dominantly volcanic to dominantly sedimentary character (Horton, 1981). Small lenses of amphibolite are intercalated in this sequence (Murphy and Butler, 1981). The Charlotte belt may contain the plutonic equivalents of the volcanic rocks in the Kings Mountain and Carolina slate belts. Although the stratigraphy of the Charlotte belt is unknown, it also contains amphibolites, the outcrop patterns of which suggest that they have been derived from volcanic rocks. These have not been studied, but similarities in lithology and field relations suggest that the amphibolites in the Kings Mountain and Charlotte belts may represent mafic flows and pyroclastic deposits correlative with those of the Carolina slate belt.

Gabbroic plutons comprise most of the mafic rocks of the Charlotte and Kings Mountain belts. These are both pre- (or syn-) and post-metamorphic and define an arcuate trend stretching for at least 500 km. Some intrusions are associated with subordinate syenite and/or diorite (Medlin, 1969; Wilson, 1981; Olsen, McSween, and Sando, 1983), and a few are quartz norites. These gabbros and metagabbros appear to be parts of
bimodal intrusive suites ranging in age from about 450 to about 300 my, though they are not necessarily intimately associated with contemporaneous granites. The most complete published descriptions of gabbros are for the Mecklenburg (Hermes, 1968; Wilson, 1981) and the Concord (Morgan and Mann, 1964; Olsen, McSween, and Sando, 1983) plutons, both in the Charlotte belt of North Carolina. Studies of other plutons (for example, Gladesville, Ga.; Rock Hill, S.C.; Presley’s Mill, Ga.; Buffalo, S.C.; Ogden, S.C.; Calhoun Falls, S.C.—see references in McSween and Nystrom, 1979; McSween and others, this issue, p. 437-461) indicate that the Mecklenburg and Concord gabbros are typical. Hermes’ (1968) study of the Mecklenburg complex includes the only detailed account of metagabbro. A summary of several of these complexes is presented by McSween and others (this issue), who have proposed that these gabbros represent the eroded plutonic core of a volcanic arc.

The Mecklenburg complex (loc. 11) consists of one large gabbro pluton and several satellite bodies intruding a metagabbro pluton. Hermes (1968) observed crosscutting relationships and xenoliths of metagabbro within gabbro, though Wilson (1981) argued that both lithologies were part of one differentiated gabbroic complex. Gravity data suggest that the Mecklenburg complex is a lopolithic structure 3.5 to 4.5 km thick with a 1 to 2 km thick subsurface sill extending to the north (Wilson, 1981). Metagabbro samples exhibiting various degrees of recrystallization are intermingled in the field, probably reflecting local variations in accessibility of fluids during metamorphism (Hermes, 1968). Gabbric rocks of the complex are unmetamorphosed.

The Concord complex, North Carolina (loc. 12), is composed of a gabbro stock enclosed on three sides by a syenite ring dike (Olsen, McSween, and Sando, 1983). Gravity modelling suggests that the plug-shaped complex extends to a depth of about 6 km. A Sm-Nd isochron from gabbro and a Rb-Sr isochron for syenite indicate that both were emplaced approx 405 my ago. Gabbro samples are texturally and mineralogically similar to the Mecklenburg pluton, and syenites are strongly porphyritic. Overlapping initial Nd and Sr isotopic compositions suggest that the gabbro and syenite may be related through closed-system fractionation. Olsen, McSween, and Sando (1983) determined that fractional crystallization of the observed cumulus phases in gabbro would drive residual liquid compositions toward syenite.

Both metagabbros and gabbros also intrude the Kings Mountain belt. In contrast to the metagabbro plutons of the Charlotte belt, metagabbros of the Kings Mountain belt occur in the form of dikes and sills (Murphy and Butler, 1981). The Kings Mountain belt is also intruded by at least one possible post-metamorphic gabbro, the Buffalo pluton (loc. 13). However, Medlin, Thornton, and Gold (1972) noted that this body contains a large portion of altered mafic rocks, presumably deuterically altered gabbro.

_Carolina Slate belt, Kiokee belt, and Raleigh belt._—The Carolina slate belt consists primarily of well-laminated epiclastic sediments, volcanic
flows, and pyroclastics, all apparently deposited in submarine environments. The belt experienced greenschist facies metamorphic conditions during the Taconic orogeny; Acadian metamorphic effects are restricted to a few shear zones along faults near the Charlotte belt-slate belt boundary (Butler and Fullagar, 1978). The volcanic sections are clearly bimodal in composition (Seiders, 1978; Whitney and others, 1978), with subordinate mafic members generally comprising 20 to 40 percent of the volcanic products (Feiss, 1982). Mafic tuffs are common, and pillow structures, amygdalae, and flow breccias have been observed in flows (Wilson and Allen, 1968; Sundelius, 1970). The most comprehensive studies of slate belt mafic volcanic rocks have been conducted in central North Carolina and near the Georgia-South Carolina border.

In the Albemarle area, N.C. (loc. 14), the stratigraphy consists of a lower, felsic Uwharrie Formation overlain by a middle volcanic sequence, the Albemarle Group, and succeeded by an upper volcanic sequence, the Tater Top Group (Conley and Bain, 1965). U/Pb dates from zircons in the Uwharrie Formation yield ages of about 580 my (Wright and Seiders, 1977), corresponding to the early to middle Cambrian age of *Paradoxides carolinaensis*, a trilobite found in the Albemarle Group (St. Jean, 1978). The lower portion of the Tater Top Group, the Badin Greenstone, contains the greatest concentration of mafic volcanics in the area and is separated from the underlying Albemarle Group by an unconformity.

In the Lincolnton, Ga.-McCormick, S.C., area (loc. 15), volcanoclastic and epiclastic rocks of the Little River Series overlie a lower volcanic unit, the Lincolnton "metadacite," actually a quartz porphyry (Whitney and others, 1978). The Little River Series pyroclastic rocks are lithologically similar to the Uwharrie Formation in the Albemarle area, and Carpenter, Odom, and Hartley (1978) reported a correlative age of about 565 my for the Lincolnton metadacite. A lithologic counterpart to the Lincolnton unit is not represented in the Albemarle area, and an equivalent to the Tater Top Group does not occur in the Little River Series. Mafic rocks in the Lincolnton-McCormick area are concentrated within the Lincolnton metadacite in the form of sills, dikes, and pyroclastic units. Although metamorphosed (greenschist facies), the intrusive bodies exhibit recognizable chilled margins and porphyritic interiors. The mineralogy of mafic tuffs is similar to dikes and sills, but the former are distinctly banded and contain quartzofeldspathic clasts.

Geochemical studies (Butler and Ragland, 1969; Seiders, 1978) of volcanic rocks from the Albemarle area suggested that this is a calc-alkaline suite, whereas Whitney and others (1978) indicated that volcanic rocks in the Lincoln-McCormick area are tholeiitic. As the mafic rocks within the Lincolnton metadacite lie stratigraphically lower than those of the Tater Top Group, Whitney and others (1978) proposed that this pattern reflects a transition from early tholeiitic volcanics to later calc-alkaline series volcanics, a typical progression for developing island arcs. Feiss (1982) noted the pervasive effects of metasomatic and/or hydrothermal alteration in all these rocks and argued that major-element chemistry
yields ambiguous results with respect to either trend. Analyses of trace elements that are not mobilized during metamorphism indicate both tholeiitic and calc-alkaline affinities for these rocks (Feiss, 1982), and limited Sr isotopic studies suggest that the magmas were derived from primitive upper mantle or lower crustal sources (Fullagar, 1971; Black, ms).

The Chopawamsic Formation in central Virginia (loc. 16) consists of early Cambrian (?) calc-alkaline and tholeiitic rocks of island arc affinity (Pavlides, 1981). The Chopawamsic has been correlated with rocks of the Carolina slate belt by Higgins (1972) and Glover (1974). Pavlides (1981) indicated that sufficient differences exist in terms of stratigraphy and geochemistry to preclude their having been part of a single volcanic province. However, differences between the two slate belt locations described above are as great as between either of these and the Chopawamsic Formation, and the slate belt is probably insufficiently characterized to rule out such a correlation. The Chopawamsic Formation consists of a western belt of tholeiitic and calc-alkaline metavolcanic rocks and volcaniclastic sediments and an eastern belt of tholeiitic amphibolites that may represent an oceanward facies.

The Carolina slate belt has also been locally intruded by gabbroic sills and iopoliths. Swarms of these bodies occur in the Albemarle, N.C., area (Conley, 1962; Butler, 1979) at loc. (14). Although these bodies are premetamorphic, they are somewhat different in chemical composition from mafic dikes and tuffs in this area and are probably not comagmatic. Butler (personal commun.) believes these to have been emplaced after the volcanic series. Most are massive, medium- to coarse-grained, hornblende–plagioclase–pyroxene rocks (Sundelius, 1970). Wagener (1965) described one of these, the West Fairington pluton (not necessarily representative of the suite), as concentrically zoned from gabbro–diorite at the margins to leucogranodiorite in the interior. Fullagar (1971) reported a Rb/Sr age of about 520 my for this intrusion.

In the Eastern slate belt of North Carolina (loc. 17), Stoddard and others (1982) have recently described another type of mafic suite, the Halifax County complex. This complex is separated from slate belt rocks to the west by a late Paleozoic mylonite zone and disappears beneath the Coastal Plain to the east. The complex consists of low-grade metamorphic equivalents of the following: an ultramafic group containing peridotite, dunite, and pyroxenite; gabbroic rocks including anorthosite and gabbro; localized intrusions of quartz diorite and plagiogranite; and basalts. Ultramafic and gabbroic lithologies appear to form a layered series with gradational contacts. Basalt-gabbro contacts have not been observed, except for one basaltic dike cutting gabbro. Relict textures range from cumulate in ultramafic rocks to diabasic or porphyritic in metabasalts. Major element analyses show an Fe-enrichment trend extending from the ultramafic rocks through gabbroids to metabasalts. Gabbroids are less differentiated than basaltic rocks, as shown by lower incompatible element abundances in the former. The sequence of lithologic units and their relict mineralogies closely resemble many ophiolitic sequences. Fur-
thermore, the basaltic rocks consistently plot within the field of ocean-floor basalts on trace-element discrimination diagrams. Despite the fact that REE patterns do not display the light rare-earth depletions characteristic of mid-ocean ridge tholeiites, the data suggest that the Halifax County complex represents tectonically-emplaced (early Paleozoic?) oceanic lithosphere (Kite and Stoddard, 1983).

Post-metamorphic gabbro plutons also intrude the slate belt. Waskom and Butler (1971) briefly described a small gabbro stock (the Pee Dee gabbro) occurring within the approx 326 my old (Fullagar and Butler, 1979) Lilesville granite batholith, N.C. They argued that the gabbro had intruded the granite, but Speer, Becker, and Ferrar (1980) suggested that the granite and gabbro were contemporaneous. Small pillow-like masses of fine-grained gabbro were found at contacts with granite, suggesting mechanical mixing of magmas. The Dutchmans Creek (McSween and Nystrom, 1979) and Greenwood (Chalcraft, Lawrence, and Taylor, 1978) plutons intrude the boundary between the slate and Charlotte belts (loc. 18 and 19, respectively). A biotite separate from the Dutchmans Creek pluton has been dated at about 305 my (Fullagar, personal commun.). This pluton appears to be differentiated, with cumulate rocks occurring at lower stratigraphic levels within the pluton.

Rocks of the Kiowee belt are stratigraphically similar to those of the Carolina slate belt (Secor and Snoke, 1978), though at higher grade due to Hercynian metamorphism. Mafic rocks are uncommon in the limited exposure of this belt, but the Clouds Creek igneous complex does contain a quartz diorite intrusion with serpentinitized ultramafic rocks (Secor and Snoke, 1978).

The Raleigh belt may be stratigraphically gradational into the Carolina slate belt as well but, like the Kiowee belt, is of higher metamorphic grade. Limited amounts of amphibolite occur on the limbs of a large-anticlinal structure that characterizes this belt (Stoddard, Cavaroc, and McDaniel, 1978), but these have not been studied.

TECTORIC IMPLICATIONS

Mafic rocks in the eastern Blue Ridge and Inner Piedmont belts are mostly late Precambrian tholeiites. These are either seafloor or rifted continental margin basalts (Hatcher and others, 1980; Stow, Neilson, and Neathery, this issue). Basalts in the Inner Piedmont belt were probably extruded on continental crust (Hatcher, 1978). For the eastern Blue Ridge, volcanism may have occurred on rifted continental crust (Rankin, 1975) or on oceanic crust (Abbott and Raymond, this issue). The scarcity of similar mafic rocks in the western Blue Ridge has been noted by Hatcher and others (1980), who argued that the Hayesville-Fries fault system marks a major tectonic boundary within this belt. Although we concur with this interpretation, it should be noted that mafic rocks occur on both flanks of the Blue Ridge anticlinorium in Virginia and northwestern North Carolina (Rankin, Espenshade, and Shaw, 1973) and are thus not restricted to the eastern Blue Ridge. South of the termination of the Blue Ridge anticlinorium, the absence of mafic rocks in the Ocoee
Supergroup has been explained as resulting from deposition in a basin farther removed from the rift system (Rankin, 1975) or on the continental edge adjacent to a marginal sea (Hatcher, 1978).

The mafic and felsic volcanic rocks of the late Precambrian stratified sequences (Ashe, Lynchburg, Grandfather Mountain, Mount Rogers, Catoctin, et cetera) as well as the intrusives (for example, Bakersville and Linville) that cut the stratified sequences and the basement rocks have been considered a consanguinous suite, the Crossnore plutonic-volcanic group, by Rankin, Espenshade, and Shaw (1973). The felsic volcanic rocks, mainly peralkaline metarhyolite, are concentrated at the salients and recesses of the Blue Ridge structural trends (Rankin, 1976b) and may have been derived by partial melting of the mafic rocks in the deep crust (Rankin, 1982). The bimodal nature of the Crossnore volcanic suite and the peralkaline felsic rocks have been interpreted to be indicative of a continental rifting environment (Rankin, 1975). It is not clear whether or to what extent this late Precambrian (early Paleozoic?) continental break-up and opening of the Iapetus Ocean resulted in generation of new oceanic crust (Rankin, 1975; Misra and Keller, 1978). It probably did, at least at places along the rift zone (Shaw and Wasserburg, this issue; Abbott and Raymond, this issue).

Mafic volcanics in the Piedmont belts of low metamorphic grade (Carolina slate belt and parts of the Kings Mountain belt) are clearly mafic members of volcanic arc sequences of late Precambrian to Cambrian age (for example, Butler and Ragland, 1969; Horton, 1981). Chemical characteristics, summarized by Feiss (1982), indicate that this suite of rocks is bimodal with calc-alkaline to tholeiitic affinities. Amphibolites in the intervening Charlotte belt are presumed to have the same origin, though their characteristics have not been documented.

Devonian bimodal volcanism in the southernmost Appalachians (eastern Alabama) produced the Hillabee Greenstone. These rocks are also arc volcanics (Tull and Stow, 1980) but are removed spatially and temporally from arc volcanics in the eastern Piedmont.

In an attempt to discriminate among the different plate-tectonic settings of the southern Appalachian mafic rocks, available chemical data are plotted on a MgO–FeO (total)–Al₂O₃ diagram (fig. 2). Application of this discriminant diagram (Pearce, Gorman, and Birkett, 1977) to these rocks suffers from several limitations: (1) the number of available analysis for any suite is too small compared to its extent and variability; (2) the SiO₂ content of many of the samples is lower than the SiO₂ screen (51-56 percent) recommended by Pearce, Gorman, and Birkett (1977); and (3) the rocks have been subjected to greenschist or amphibolite facies metamorphism which may have affected their Mg–Fe–Al ratios. However, the discriminant diagram does show a noticeable difference among the Blue Ridge-Inner Piedmont, the Piedmont, and the Talladega belts. The late Precambrian (early Cambrian?) Blue Ridge mafic rocks appear to represent continental rift tholeiites, in agreement with conclusions discussed earlier; the clearly anomalous nature of the Cartersville amphib-
olite samples may reflect significant metasomatism. It should be noted that amphibolites of the Smith River Allochthon (Inner Piedmont) also plot in the continental field. In contrast, the chemistry of the early Paleozoic mafic rocks of the Piedmont (Carolina slate belt) suggests a shift toward a convergent plate-tectonic setting. Surprisingly, none of the Hillabee Greenstone samples (Talladega belt) plot in the orogenic field.

The major differences between the inferred tectonic settings (tensional and compressional) for mafic volcanic rocks in the western, eastern, and southernmost Appalachians coincide with suspect terranes proposed by Williams and Hatcher (1982). These authors separated Piedmont terrane (eastern Blue Ridge and Inner Piedmont belts), Avalon terrane (Kings Mountain, Charlotte, and Carolina slate belts), and Talladega terrane (Talladega belt and Hillabee Greenstone) based on systematic differences in deformational and metamorphic history and regional geophysical patterns. The inferred tectonic environments of mafic rocks within these terranes support the idea of sequential accretion of independent geologic provinces.

Examples of mafic-ultramafic complexes of possible ophiolitic affinity have also been described, several in the Blue Ridge and one in the Eastern slate belt. These isolated occurrences in different terranes are probably unrelated, but the Blue Ridge and Eastern slate belt occurrences

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Fig. 2. The MgO–FeO (total)–Al₂O₃ discriminant diagram of Pearce, Gorman, and Birkett (1977) showing the compositional fields of volcanic rocks from ocean ridge and floor (ORF), oceanic islands (OI), continents (CN), spreading center islands (SCI), and orogenic zones (OR). Mafic rocks from the Blue Ridge and Inner Piedmont are: filled circles—Bakersville (Wilcox and Poldervaart, 1958), open circles—Catoctin (Reed, 1955; Reed and Morgan, 1971), filled squares—Grandfather Mountain (Bryant and Reed, 1970b), filled stars—Cartersville (Kessler and Gessler, 1971), open stars—possible Ashe (Bryant and Reed, 1970b), circled stars—Inner Piedmont (Bryant and Reed, 1970b), open squares—Smith River Allochthon (Achaibar, ms). Mafic rocks from the Piedmont are: filled circles—Carolina slate belt (Butler and Ragland, 1969), open circles—Carolina slate belt (Seiders, 1978), filled squares—Chopawamsic (Pavlides, Gair, and Cranford, 1982), open stars—To River (Pavlides, 1981). Mafic rocks for the Talladega belt are “select” samples of the Hillabee Greenstone (Tull and others, 1978).
may represent oceanic crust incorporated during Paleozoic accretional events. Such complexes in the Blue Ridge lie near the proposed boundary between the Piedmont terrane and the Appalachian miogeocline (the Hayesville fault), but the Halifax County complex in the Eastern slate belt lies completely within the Avalon terrane. However, it is fault bounded (Kite and Stoddard, 1983), and Williams and Hatcher (1982) note that this terrane may be composite.

Several generations (pre- and post-metamorphic) of gabbroic intrusions in the eastern Piedmont may be related to subsequent periods of compression (for example, McSween and others, this issue). Isolated metagabbros also occur in the Inner Piedmont belt, but post-metamorphic gabbros are unknown. The Charlotte and Carolina slate belts in the Piedmont have positive gravity patterns distinct from the negative Bouguer anomalies of adjacent belts. This pattern has been interpreted to reflect different deep-crustal lithologies, with more mafic rocks underlying the Charlotte and slate belts (Long, 1979; Hatcher and Zietz, 1980). Wenner (1981) determined that regional \( ^{180}/^{160} \) patterns in Piedmont granitoid bodies correspond to gravity patterns, implying that these intrusions are rooted to their respective mafic and felsic protoliths. This in turn suggests that the subhorizontal seismic discontinuity observed in COCORP data is not a decollement along which the entire Piedmont has been displaced, as proposed by Cook and others (1979), unless thrusting occurred prior to emplacement of these 325 to 265 m.y. old plutons. Gabbro intrusions in the Piedmont are localized only in belts characterized by positive Bouguer anomalies. As many of these complexes were emplaced prior to 400 m.y. ago (McSween and others, this issue), this may place a more stringent time constraint on COCORP thrusting (if it occurred at all). Palinspastic restoration of the COCORP data suggests that the decollement surface may not have extended below the Charlotte and slate belts but may have terminated in the Kings Mountain belt to the west (Iverson and Smithsonian, 1982). This is consistent with the interpretation of the belts east of the Inner Piedmont as one suspect terrane (Williams and Hatcher, 1982).

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