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Terranes and Overlap Sequences in the Central and Southern Appalachians, An Expanded Explanation for Part of the Circum-Atlantic Terrane Map

by

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FOREWORD

The following text was submitted for publication in 1989 as part of a "terrane catalogue," which was intended to serve as an expanded explanation for the *Tectonic Map of Pre-Mesozoic Terranes in Circum-Atlantic Phanerozoic Orogens* (Keppie and Dallmeyer, 1989) in cooperation with International Geological Correlation Program Project 233. Plans to publish the terrane catalogue have been cancelled, because texts for some of the other regions were not completed. Consequently, this open-file report is being released in order to make the expanded explanation for the central and southern Appalachian part of the circum-Atlantic terrane map available. Although some of the material is outdated or superseded, it is important for this report to agree with the published map and to reflect the state of knowledge and thinking at the time it was produced. Therefore, the text is presented as it was written in 1989 except for updating of references that were "in press" at the time and for the addition of references cited in this "foreword." Numerical designations for terranes match those on the published map (Horton and others, 1989b; Keppie and Dallmeyer, 1989).

Terrane concepts in eastern North America have evolved since the circum-Atlantic terrane map was published. Interpretations of tectonostratigraphic terranes in the central and southern Appalachians based on more current information are available in Horton and others (1991), Goldsmith and Secor (1993), Rankin and others (1993a, 1993b), and Rankin (1994).

INTRODUCTION

This section of the terrane catalogue to accompany the *Tectonic Map of Pre-Mesozoic Terranes in Circum-Atlantic Phanerozoic Orogens* (Keppie and Dallmeyer, 1989), covers the central and southern Appalachian region of the United States, from New York City to central Florida. Alphanumeric symbols for terranes and an overstep sequence are keyed to the map. The circum-Atlantic terrane map of this region (Horton and others, 1989b) and the following descriptions of tectonostratigraphic terranes and overlap sequences are adapted from Horton and others (1989a). Readers interested in more detailed discussions of these terranes and their Paleozoic histories of amalgamation and accretion should consult that report. Accretionary-history diagrams for the central Appalachians (Fig. 1) and southern Appalachians (Fig. 2) are modified from those on the terrane map (Horton and others, 1989b; Keppie and Dallmeyer, 1989).

PRE-MESOZOIC OVERSTEP SEQUENCES

m-l0: POSSIBLE MIDDLE TO LATE ORDOVICIAN OVERSTEP SEQUENCE

The Chopawamsic Formation of the Chopawamsic terrane is unconformably overlain by the paleontologically dated Middle and Upper Ordovician Arvonia Slate and Quantico Formation (Pavlides, 1980). Because the Arvonia and Quantico are post-Taconian, the Chopawamsic terrane is overlapped by them.

The Arvonia Slate contains assemblages of fossil brachiopods, trilobites, bryozoans, and echinoderms, which collectively indicate an open marine environment (Kolata and Pavlides, 1986, and references therein). The trilobites indicate a Middle to Late Ordovician age (Tillman, 1970). The similar and probably correlative Quantico Formation has yielded segments of crinoid stems and a few other fossils, and is also probably Late Ordovician (Pavlides and others, 1980).

The Peach Bottom Slate in Maryland may correlate with the Arvonia Slate and Quantico Formation in Virginia (Drake and others 1989); if so, all of these would collectively constitute a late Taconian or post-Taconian overstep sequence across the Potomac and Chopawamsic terranes (Horton and others, 1989a). The overstep interpretation is illustrated diagrammatically on Figure 1. In addition, mapping by Gates and others (1986) suggests that the southwestern end of the Arvonia Slate may overstep the boundary between the Chopawamsic and Milton terranes.

REFERENCES--Gates and others (1986); Horton and others (1989a); Kolata and Pavlides (1986); Pavlides (1980);Pavlides and others (1980); Tillman (1970)

TERRANES

NA1d: WESTMINSTER TERRANE

The Westminster terrane of Muller and others (1989) and Horton and others (1989a) was previously termed the Ijamsville-Pretty Boy-Octoraro terrane by Horton and Drake (1986).

TERRANE BOUNDARIES--The northwest boundary of this terrane is the Martic overthrust, which brings it onto the Honey Brook Upland and the Blue Ridge tectonic province. Its southeast boundary, with the Potomac composite terrane, is the Pleasant Grove-Huntingdon Valley fault, which is interpreted to be the Taconian suture.

STRATIGRAPHY--The Westminster terrane (Fig. 1) consists of a unit of pelitic schist or phyllite characterized by albite porphyroblasts (Prettyboy Schist of Crowley, 1976, and Octoraro Phyllite) and a green and purple phyllite unit (Ijamsville Phyllite) that is sodium-rich and characterized by the mineral assemblage muscovite-paragonite-chloritoid. The terrane also contains metabasalt of the Sams Creek Formation, which has not yet been chemically characterized, as well as Wakefield Marble and Silver Run Limestone.

DEFORMATIONAL AND METAMORPHIC EVENTS--The terrane-boundary thrust faults date from the Taconian orogeny. Both of these major faults later experienced dextral strike-slip motion during the Alleghanian orogeny. The rocks of the terrane were interpreted to be polymetamorphic by Stose and Stose (1946), although this interpretation has yet to be confirmed by modern work.

IGNEOUS INTRUSIONS--None have been reported.

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--Rocks of the Westminster terrane are interpreted to be part of the rise-prism deposited off the Laurentian continental margin and to correlate with rocks in the Hamburg terrane and some of the higher slices of the Taconic allochthon in New England and New York (Knopf, 1935; Lyttle, 1982; Drake, 1986; Drake and others, 1989).

REFERENCES--Crowley (1976); Drake (1986); Drake and others (1989); Horton and Drake (1986); Horton and others (1989a); Knopf (1935); Lyttle (1982); Muller and others (1989); Stose and Stose (1946)

NA1e: HAMBURG TERRANE

TERRANE BOUNDARIES--The Hamburg terrane, originally named by Williams and Hatcher (1982), occurs in several allochthonous slices that include the Hamburg, Jutland, Peapack, Cocalico, and Furlong klippen (Lyttle and Epstein, 1987; Drake and others, 1989). Slices of the Hamburg terrane occur only on Laurentian cover rocks of the Reading Prong and Honey Brook Upland.

STRATIGRAPHY--Much of the Hamburg terrane consists of variegated shale and mudstone, deep-water limestone, chert, some basalt and mafic intrusive rocks of Early Ordovician age, and turbidites and related shales of Middle Ordovician age (Fig. 1). These rocks represent abyssal deposits and younger submarine fan deposits. The Hamburg klippe also contains a slice of siliciclastic and carbonate rocks of Late Cambrian and Early Ordovician age that was deposited at the base of a slope. The Furlong klippe consists of variegated shale, quartzite, and conglomerate interpreted as a rift sequence of Late Proterozoic to earliest Cambrian age.

DEFORMATIONAL AND METAMORPHIC EVENTS--The terrane was probably assembled with rock of the Reading Prong and Honey Brook Upland by thrusting during Taconian foreland basin sedimentation in the late Middle Ordovician, but most contacts seen now result from later thrust faulting, probably during both the Taconian and Alleghanian orogenies.

IGNEOUS INTRUSIONS--Minor amounts of mafic intrusive rocks occur with pillow lavas and flow breccias in the Hamburg klippe. These rocks have both calc-alkaline and oceanic basalt affinities and are interpreted to result from near-trench volcanism (Lash, 1986).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--The Hamburg terrane is interpreted by Horton and others (1989a) to be a Laurentian native terrane. Williams and Hatcher (1982, 1983) consider the Hamburg terrane, as well as some of the highest thrust slices in the Taconic allochthon to be suspect because they contain rocks of undetermined paleogeographic origin, which have apparently been transported great distances. Stanley and Ratcliffe (1985), however, interpret the highest Taconic rocks to be the slope-rise prism of the Laurentian margin. The Hamburg terrane may have been deposited in a marginal basin between the Laurentian craton and a microcontinent, perhaps the Baltimore terrane (Lash and Drake, 1984), although the evidence for this is not compelling.

REFERENCES--Drake and others (1989); Horton and others (1989a); Lash (1986); Lash and Drake (1984); Lyttle and Epstein (1987); Stanley and Ratcliffe (1985); Williams and Hatcher (1982, 1983)

NA2e: JEFFERSON TERRANE

The Jefferson terrane, as named by Horton and others (1989a), is a very large terrane of gneiss (metasandstone), schist (metapelite), amphibolite (metabasalt), and ultramafic rocks (fragmented ophiolite) occupying much of the eastern part of the Blue Ridge tectonic province from Virginia to Alabama (see Figs. 1 and 2). Toward the southern end, the terrane consists of several large thrust sheets. Future work may show that this large terrane consists of several independently definable terranes.

TERRANE BOUNDARIES--The Jefferson terrane is separated from Laurentia by a series of northwest-verging thrust faults, initially of Taconian age, although some segments were reactivated, probably in the Alleghanian. The Hollins line and Goodwater-Enitachopco faults are taken to bound the Jefferson terrane on the northwest in Alabama. The premetamorphic Hayesville fault marks the boundary between metabasalt- and ultramafic-bearing strata of the Jefferson terrane and ultramafic-free and essentially volcanic-free rocks of the Ocoee Supergroup near the North Carolina-Georgia border. Farther northeast in North Carolina, the western limit of the Jefferson terrane is interpreted to be a hypothetical extension of the Hayesville fault, which is drawn more or less along the western limit of ultramafic bodies and which thrusts the interpreted accretionary wedge over Grenvillian basement (Rankin and others, 1989). Immediately north of the Grandfather Mountain window, the Jefferson terrane overrides Grenvillian basement on the post-metamorphic Fries fault. Farther northeast, in North Carolina and across most of Virginia, the footwall fault of the Jefferson terrane is inferred as a requirement of the tectonic model but has not been mapped. It is interpreted to diverge from the Fries fault and to be mostly within the sequence of stratified rocks structurally above the basement. In North Carolina and southern Virginia this inferred fault carries the redefined, ultramafic-bearing Ashe Formation of the Jefferson terrane over the newly defined, ultramafic-free Wills Ridge Formation which is stratigraphically tied to Laurentia through a basal conglomerate (Rankin and others, 1993a). Farther north in Virginia, the inferred fault carries the redefined, ultramafic-bearing Lynchburg Group over Grenvillian basement or the redefined, ultramafic-free Fauquier Group (Rankin and others, 1993a). It is suggested that the unconformity mapped by Wehr (1985) within the package of stratified rocks (now Lynchburg Group and Fauquier Group) in northern Virginia is the inferred fault at the base of the Jefferson terrane.

The southern half of the Jefferson terrane is separated from the Inner Piedmont terrane to the southeast by the Brevard fault zone, which has had complex and repeated movement, perhaps beginning in the Taconian and ending with Alleghanian dextral strike-slip and brittle dip-slip movement (Edelman and others, 1988). The Jefferson terrane is relatively thin where, bounded by the Forbush thrust (Hatcher and others, 1988), it frames the Sauratown terrane. Southeast of the Sauratown terrane, the Jefferson terrane is bounded by the Yadkin fault and the Mesozoic Chatham fault. It is overlain and in part bounded by the Smith River terrane. Farther north it is bounded on the southeast by the Mountain Run fault zone, which carries the Potomac terrane, and by the Mesozoic Culpeper basin.

STRATIGRAPHY--Major stratigraphic units within the Jefferson terrane from north to south include the Lynchburg Group as redefined by Rankin and others (1993a), a mafic volcanic unit east of Charlottesville, Virginia, which has been mapped as the "Catoctin Formation," Ashe Formation as redefined by Rankin and others (1993a), Alligator Back and Tallulah Falls Formations, Coweeta Group of Hatcher (1979), Richard Russell Formation, Helen Group, Sandy Springs Group (in part), New Georgia Group of Abrams and McConnell (1981), Wedowee Group as used by Tull (1978), Emuckfaw Formation of Neathery and Reynolds (1975), and Ashland Supergroup as revised by Tull (1978).

The gneisses are quartzose, indicating a significant continental contribution. Generally gneiss is dominant over schist, but thick schist units occur. The gneiss and schist are generally interpreted to have been marine deposits.

Most stratified units of the Jefferson terrane are characterized by the presence of ultramafic pods and mafic-ultramafic complexes. Some ultramafic-bearing suites have been interpreted as ophiolitic melanges (Abbott and Raymond, 1984; Lacazette and Rast, 1989). The ultramafic bodies and mafic-ultramafic complexes are commonly interpreted to be fragments of oceanic crust (see Lipin, 1984; Hatcher and others, 1984), but Shaw and Wasserburg (1984) cautioned that they probably have more than one origin.

DEFORMATIONAL AND METAMORPHIC EVENTS--Paleozoic metamorphic grades as high as granulite facies (probably Taconian, at least in part) are reported in southwestern North Carolina by Absher and McSween (1985). Toward the northeastern end of the terrane the metamorphic grade is lower (greenschist facies) and possibly younger (Alleghanian) (Rankin and others, 1989). The Jefferson terrane is polydeformed; the isogradic surfaces are folded (Rankin and others, 1991).

IGNEOUS INTRUSIONS--Chemical data on metabasalts of the Jefferson terrane are sparse, but suggest that those in Alabama are oceanic rift basalt (Stow and others, 1984) and that those in southwestern North Carolina are oceanic. Whether the metabasalts are of arc or ridge origin is undetermined (Hatcher and others, 1984). Shaw and Wasserburg (1984) concluded that amphibolites of Chunky Gal Mountain (North Carolina) and near Lake Chatuge (Georgia), have the Sm-Nd and Rb-Sr isotopic signatures of ancient oceanic crust (depleted mantle source).

The Jefferson terrane is intruded by two-mica, epidote-bearing granodiorite and quartz diorite including the Spruce Pine Plutonic Suite (Rankin and others, 1991) in a broad belt from the Coastal Plain overlap in Alabama to southern Virginia. Except for the area just south of the Grandfather Mountain window, the belt of granitoids lies southeast of the regions of peak Taconian metamorphism (Rankin and others, 1989). One of the granitoids, the Austell Gneiss of Georgia, is well dated (Rb-Sr and U-Pb) at 430 Ma (J.G. Arth, written communication, 1986). The granitoids may have been generated by decompression melting after stacking of the Taconian thrust sheets (Wones and Sinha, 1988).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--Rocks of the Jefferson terrane have been previously interpreted as marine sequences deposited on Laurentian basement (Rankin, 1975). More recently, however, other interpretations have become appealing. The Jefferson terrane is interpreted by Horton and others (1989a) to be a metamorphosed accretionary wedge thrust onto the

Laurentian margin during the Taconian orogeny.

The absence of an Ordovician magmatic arc in, or west of the Grenvillian massifs for the entire length of the Appalachian orogen has been taken as evidence that the subduction zone on which the Iapetus Ocean closed was east-dipping (Odom and Fullagar, 1973; Robinson and Hall, 1980). A magmatic arc presumably grew above the east-dipping subduction zone and in New England, the Bronson Hill anticlinorium exposes part of that arc. Hall and Robinson (1982) and Stanley and Ratcliffe (1985) argued that this arc developed on an eastern, non-Laurentian basement.

Geometrically, the easiest way to generate a westward-verging, subduction-related accretionary wedge containing ophiolitic fragments is to have the accretionary wedge also formed on the eastern side, or above the subduction zone. If the Iapetus Ocean was an ocean of any significant width (Stanley and Ratcliffe (1985) suggest Taconian crustal shortening of about 1000 km at the latitude of Massachusetts) the westward-verging accretionary wedge may have developed from the Laurentian margin, even east of the original spreading center, possibly even near the eastern edge of Iapetus. By this interpretation, the western leading edge of the accretionary wedge is the surface exposure of the Iapetan or Taconian suture. Such an interpretation, which makes the Jefferson terrane exotic, was adopted by Rankin and others (1989) and Horton and others (1989a). On the other hand, Stanley and Ratcliffe (1985) and Zen and others (1986) argue that lithologic similarities between rocks of the accretionary wedge in New England east of the Grenvillian external massifs and Laurentian slope-rise deposits of the Taconic allochthons make it more likely that the rocks of the accretionary wedge were a deep-sea facies of pre-Silurian Laurentian cover rocks obducted onto the North American craton. The westward vergence of the wedge might have resulted from underplating an obducting oceanic slab and somehow mixing ophiolitic fragments in the underplating material.

REFERENCES--Abbott and Raymond (1984); Abrams and McConnell (1981); Absher and McSween (1985); Edelman and others (1988); Hatcher (1979); Hatcher and others (1984, 1988); Horton and others (1989a); Lacazette and Rast (1989); Lipin (1984); Neathery and Reynolds (1975); Odom and Fullagar (1973); Rankin and others (1989, 1991, 1993a); Shaw and Wasserburg (1984); Stow and others (1984); Tull (1978); Wehr (1985); Wones and Sinha (1988)

NA2g: POTOMAC COMPOSITE TERRANE

TERRANE BOUNDARIES--In Virginia, the Potomac composite terrane, as defined by Drake (1985a), has been thrust along the Mountain Run fault zone onto the True Blue formation (informal name) of Pavlides (1989). This map includes the True Blue in the Jefferson terrane, following the interpretation of Horton and others (1989a), although Pavlides (1989) regards the True Blue as part of Laurentia. From Maryland north, the Potomac terrane has been thrust onto the Westminster terrane on the Pleasant Grove-Huntingdon Valley thrust system, thought to be the Taconian suture. The Potomac terrane is thrust over the Baltimore terrane, which is exposed in windows beneath it, presumably on the Pleasant Grove-Huntingdon Valley thrust system.

On the east the Potomac terrane is overthrust by the Chopawamsic, Bel Air-Rising Sun, and Wilmington terranes. These amalgamations probably occurred during the Penobscottian orogeny (Horton and others, 1989a). The Pleasant Grove-Huntingdon Valley thrust system experienced dextral slip during the Alleghanian orogeny (Hill, 1987).

STRATIGRAPHY--The Potomac terrane is a composite terrane of thrust sheets that contain melange complexes as well as fragments of probable ophiolites, volcanic arcs, and submarine-fan turbidites (Drake and Morgan, 1981). Rocks from different tectonostratigraphic environments interpreted to be fragments in this terrane include the Piney Branch Complex (ophiolite fragment), Peters Creek Schist (high-energy submarine-fan ophiolitic melange), Piney Run Formation of Crowley (1976; ophiolitic melange), Annandale Group (suprafan deposit), and Wissahickon Formation, sensu stricto (turbidite-ophiolitic melange; Drake, 1986). From the Maryland-Pennsylvania border to northern Virginia, each thrust sheet is underlain by a precursory sedimentary melange characterized by olistoliths of the overlying thrust sheet (Drake, 1985b).

DEFORMATIONAL AND METAMORPHIC EVENTS--The thrust faults bounding the different terrane fragments date from the Penobscottian orogeny. Rocks in all thrust sheets are polyphase folded and each higher sheet contains fold phases not present in its underlying sheet. Each sheet has experienced a different metamorphic history, that of higher sheets being more complex than in lower sheets.

IGNEOUS INTRUSIONS--The boundary between the Chopawamsic and Potomac terranes is stitched by the Occoquan Granite (494±14 Ma Rb-Sr whole-rock isochron by Mose and Nagel, 1982), as illustrated in Figure 1.

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--In northern Virginia the thrust stack was assembled and the composite terrane was amalgamated prior to the deposition of the overlapping Popes Head Formation (Drake and Lyttle, 1981; illustrated in Figure 1). The thrust stack was amalgamated and the overlap sequence was deposited prior to the emplacement of the Early Ordovician (or Late Cambrian?) Occoquan Granite, suggesting that amalgamation was a result of the Penobscottian orogeny (Drake, 1987).

The Peters Creek Schist fragment of this composite terrane is overlain and interpreted to be overlapped in Maryland by the Peach Bottom Slate, which although not paleontologically dated, is tentatively correlated with the Middle and Upper Ordovician Arvonia Slate and Quantico Formation (Horton and others, 1989a).

REFERENCES--Crowley (1976); Drake (1985a, 1985b, 1986, 1987); Drake and Lyttle (1981); Drake and Morgan (1981); Hill (1987); Horton and others (1989a); Mose and Nagel (1982); Pavlides (1989)

NA2h: SMITH RIVER TERRANE

TERRANE BOUNDARIES--The Smith River terrane, as defined by Horton and others (1989a), lies in a fault-bounded synform within the Jefferson terrane just northwest of the Sauratown terrane. The Smith River terrane is bounded by the Ridgeway thrust fault, and locally by the younger Bowens Creek fault (Espenshade and others, 1975; Conley, 1988). These faults converge southwestward into the Brevard fault zone, wherein the terrane pinches out as a fault slice. The Ridgeway thrust is younger than probable Middle Ordovician rocks of the Martinsville igneous complex which it truncates, but older than the Chatham fault. The Chatham fault cuts the Ridgeway and juxtaposes the northern end of the Smith River terrane against Upper Triassic rocks of the Dan River-Danville basin (Conley, 1985). The northern limit of the terrane is undetermined. The Smith River terrane may feather out by infolding with the Potomac composite terrane, or it may actually be another thrust slice of that terrane (Horton and others, 1989a).

STRATIGRAPHY--The Smith River terrane in North Carolina and Virginia consists of two major rock units (Fig. 2). The lower of these, the Bassett Formation of Conley and Henika (1973), contains a debris of ultramafic and mafic rocks. The Bassett thereby resembles some of the rocks in both the Potomac and Jefferson terranes and might contain a type of ophiolitic melange. The upper part of the Bassett is amphibolite that is apparently metamorphosed basalt. The Bassett is overlain by schist and gneiss of the Fork Mountain Formation of Conley and Henika (1973). The gneiss unit in the Fork Mountain contains melange reminiscent of those in the Potomac terrane.

DEFORMATIONAL AND METAMORPHIC EVENTS--The Smith River rocks have undergone a distinctive metamorphism: high prograde, retrograde to greenschist facies, and second prograde to staurolite grade. This metamorphic sequence is reminiscent of the metamorphism in the Peters Creek Schist of the Potomac terrane (Drake, 1980). Regional amphibolite-facies metamorphism in the Smith River terrane pre-dates the Leatherwood Granite (Conley, 1985; Odom and Russell, 1975), and thereby is interpreted as Taconian or older (Penobscottian?).

IGNEOUS INTRUSIONS--The Bassett and Fork Mountain Formations are intruded by the Martinsville igneous complex, which includes the Leatherwood Granite of Pegau (1932), Rich Acres Formation of Conley and Toewe (1968; gabbro-diorite), and norite (Conley, 1985). A Pb/Pb zircon age of 450 Ma (Rankin, 1975) and a whole-rock Rb-Sr age of 455±20 Ma (recalculated from Odom and Russell, 1975) date the Leatherwood Granite as Middle Ordovician (Fig. 2).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--Rocks of the Smith River terrane may or may not correlate with those in the Inner Piedmont terrane as suggested by Conley and Henika (1973). On aeromagnetic maps, the Smith River terrane appears similar to the Potomac terrane but dissimilar to the Inner Piedmont and Milton terranes (Horton and others, 1989a). The age of metamorphism suggests that the Smith River terrane was amalgamated with its surrounding terranes during the Taconian orogeny.

REFERENCES--Conley (1985, 1988); Conley and Henika (1973); Conley and Toewe (1968); Drake (1980); Espenshade and others (1975); Horton and others (1989a); Odom and Russell (1975); Pegau (1932); Rankin (1975)

NA2i: INNER PIEDMONT COMPOSITE TERRANE

Williams and Hatcher (1982, 1983) combined the Inner Piedmont, Jefferson, Potomac and other terranes as far north as Newfoundland into a single Piedmont super-terrane. Horton and others' (1989a) definition of the Inner Piedmont and Jefferson terranes is regarded as only a first cut toward sorting out the terrane fragments in this complex stack of thrust sheets.

TERRANE BOUNDARIES--On the northwest, the Inner Piedmont terrane is separated from the Jefferson terrane by the Brevard fault zone, which is clearly a major crustal boundary (Cook and others, 1979). Williams and Hatcher (1983) and Hatcher (1987) do not regard the Brevard fault zone as a terrane boundary, presumably because of rough lithologic similarities between rocks of the Tallulah Falls Formation on the northwest and Alto allochthon on the southeast (Hatcher, 1978). Nelson and others (1987) and Horton and others (1989a), however, do not recognize a stratigraphic correlation between these metamorphic suites on opposite sides of the fault.

On the southeast, the Inner Piedmont terrane is bounded by the Towaliga, Lowndesville, Kings Mountain, and Eufola fault zones (Horton and others, 1989a).

STRATIGRAPHY--The Inner Piedmont composite terrane is a stack of thrust sheets containing schists, gneisses, amphibolites, and sparse ultramafic bodies (Fig. 2). It appears to contain metamorphic complexes of different tectonic affinities and may be an amalgamation of several disrupted terranes. Scattered ultramafic bodies and mafic-ultramafic complexes suggest that oceanic crustal material is also present (Mittwede and others, 1987). The diamictite gneiss in the South Mountains of North Carolina (Goldsmith and others, 1988) and the Clairmont Formation near Atlanta, Georgia (Higgins and others, 1984), may represent metamorphosed melange complexes. Other parts of the Inner Piedmont appear to have a coherent stratigraphy of metasedimentary and metavolcanic gneisses and schists reminiscent of the Jefferson terrane.

DEFORMATIONAL AND METAMORPHIC EVENTS--Zircons from mylonitized Henderson Gneiss in the Brevard fault zone yield a U-Pb upper concordia-intercept age of 456 Ma, according to Sinha and Glover (1978) who interpret the age as evidence of mylonite formation during the Taconian orogeny. There is also some evidence for Acadian metamorphism (Dallmeyer and Hatcher, 1985). As noted by Glover and others (1983), either Acadian remobilization of an earlier Taconic terrane or a continuum of high-grade conditions from Taconic through Acadian times is permissible on the basis of available evidence.

IGNEOUS INTRUSIONS--The Late Proterozoic or Cambrian Henderson Gneiss is the predominant rock unit just southeast of the Brevard zone for more than 120 km. Neither the Henderson Gneiss nor any rock of similar petrology and age is known in the Jefferson terrane northwest of the Brevard zone (Odom and Fullagar, 1973).

Granitic gneisses interpreted as pre- or syn-tectonic with respect to isoclinal folding and regional metamorphism have yielded Rb-Sr whole-rock isochron ages of 460±9 Ma, 431±22 Ma, 429±22 Ma, and 427±9 Ma (Odom and Russell, 1975, recalculated; Harper and Fullagar, 1981).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--Horton and others (1989a) interpret the onset of accretion of the Inner Piedmont terrane to be about 460 Ma (Middle to Late Ordovician) on the basis of metamorphic and plutonic ages discussed above, although plutonism associated with this event continued well into the Silurian.

REFERENCES--Cook and others (1979); Dallmeyer and Hatcher (1985); Glover and others (1983); Goldsmith and others (1988); Harper and Fullagar (1981); Hatcher (1978, 1987); Higgins and others (1984); Horton and others (1989a); Mittwede and others (1987); Nelson and other (1987); Odom and Fullagar (1973); Odom and Russell (1975); Sinha and Glover (1978); Williams and Hatcher (1982, 1983)

NA28: BALTIMORE TERRANE

TERRANE BOUNDARIES--The Baltimore terrane, as named by Williams and Hatcher (1982, 1983), is exposed in several windows through a thrust fault at the base of the Potomac terrane (Horton and others, 1989a, Fig. 1).

STRATIGRAPHY--The Baltimore terrane (Fig. 1) consists of the Baltimore Gneiss and its cover sequence, the Glenarm Group of Cambrian and probably Ordovician age (Muller and Chapin, 1984; Drake, 1986; Drake and others, 1989). The Baltimore Gneiss is a metamorphosed sequence of mostly felsic to intermediate volcanic, volcaniclastic, and epiclastic rocks of Middle Proterozoic age. This age is firmly established by U-Pb concordia-intercept ages (Grauert and others, 1973; Grauert, 1974) as well as a Rb-Sr whole-rock isochron age (Wetherill and others, 1968). The overlying Glenarm Group consists of the basal Setters Formation (siliciclastic), the Cockeysville Marble, and the very pelitic Loch Raven Schist of Crowley (1976) (Drake, 1986; Drake and others, 1989).

DEFORMATIONAL AND METAMORPHIC EVENTS--Mineral assemblages in pelitic rocks of the Glenarm Group indicate that the terrane has undergone Paleozoic regional metamorphism of kyanite-staurolite grade (Muller and Chapin, 1984).

IGNEOUS INTRUSIONS--The Baltimore Gneiss differs from the other basement massifs in the central Appalachians in its almost total lack of intrusive rocks (Drake, 1984; Rankin and others, 1989).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--The relationship of the Baltimore terrane to Laurentia is uncertain. It may be a Laurentian fragment that rifted away from the margin and returned (Drake and others, 1989; Muller and Chapin, 1984; Thomas, 1977), a thrust slice of Laurentian basement and cover, or a Laurentian fragment emplaced by strike-slip movement from the north or south. A third alternative is that the Baltimore terrane may not be a Laurentian fragment at all, because it does not contain the Late Proterozoic metadiabase dikes so common in Laurentian basement rocks to the west.

The Potomac terrane was thrust upon the Baltimore terrane during the Taconian orogeny.

REFERENCES--Crowley (1976); Drake (1986); Drake and others (1989); Grauert (1974); Grauert and others (1973); Horton and others (1989a); Muller and Chapin (1984); Rankin and others (1989); Thomas (1977); Wetherill and others (1968); Williams and Hatcher (1982, 1983)

NA29: SAURATOWN TERRANE

TERRANE BOUNDARIES--The Sauratown terrane of Horton and others (1989a) is equivalent to the Sauratown Mountain terrane of Williams and Hatcher (1982, 1983). This terrane is interpreted to be exposed in a window through a thin sheet of the Jefferson terrane that moved on the pre-metamorphic Forbush thrust (Hatcher and others, 1988). Both terranes are cut off on the east by the Chatham fault which forms the western border of the Dan River-Danville Triassic basin.

STRATIGRAPHY--The Sauratown terrane of North Carolina and Virginia (Fig. 2) contains a continental basement complex of Grenvillian age and its nonfossiliferous metasedimentary cover (Espenshade and others, 1975; Rankin and others, 1973). The basement complex includes biotite gneisses, schists and granitic migmatites and rare marble.

Crossbedded muscovitic quartzite, at least 75 m thick, crops out for about 24 km along the middle of the Sauratown terrane. Its structural and stratigraphic relations to the surrounding basement rocks and granite of the Crossnore Complex have not been determined.

DEFORMATIONAL AND METAMORPHIC EVENTS--The history of Paleozoic deformation and metamorphism in the Sauratown terrane is inferred to be similar to that in nearby parts of the Jefferson, Inner Piedmont, and Smith River terranes. The timing of regional metamorphism and deformation in the Sauratown terrane itself is poorly constrained to be later than the Late Proterozoic intrusions (see below) and the cover sequence and earlier than the Mesozoic Stony Ridge and Chatham faults.

IGNEOUS INTRUSIONS--The basement rocks of the Sauratown terrane are intruded by Late Proterozoic granites and felsic dikes, some of which contain sodic pyroxene. These intrusions are thought to be correlative with the Late Proterozoic Crossnore Complex and related to Iapetan rifting.

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--The basement orthogneisses are interpreted to be correlative with those in the Blue Ridge to the northwest and are at least 1,170 Ma based upon a Pb/Pb age of zircon (T. W. Stern, in Rankin and others, 1983).

REFERENCES--Espenshade and others (1975); Hatcher and others (1988); Horton and others (1989a); Rankin and others (1973, 1983); Williams and Hatcher (1982, 1983)

NA30: PINE MOUNTAIN TERRANE

TERRANE BOUNDARIES--The Pine Mountain terrane, as named by Williams and Hatcher (1982, 1983), is exposed as a series of fold nappes within a structural window (Schamel and Bauer, 1980; Sears and Cook, 1984). This window is bounded by the premetamorphic Box Ankle thrust on the northeast (Hatcher and others, 1988; Hooper and Hatcher, 1988). The Pine Mountain terrane is separated from the Uchee terrane on the southeast by the Bartletts Ferry fault (Schamel and Bauer, 1980). A 375 Ma Rb-Sr whole-rock isochron age of mylonite from the Bartletts Ferry fault has been interpreted as evidence of Devonian movement (Russell, 1978). The Pine Mountain terrane is juxtaposed against the Inner Piedmont terrane on the northwest along the Towaliga fault, a relatively late northwest-dipping normal fault characterized by cataclasites that overprint earlier mylonites (Schamel and Bauer, 1980; K.D. Nelson and others, 1987). Structures in the earlier mylonites indicate right-lateral strike-slip movement (Hooper and Hatcher, 1987; Steltenpohl, 1988).

STRATIGRAPHY--The Pine Mountain terrane of Georgia and Alabama consists of Grenville-age continental basement and its miogeoclinal metasedimentary cover (Fig. 2). Charnockitic rocks and felsic gneisses of the basement complex yield U-Pb ages older than a billion years (Odom and others, 1985). The overlying cover sequence, known as the Pine Mountain Group, is about 2 km thick and consists of aluminous and graphitic schist, orthoquartzite, and dolomitic marble (Sears and Cook, 1984).

DEFORMATIONAL AND METAMORPHIC EVENTS--The age of sillimanite-grade metamorphism and related deformation in cover rocks of the Pine Mountain terrane is poorly constrained to be post-late Proterozoic and pre-Mesozoic (Steltenpohl, 1988). Basement rocks, which were previously in granulite facies, developed corona structures during the amphibolite-facies Paleozoic metamorphism.

PLUTONIC AND IGNEOUS INTRUSIONS--Granitic rocks are interpreted to be parts of the Grenvillian basement complex.

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--The Pine Mountain terrane is generally interpreted as an internal massif of North American basement similar to the Sauratown terrane (Rankin, 1975; Hatcher, 1983, 1984).

REFERENCES--Hatcher (1983, 1984); Hatcher and others (1988); Hooper and Hatcher (1987, 1988); Nelson and others (1987); Odom and others (1985); Rankin (1975); Russell (1978); Schamel and Bauer (1980); Sears and Cook (1984); Steltenpohl (1988); Willams and Hatcher (1982, 1983)

NA31: GAFFNEY TERRANE

TERRANE BOUNDARIES--The Gaffney terrane, as defined by Horton and others (1989a), is separated from the Inner Piedmont terrane on the west by the Kings Mountain shear zone (Horton, 1981). On the east, the Kings Creek and Blacksburg shear zones separate the Gaffney terrane from the Battleground Formation of the Kings Mountain belt, which is regarded by Horton and others (1989a) as part of the Carolina terrane.

STRATIGRAPHY--The Gaffney terrane in the Carolinas is a small terrane that consists of the Blacksburg Formation on the western flank of what is traditionally known as the Kings Mountain belt (see Fig. 2). This formation consists of schist and phyllite, which are commonly graphitic, as well as interbedded quartzite, marble, calc-silicate rock, and amphibolite (Horton, 1984). Some of the schists are believed to have been turbidites (Supplee, 1986). Amphibolites that have basaltic compositions may represent sills or flows (Horton, 1984).

DEFORMATIONAL AND METAMORPHIC EVENTS--Well-documented late Paleozoic (Alleghanian) metamorphism and deformation appear to overprint an earlier event (Horton and others, 1987), but the pre-Alleghanian history is poorly constrained.

IGNEOUS INTRUSIONS--The High Shoals Granite (Pennsylvanian) stitches the boundary between the Gaffney and Carolina terranes (Horton and others, 1989a, Fig. 1). The High Shoals has a U-Pb zircon age of 317 Ma (Horton and others, 1987).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--The age of the rocks in the Gaffney terrane is uncertain, and their tectonic setting is controversial. Rankin (1975) pointed out that they are similar to the platform sequences that overlie Middle Proterozoic basement in the Pine Mountain and Sauratown terranes. The Gaffney terrane could be a similar internal continental terrane, but one in which the basement is not exposed. The presence of amphibolite, however, does not fit well with this interpretation unless the amphibolites are associated with continental rifting. Supplee (1986), suggests that the Blacksburg Formation conformably overlies the Battleground Formation and that displacement on the intervening Kings Creek shear zone is a minor disturbance. If correct, a separate Gaffney terrane would not be required and these rocks would belong to the Carolina terrane.

REFERENCES--Horton (1981, 1984); Horton and others (1987, 1989a); Rankin (1975); Supplee (1986)

NA32: BEL AIR-RISING SUN TERRANE

The Bel Air-Rising Sun terrane (Fig. 1), as defined by Horton and others (1989a), consists of mafic and ultramafic rocks of the Baltimore Complex as well as the Aberdeen metagabbro, as used by Crowley (1976). Note, however, that the mafic-ultramafic rocks of the Soldiers Delight belt and the chromite-bearing ultramafic bodies of the State Line district are interpreted by Horton and others (1989a) to be in the Potomac composite terrane rather than to be part of the Baltimore Complex as earlier interpreted by Southwick (1970). The name Bel Air-Rising Sun was introduced by Horton and others (1989a) to distinguish this terrane from the very different Baltimore terrane.

TERRANE BOUNDARIES--The main (lower) block of the Bel Air-Rising Sun terrane is thrust onto the Potomac terrane and probably onto the Baltimore terrane in the Baltimore area. This block of the terrane is bounded on the southeast by a thrust that carries the the Chopawamsic terrane (James Run Formation) over the Bel Air-Rising Sun terrane. Later imbrication brought the Potomac terrane into the south margin of the main block of the Bel Air-Rising Sun terrane.

Structurally, the Aberdeen metagabbro (Aberdeen block of Horton and others, 1989a) is anomalous in that it lies atop the James Run Formation of the Chopawamsic terrane rather than beneath it. This block was apparently thrust northwestward onto the James Run Formation of the Chopawamsic terrane, which is exposed in windows along the Susquehanna River (Higgins and Conant, 1990). Although the circum-Atlantic terrane map (Horton and others, 1989b) portrays the Aberdeen metagabbro as part of the Bel Air-Rising Sun terrane, the Aberdeen alternatively can be interpreted as a separate terrane fragment (Horton and Drake, 1986).

STRATIGRAPHY--The metamorphosed ultramafic rocks of the main (lower) block of this terrane were originally dunite, peridotite, pyroxenite, and olivine pyroxenite. The bulk of the mafic rocks is hypersthene gabbro. Norite and olivine gabbro are much less common.

The Aberdeen (upper) block of the Bel Air-Rising Sun terrane consists of strongly lineated epidiorites and epidote amphibolites (metagabbros) that lie between the James Run Formation of the Chopawamsic terrane and the Coastal Plain overlap in Harford and Cecil Counties, Maryland (Horton and others, 1989a). Local occurrences of ultramafic rocks are also known.

The age of the Bel Air-Rising Sun terrane and its time of amalgamation are uncertain. Only rocks from the main (lower) block have been sampled for isotopic studies. A model Nd-Sm age of 490±20 Ma is Early Ordovician (Shaw and Wasserburg, 1984), and a single discordant zircon date suggests a minimum age of 510 Ma (T. W. Stern and A. A. Drake, Jr., in Horton and others, 1989a).

DEFORMATIONAL AND METAMORPHIC EVENTS--Shaw and Wasserburg (1984) interpreted their Nd-Sm mineral isochron ages as an igneous crystallization age, but noted alternatively, that the mineral isochrons might record a metamorphic event.

IGNEOUS INTRUSIONS--Sinha and Hanan (1987) reported a U-Pb age of nearly 510 Ma for zircons from a plagiogranite, which they interpret as part of the "Baltimore Mafic Complex."

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--The Baltimore Complex has been variously interpreted as a partial ophiolite (Crowley, 1976; Morgan, 1977), the plutonic base for an island arc (Hanan, 1980; Sinha and Hanan, 1987), and(or) a stratiform intrusive complex (Southwick, 1970).

If the Bel Air-Rising Sun terrane is the plutonic base of an island arc, that arc probably was not the Chopawamsic arc, because rocks of the James Run Formation are tectonically above and separated from the main block of the Bel Air-Rising Sun terrane by a sedimentary melange similar to the Sykesville and Indian Run Formations of the Potomac terrane. The Bel Air-Rising Sun terrane could also be considered to be another fragment in the Potomac terrane. The main block of the Bel Air-Rising Sun is separated from the Potomac by a thrust fault and a precursory sedimentary melange, and it is overlain by the precursory sedimentary melange beneath the James Run Formation of the Chopawamsic terrane. The Aberdeen block of the Bel Air-Rising Sun terrane could have been thrust onto the James Run Formation of the Chopawamsic terrane during either the Penobscottian or Taconian orogeny.

REFERENCES--Crowley (1976); Hanan (1980); Higgins and Conant (1990); Horton and Drake (1986); Horton and others (1989a, 1989b); Morgan (1977); Shaw and Wasserburg (1984); Sinha and Hanan

(1987); Southwick (1970)

NA33: CHOPAWAMSIC TERRANE

The Chopawamsic terrane, as named by Williams and Hatcher (1982, 1983), is interpreted to be a volcanic-arc fragment. It consists of the Chopawamsic Formation and Ta River Metamorphic Suite in Virginia (Pavlides, 1980) as well as the James Run Formation in Maryland (Fig. 1). It includes the Central Virginia volcanic-plutonic belt of Pavlides (1981).

TERRANE BOUNDARIES--On the west, the Chopawamsic terrane is thrust onto the Potomac terrane along the Chopawamsic fault of Pavlides (1989).

In northern Virginia the Chopawamsic Formation overlies a precursory sedimentary melange, as do the terrane fragments in the Potomac composite terrane in that area. Similarly, the James Run Formation overlies a precursory sedimentary melange over at least part of its length. In that respect, the Chopawamsic terrane has the character of the terrane fragments within the Potomac terrane and could be considered to be yet another terrane fragment (island arc) in that composite terrane. In Virginia the Chopawamsic terrane has been overthrust by the Goochland terrane along the Spotsylvania fault.

To the north, the James Run Formation of the Chopawamsic terrane is thrust onto both the Bel Air-Rising Sun and Potomac composite terranes on the west and has overridden the Baltimore terrane, as the Loch Raven Schist is exposed in two windows at the Coastal Plain overlap in Harford County, Maryland (Crowley, 1976). Where its eastern boundary is exposed, the James Run Formation of the Chopawamsic terrane is overthrust by the enigmatic Aberdeen block of the Bel Air-Rising Sun terrane and can be seen in windows through the thrust along the Susquehanna River (Higgins and Conant, 1990).

STRATIGRAPHY--The Chopawamsic Formation in Virginia consists of felsic to mafic metavolcanic rocks derived from flows, breccias, and tuffaceous clastic rocks interbedded with nonvolcanic metagraywacke and phyllite or schist. The Ta River Metamorphic Suite, interpreted to be an eastern mafic facies of the Chopawamsic, consists of amphibolite and interlayered biotite schist and gneiss. Discordant zircon dates suggest that the Chopawamsic Formation is of Early Cambrian age (discussion and references in Pavlides, 1981).

The James Run Formation in Maryland is a complex sequence of vertically and laterally intergrading volcanic and volcaniclastic rocks, most of which are felsic in composition (Higgins, 1977). Mafic rocks are locally present. Pillow basalts, the Gilpins Falls Member of the James Run Formation, are fairly abundant, but it is uncertain that they are actually part of the James Run. Chemically, they more closely resemble the mafic and ultramafic rocks of the Bel Air-Rising Sun terrane, and they may well be the upper part of that complex. Discordant zircon ages suggest that the James Run is Cambrian in age (Tilton and others, 1970).

DEFORMATIONAL AND METAMORPHIC EVENTS--Detailed structural studies of rocks of this terrane have not been made, but in northern Virginia the rocks have experienced at least one phase of folding not present in the overlying Quantico Formation. In northern Virginia, the rocks are in greenschist facies, but in central Virginia, northeastern Maryland, and Delaware they contain staurolite, kyanite, and sillimanite so are in amphibolite facies. The high grade metamorphism in northern Virginia has been dated as Alleghanian by $^{40}Ar/^{39}Ar$ techniques (Flohr and Pavlides, 1986). Rocks in the terrane are almost certainly polymetamorphic, but the necessary textural studies have not been made.

IGNEOUS INTRUSIONS--The Chopawamsic Formation in Virginia is intruded by small bodies of plagiogranite and trondhjemite.

Both the Chopawamsic and Potomac terranes are intruded by the Occoquan Granite (494±14 Ma Rb-Sr whole-rock isochron age according to Mose and Nagel, 1982) so they were amalgamated prior to the Late Cambrian, presumably during the Penobscottian orogeny.

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--The Chopawamsic Formation and Ta River Metamorphic Suite are interpreted to constitute an island arc of Cambrian(?) age (Pavlides, 1981). The Chopawamsic Formation has rare earth and trace element geochemical characteristics of a tholeiitic island arc suite, as well as some calc-alkaline components. Tholeiitic amphibolites of the Ta River Metamorphic Suite to the east have rare earth and trace element characteristics of oceanic tholeiites. On the basis of this chemistry, Pavlides (1981) and Pavlides and others (1982) interpret the Ta River as a more oceanward facies of the volcanic arc, noting that this distribution implies a west-dipping Cambrian(?) subduction zone beneath the terrane. This is further evidence for the multistage closing of Iapetus.

The Chopawamsic terrane was probably amalgamated with the Bel Air-Rising Sun and Potomac terranes in the Late Cambrian during the Penobscottian event. This combined package was thrust upon the Baltimore terrane during the Taconian orogeny, because the underlying Loch Raven Schist is probably Ordovician in age.

The Chopawamsic Formation is unconformably overlain by the paleontologically dated Middle and Upper Ordovician Arvonia Slate and Quantico Formation (Pavlides, 1980). Mapping by Gates and others (1986) indicates that the Arvonia comes very close to overlapping the Milton terrane also. More detailed mapping is needed to determine whether or not the Arvonia oversteps this terrane boundary. Trilobites and other fauna in the Arvonia indicate a Middle to Late Ordovician age (Tillman, 1970; see also Kolata and Pavlides, 1986). Crinoid stems and other fossils indicate that the Quantico Formation is also probably Late Ordovician in age (Pavlides and others, 1980).

REFERENCES--Crowley (1976); Flohr and Pavlides (1986); Gates and others (1986); Higgins (1977); Higgins and Conant (1990); Higgins and others (1971); Kolata and Pavlides (1986); Mose and Nagel (1982); Pavlides (1980, 1981, 1989); Pavlides and others (1980, 1982); Tillman (1970); Tilton and others (1970); Williams and Hatcher (1982, 1983)

NA34: MILTON TERRANE

Horton and others (1989a) defined the Milton terrane to include rocks previously assigned to the Milton belt (North Carolina Geological Survey, 1985) or northern Charlotte belt (Tobisch and Glover, 1969, 1971). This terrane is distinguished primarily on the basis of lithology, rather than metamorphic grade, from the Charlotte belt in its type area near Charlotte, North Carolina, which is interpreted by Horton and others (1989a) as part of the Carolina terrane.

TERRANE BOUNDARIES--The Milton terrane is separated from terranes to the west by the Dan River-Danville Triassic basin and its associated Chatham fault, and north of the basin by Alleghanian dextral strike-slip faulting on the Brookneal shear zone (Gates and others, 1986). It is separated from the Carolina terrane on the east by a steep metamorphic gradient (Tobisch and Glover, 1969) which, in southern Virginia at least, coincides with faults that border the small Scottsburg Triassic basin (Kreisa, 1980).

STRATIGRAPHY--The Milton terrane of North Carolina and Virginia is a highly deformed package of interlayered felsic and mafic gneisses, and minor pelitic schist (Fig. 2). U-Pb analyses of zircons from felsic gneiss in the eastern part of the terrane yield an upper concordia-intercept age of 740 Ma (Glover and others, 1971). This is older than any reported ages from either the Chopawamsic or Carolina terranes as delineated by Horton and others (1989a, 1989b).

DEFORMATIONAL AND METAMORPHIC EVENTS--The dominant structure of the Milton terrane is a nearly recumbent antiformal nappe rooted just west of the boundary with the Carolina slice of the Carolina terrane (Tobisch and Glover, 1971). Nappe emplacement and associated deformation and metamorphism was probably no later than Early Silurian (i.e., Taconian) on the basis of intrusive relationships (see below).

IGNEOUS INTRUSIONS--Leucocratic granitic gneiss, known as the Shelton Granite Gneiss (Jonas, 1932) or Shelton Formation (Henika, 1977), occurs as sill-like bodies throughout the terrane (Fig. 2). According to Henika (1980), these were emplaced as intrusions either during or after nappe emplacement. The Shelton has a Silurian Rb-Sr whole-rock age (429±7 Ma according to Kish, 1983).

The Milton terrane is stitched to the Carolina terrane by the Alleghanian Churchland pluton (Horton and others, 1989a, Fig. 1).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--Some have suggested that these rocks are higher grade equivalents of those in the Carolina slate belt of the Carolina terrane (Tobisch and Glover, 1969; Henika, 1977). Others have compared the lithologies, deformational style, and chronology of Paleozoic folding, metamorphism, and igneous activity, and aeromagnetic map character to the Inner Piedmont terrane (Kish, 1983; Horton and others, 1989a). Conley (1985) notes that these rocks are lithologically distinct from those in the Carolina slate belt of the Carolina terrane and suggests that a suture zone might coincide with the steep metamorphic gradient between them.

REFERENCES--Conley (1985); Gates and others (1986); Glover and others (1971); Henika (1977, 1980); Horton and others (1989a, 1989b); Jonas (1932); Kish (1983); Kreisa (1980); North Carolina Geological Survey (1985); Tobisch and Glover (1969, 1971)

NA35: UCHEE TERRANE

TERRANE BOUNDARIES--The Uchee terrane, as defined by Horton and others (1989a), includes rocks within the Goat Rock shear zone and is separated from terranes on the northwest by the Bartletts Ferry fault. The nature of the boundary of the Uchee terrane with rocks of the Carolina terrane is undetermined. Higgins and others (1988), who consider the Uchee terrane to be part of their Macon melange complex, have inferred a major thrust fault along this boundary.

STRATIGRAPHY--The Uchee terrane (Fig. 2) or Uchee belt of Georgia and Alabama is a metamorphic complex of paragneiss, amphibolite, migmatite, and granitoid gneiss (Hanley, 1986). Stow and others (1984) concluded, on the basis of geochemistry, that the amphibolites represent tholeiitic basalt characteristic of an oceanic rift environment. Discordant U-Pb zircon and Rb-Sr whole-rock ages indicate that the Phenix City Gneiss of Bentley and Neathery (1970), one of the principal rock units, is Late Proterozoic to Early Cambrian in age (Russell, 1985).

DEFORMATIONAL AND METAMORPHIC EVENTS--The Uchee terrane is characterized by regional metamorphic conditions ranging from epidote-amphibolite facies to amphibolite facies (Chalokwu, 1989), migmatization, and at least two episodes of folding and penetrative deformation. The ages of these events are poorly constrained (Schamel and others, 1980; Hanley, 1986).

IGNEOUS INTRUSIONS--Granitoid gneiss of undetermined age is present, and pegmatite veins locally crosscut the gneissic layering (Schamel and others, 1980; Hanley, 1986).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--The relationship of the Uchee terrane to adjacent terranes and its time of accretion are undetermined.

REFERENCES--Bentley and Neathery (1970); Chalokwu (1989); Hanley (1986); Higgins and others (1988); Horton and others (1989a); Russell (1985); Schamel and others (1980); Stow and others (1984)

NA36: JULIETTE TERRANE

TERRANE BOUNDARIES--Rocks assigned by Horton and others (1989a) to the Juliette terrane are interpreted by Higgins and others (1988, 1989b) to be in thrust contact with, and to structurally underlie stratified volcanogenic rocks that are here assigned to the Carolina terrane.

STRATIGRAPHY--The Juliette terrane corresponds to Higgins and others' (1989) Gladesville facies of the Juliette melange. It includes three rock bodies in Georgia characterized by abundant mafic and ultramafic fragments in a matrix of schistose metamudstone and metagraywacke (Fig. 2). The interpretation of Horton and others (1989a, Fig. 1) as shown on this map differs from Higgins and others (1989b) in that it does not extend the Juliette melange to include much of the Charlotte belt in the Carolinas.

DEFORMATIONAL AND METAMORPHIC EVENTS--The ages and character of deformation and metamorphism are poorly constrained. Rocks formerly interpreted as hornblende hornfels and pyroxene hornfels aureoles around mafic intrusions have been reinterpreted by Higgins and others (1989b) as regionally metamorphosed margins of large mafic blocks in a melange.

IGNEOUS INTRUSIONS--The Gladesville mafic body in central Georgia is interpreted by Higgins and others (1988, 1989b) as an ophiolite fragment and by Hatcher and others (1984) as part of a mafic arc complex.

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--Rocks assigned to the Juliette terrane have been interpreted as a melange complex of an accretionary wedge into which fragments of ophiolite have been tectonically sliced or imbricated (Higgins and others, 1988, 1989b).

REFERENCES--Hatcher and others (1984); Higgins and others (1988, 1989); Horton and others (1989a)

NA37a: CAROLINA TERRANE

The Carolina terrane was named by Secor and others (1983) to include rocks traditionally assigned to the Carolina slate belt and Charlotte belt. Horton and others (1989a) also include most of the Kiokee belt, the Belair belt, and the Battleground Formation of the Kings Mountain belt. The Carolina terrane may be a composite terrane.

TERRANE BOUNDARIES--On the west, the Carolina terrane is separated from the Inner Piedmont terrane by the Lowndesville, Kings Mountain, and Eufola fault zones; from the Gaffney terrane by the Kings Creek and Blacksburg shear zones within the Kings Mountain belt; and from the Milton terrane by a steep metamorphic gradient which, in southern Virginia at least, coincides with a fault that border the small Scottsburg Triassic basin (Horton and others, 1989a).

On the east, the sharpness of the boundary between the Carolina terrane and the structurally lower Falls Lake and Crabtree terranes suggests that it is a fault (Horton and others, 1986). The Nutbush Creek fault zone separates the Carolina terrane from the Spring Hope terrane farther east.

STRATIGRAPHY--Geochemical studies summarized by Rogers (1982) indicate that the Carolina terrane (Fig. 2) contains at least two types of volcanic-sedimentary assemblages: (1) Late Proterozoic, partly andesitic assemblages in North Carolina have compositions consistent with calc-alkaline differentiation trends and may have formed by subduction along a continental margin. (2) Younger, Late Proterozoic to Middle Cambrian assemblages to the south, composed largely of interbedded felsic metatuffs and fine-grained marine metasedimentary rocks, probably formed in a tectonic setting that had both continental and oceanic features (Rogers, 1982). The metasedimentary rocks appear to be largely volcanogenic, but there is evidence that some material had a continental provenance (Milton and Reinhardt, 1980). Rogers' (1982) reassessment of previous geochemical studies found no evidence of volcanism on purely oceanic crust, in spite of earlier suggestions of oceanic environments (i.e., Whitney and others, 1978) based largely on major-element geochemistry.

Fossils of soft-bodied metazoans that represent the Late Proterozoic Ediacaran fauna have been found in North Carolina (Cloud and others, 1976; Gibson and others, 1984). A younger assemblage of Atlantic province trilobites in South Carolina is restricted to the upper two-thirds of the Middle Cambrian and indicates that the Carolina terrane was located away from Laurentia at that time (Secor and others, 1983).

DEFORMATIONAL AND METAMORPHIC EVENTS--Whole rock K-Ar ages averaging 483±15 Ma for low-grade slates of the Albemarle Group (Kish and others, 1979) and $^{40}Ar/^{39}Ar$ whole-rock plateau ages of 455±2 Ma for slates of the Tillery Formation in the Albemarle Group of North Carolina (Noel and others, 1988) indicate a Late Ordovician regional metamorphic event in that part of the Carolina terrane. Secor and others (1983) interpreted Kish's isotopic evidence for Ordovician metamorphism as evidence for Taconian accretion, noting that this age of metamorphism and associated deformation is significantly older than the middle and late Paleozoic ages suggested for the first Paleozoic deformational event in "Avalonian" terranes of Canada and New England.

A subsequent 340 to 360 Ma thermal event is suggested by $^{40}Ar/^{39}Ar$ age spectra of whole-rock slate and phyllite and from hornblende in higher-grade rocks (Dallmeyer and others, 1986).

IGNEOUS INTRUSIONS--The Carolina terrane contains numerous plutonic bodies. Late Proterozoic plutonic rocks are believed to be related to the volcanic rocks of similar age. Several Paleozoic plutonic suites of different ages and compositions are also present, particularly in the Charlotte belt.

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--Most tectonic models agree that the Carolina terrane originated in a volcanic-arc setting. The models very considerably, however, postulating either eastward- or westward-dipping subduction zones, possible multiple or compound arcs, and crustal environments ranging from oceanic to continental (Kish and Black, 1982).

Isotopic ages of the metamorphosed volcanic and related plutonic rocks range from Late Proterozoic to Cambrian. It is possible that the Late Proterozoic stratigraphic sequence in North Carolina is in a different terrane than the Cambrian (Ordovician?) sequence in South Carolina (LeHuray, 1987; Secor and others, 1988), although they are treated here and by Horton and others (1989a) as parts of the same (composite?) terrane.

Secor and others (1983) pointed out that the paleontology, stratigraphy, deformational chronology, and displacement history of the Carolina terrane are sufficiently distinct to suggest that it may be exotic even with respect to Avalonian terranes of the northern Appalachians. Although the Atlantic fauna are common to both the Carolina terrane and the Avalonian terranes of the northern Appalachians (Neuman and others, 1988), Secor and others (1983) and Horton and others (1989a) recommended that the terms "Avalon zone" and "Avalonian terrane" should be discontinued in the southern Appalachians until the interrelationships of these terranes are better understood.

Recent paleomagnetic studies in the Albemarle Group of North Carolina, where the age of magnetization, deformation, and metamorphism are well constrained by the above-mentioned 455 Ma $^{40}Ar/^{39}Ar$ plateau age, indicate a Late Ordovician paleolatitude of about 22°S (Vick and others, 1987; Noel and others, 1988). This suggests that the Carolina terrane was at or close to the Laurentian margin at that time (Vick and others, 1987; Noel and others, 1988). Vick and others propose that the regional metamorphism, deformation, and magnetization (acquired during folding) were coeval with the docking and accretion of the Carolina terrane onto Laurentia. The paleolatitude determined for the Carolina terrane contrasts sharply with the high southerly Ordovician paleolatitudes reported for the Wilmington terrane and for the "Avalon terrane" of Nova Scotia implying a different Ordovician paleogeography (Horton and others, 1989a).

REFERENCES--Cloud and others (1976); Dallmeyer and others (1986); Gibson and others (1984); Horton and others (1989a); Kish and Black (1982); Kish and others (1979); LeHuray (1987); Milton and Reinhardt (1980); Neuman and others (1988); Noel and others (1988); Rogers (1982); Secor and others (1983, 1988); Vick and others (1987); Whitney and others (1978)

NA37b: SPRING HOPE TERRANE

TERRANE BOUNDARIES--The Spring Hope terrane, as defined by Horton and others (1989a), is separated from structurally lower rocks of the Goochland terrane (informally named Raleigh gneiss of Farrar, 1985a) by an inferred pre-Alleghanian thrust fault of undetermined age (Farrar, 1985b). On the west and east, the Spring Hope terrane is bounded by Alleghanian dextral strike-slip faults of the Nutbush Creek and Hollister fault zones, respectively.

STRATIGRAPHY--The Spring Hope terrane (Fig. 2) consists of greenschist-facies mafic to felsic metavolcanic rocks and volcanogenic metasedimentary rocks of undetermined age. Most of these rocks have been traditionally assigned to the Eastern slate belt, but the Spring Hope terrane also includes amphibolite-facies equivalents of the same rocks in the Raleigh metamorphic belt. Metamorphosed mudstone (argillite, phyllite, and schist), siltstone, graywacke, and minor conglomerate occur in sequences interpreted as turbidites and as reworked pyroclastic-epiclastic deposits (Boltin and Stoddard, 1987; Corbitt and Spruill, 1985; Farrar, 1985a). Metavolcanic rocks include felsic crystal and lapilli metatuffs and greenstone-metabasalt (amphibolite at higher grade), some of which contains quartz amygdules (Boltin and Stoddard, 1987; Farrar, 1985a).

DEFORMATIONAL AND METAMORPHIC EVENTS--Felsic metavolcanic rocks have yielded Rb-Sr whole-rock ages of 365±4 Ma and 386±27 Ma (Fullagar and others, 1987), indicating that the rocks are no younger than Devonian. High initial $^{87}Sr/^{86}Sr$ ratios suggest that these ages were reset, perhaps by a Devonian (Acadian) regional metamorphic episode. Rb-Sr whole-rock ages of metavolcanic rocks from the Carolina terrane to the west are all Ordovician (Taconian) or older, suggesting that the Carolina and Spring Hope terranes may have different thermotectonic histories (Fullagar and others, 1987).

IGNEOUS INTRUSIONS--Metagabbro and metadiorite of undetermined age occur locally as intrusive bodies.

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--Boltin and Stoddard (1987) interpret a few chemical analyses of metabasalt and amphibolite as evidence that they belong to a low-potassium tholeiitic suite. Tentatively, this suggests that the Spring Hope terrane originated in a volcanic-arc environment on oceanic crust or very thin continental crust.

The Spring Hope terrane may be a valid terrane or it may prove to be a fault block of the Carolina terrane similar to the Belair belt. As noted by Horton and others (1989a), it is tentatively treated as a distinct terrane until the stratigraphy and geologic history are better understood.

REFERENCES--Boltin and Stoddard (1987); Corbitt and Spruill (1985); Farrar (1985a, 1985b); Fullagar and others (1987); Horton and others (1989a)

NA37c: ROANOKE RAPIDS TERRANE

TERRANE BOUNDARIES--The Roanoke Rapids terrane of North Carolina and Virginia is essentially equivalent to the Roanoke Rapids structural block of Farrar (1985b). It consists of poorly known greenschist-facies and epidote-amphibolite facies metavolcanic and volcanogenic metasedimentary rocks that lie east of the Hollister fault zone.

STRATIGRAPHY--The Roanoke Rapids terrane (Figs. 1 and 2) as defined by Horton and others (1989) includes the informally named Easonburg formation, Roanoke Rapids complex, Halifax County (mafic-ultramafic) complex, and Rocky Mount pluton (see Farrar, 1985a and 1985b). The ages of the metavolcanic and metasedimentary sequences in the Roanoke Rapids terrane are poorly constrained.

DEFORMATIONAL AND METAMORPHIC EVENTS--The pre-Alleghanian metamorphic history of the Roanoke Rapids terrane is presently unknown. Mineral ages indicate that the Roanoke Rapids terrane cooled more rapidly in the late stages of the Alleghanian orogeny than did the Spring Hope terrane west of the Hollister fault zone (Mauger and others, 1987; Russell and others, 1985).

IGNEOUS INTRUSIONS--Granite of the Fountain (North Carolina) pluton has a Cambrian whole-rock Rb-Sr "scatterchron" age of 531±60 Ma (Mauger and others, 1983). The Fountain pluton is puzzling because it has a silicic peralkalic composition suggestive of rift-related magmatism (Mauger and others, 1983).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--If the Halifax County complex on the western flank of this terrane is an island-arc ophiolite, as proposed by Kite and Stoddard (1984), it is likely that this terrane originated at least partly in an oceanic setting.

Rocks of the Roanoake Rapids terrane superficially resemble those of the Spring Hope and Carolina terranes to the west (Horton and Stoddard, 1986). These could all be fault blocks of a single suspect terrane, but because of a lack of information about the stratigraphy and geologic history, Horton and others (1989a) tentatively consider the Roanoke Rapids as a separate terrane.

REFERENCES--Farrar (1985a, 1985b); Horton and Stoddard (1986); Horton and others (1989a); Kite and Stoddard (1984); Mauger and others (1983, 1987); Russell and others (1985)

NA37d: CHARLESTON TERRANE

The Charleston terrane of Horton and others (1989a) is equivalent to the "Charleston magnetic terrane" of Higgins and Zietz (1983) and the "Brunswick terrane" of Williams and Hatcher (1982, 1983) except for some boundary differences. The Charleston terrane is partly covered by overlapping Mesozoic strata of the South Georgia basin and is completely covered by Coastal Plain sediments.

TERRANE BOUNDARIES--The northwestern boundary of the Charleston terrane is poorly constrained. It is tentatively portrayed by Horton and others (1989a, Fig. 1) as a modified version of the magnetic lineament which Higgins and Zietz (1983) term the Carolina-Mississippi fault.

The southeastern boundary of the Charleston terrane is interpreted to coincide approximately with a zone of south-dipping seismic reflectors that penetrate the entire crust along the northern flank of the Brunswick magnetic anomaly in southwestern Georgia (Nelson and others, 1985a, b; McBride and Nelson, 1988). At shallower levels of the crust penetrated by drilling through Coastal Plain sediments, the trace of this terrane boundary as indicated by contrasting lithology (see Suwannee terrane) coincides approximately with the northern flank of the Brunswick anomaly in Alabama and western Georgia (Chowns and Williams, 1983; Horton and others, 1984) but extends more than 25 km north of the anomaly in eastern Georgia (Chowns and Williams, 1983; Tauvers and Muehlberger, 1987; Thomas and others, 1988).

STRATIGRAPHY--Rocks recovered from the subsurface are greenschist-facies metasedimentary and metavolcanic rocks grossly similar to those in the Carolina, Spring Hope, and Roanoke Rapids terranes (Fig. 2).

DEFORMATIONAL AND METAMORPHIC EVENTS--Undetermined.

IGNEOUS INTRUSIONS--Short-wavelength circular magnetic and gravity anomalies suggest the presence of both mafic and granitic plutons. The Springfield monzogranite pluton of Speer (1982), was located by siting a core hole over one of the circular gravity lows. $^{207}Pb/^{206}Pb$ ages of 377 and 372 Ma on zircons are interpreted by Sinha and others (1980) as a crystallization age, making the Springfield one of the oldest post-metamorphic granites in the southeastern United States (Speer, 1982). Other circular short-wavelength anomalies have been attributed to plutons thought to be of Mesozoic age (Daniels and others, 1983).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--The Charleston terrane is distinguished from the Carolina and Spring Hope terranes to the northwest as an area of broad-wavelength magnetic highs (Williams and Hatcher, 1982, 1983; Higgins and Zietz, 1983; Zietz and Gilbert, 1980). The magnetically high region cannot be explained by variations in depth to the moho and must be attributed to material at middle to upper levels of the crust (Horton and others, 1989a). The magnetic and gravity anomalies together point to the main characteristic of this terrane, which is an abundance of mafic material as plutons and foliated mafic rocks (Horton and others, 1989a).

The time of accretion is undetermined.

REFERENCES--Chowns and Williams (1983); Daniels and others (1983); Higgins and Zietz (1983); Horton and others (1984, 1989a); McBride and Nelson (1988); Nelson and others (1985a, 1985b, 1985c); Rankin (1977); Sinha and others (1980); Speer (1982); Tauvers and Muehlberger (1987); Thomas and others (1989); Williams and Hatcher (1982, 1983); Zietz and Gilbert (1980)

NA38: FALLS LAKE TERRANE

TERRANE BOUNDARIES--Abrupt contacts and local mylonitic fabrics suggest that the upper contact of the Falls Lake terrane with stratified volcanogenic rocks of the Carolina terrane is a fault (Horton and others, 1989a). The Falls Lake terrane, as well as the Falls Lake thrust which separates it from the underlying Crabtree terrane, are truncated on the east by the Nutbush Creek fault zone, an Alleghanian strike-slip fault having right-lateral movement (Horton and others, 1986).

STRATIGRAPHY--The Falls Lake terrane, as defined by Horton and others (1986), is a melange complex in the eastern Piedmont of the North Carolina on the western flank of the Raleigh metamorphic belt. The melange consists of mafic and ultramafic blocks and pods in a matrix of pelitic schist and biotite-muscovite-plagioclase-quartz gneiss interpreted as metagraywacke (Fig. 2). It has been suggested that it formed by a combination of sedimentary and tectonic processes, perhaps in an accretionary wedge.

DEFORMATIONAL AND METAMORPHIC EVENTS--The basal thrust carrying the Falls Lake terrane is folded by the upright Raleigh antiform and is transected by younger, Alleghanian-age, metamorphic isograds (Parker, 1979; Russell and others, 1985; Stoddard and others, 1985).

IGNEOUS INTRUSIONS--Mafic and ultramafic rocks are interpreted as slices in a tectonic melange (Horton and others, 1986).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--The Falls Lake melange and the overlying Carolina terrane, a Late Proterozoic to Middle Cambrian volcanic-arc terrane, were thrust upon the underlying Crabtree terrane, before overprinting by late Paleozoic folding and metamorphism (Horton and others, 1986).

REFERENCES--Horton and others (1986, 1989a); Parker (1979); Russell and others (1985); Stoddard and others (1985)

NA39: CRABTREE TERRANE

The small Crabtree terrane, as defined by Horton and others (1989a), is exposed in the eastern Piedmont of North Carolina on the western flank of the Raleigh metamorphic belt.

TERRANE BOUNDARIES--The Crabtree terrane is separated from the overlying Falls Lake terrane by a pre-Alleghanian thrust, which is folded and overprinted by Alleghanian metamorphic zones (Horton and others, 1986). The Crabtree terrane is separated from the Goochland terrane to the east by the Nutbush Creek fault zone, an Alleghanian strike-slip fault having right-lateral movement.

STRATIGRAPHY--The most prevalent rock unit is a quartzofeldspathic gneiss (Fig. 2), which may have had felsic igneous or arkosic sedimentary protoliths of continental origin (Stoddard and others, 1978). A Rb-Sr isochron (Kish and Campbell, 1986) indicates that the quartzofeldspathic gneiss unit is no younger than Devonian. Interlayered with the gneiss are garnet-kyanite schist and highly aluminous graphitic mica schist, which may have originated as muds deposited in a restricted basin (Horton and others, 1986).

DEFORMATIONAL AND METAMORPHIC EVENTS--Alleghanian deformation and metamorphism are well documented (Russell and others, 1985; Horton and others, 1986). The age of earlier deformation and metamorphism is undetermined.

IGNEOUS INTRUSIONS--Some of the quartzofeldspathic gneisses have been interpreted as intrusive granitoids (Kish and Campbell, 1986).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--The Crabtree terrane is a probable continental terrane of unknown age and affinity. It lies east of and structurally beneath the Falls Lake terrane and, unlike the Falls Lake, contains no ultramafic rocks. The suite of rock units is different from that of the Raleigh gneiss to the east, which is interpreted as part of the Goochland terrane.

REFERENCES--Horton and others (1986, 1989a); Kish and Campbell (1986); Russell and others (1985); Stoddard and others (1978)

NA40: GOOCHLAND TERRANE

TERRANE BOUNDARIES--The Goochland terrane, as defined by Farrar (1984), includes rocks assigned by Williams and Hatcher (1982, 1983) to the "State Farm terrane." The Goochland terrane is separated from the Chopawamsic terrane on the west by the Spotsylvania fault, and from the Roanoke Rapids terrane on the east by the late Paleozoic Hylas fault zone (Farrar, 1984). The probable southern extension of the Goochland terrane is separated from overlying volcanogenic rocks of the Spring Hope terrane by a premetamorphic thrust within the Raleigh metamorphic belt, and from terranes to the west by the Nutbush Creek fault zone, an Alleghanian dextral strike-slip fault.

STRATIGRAPHY--The type area of the Goochland terrane (Fig. 2) is in east-central Virginia. There it includes the State Farm Gneiss of Brown (1937), which has yielded a Rb-Sr whole-rock age of 1031±94 Ma (Glover and others, 1978, 1982). The State Farm Gneiss is overlain by the Sabot Amphibolite and Maidens Gneiss, both of Poland and others (1979). The Maidens Gneiss is equivalent to the Po River Metamorphic Suite in northern Virginia and is inferred to be correlative with the Raleigh gneiss (informal name) of Farrar (1985a) in North Carolina.

DEFORMATIONAL AND METAMORPHIC EVENTS--Farrar (1984) suggests that relict granulite-facies assemblages in both the State Farm and Maidens Gneisses may be Middle Proterozoic in age (i.e. Grenvillian).

IGNEOUS INTRUSIONS--Metamorphosed anorthosite, as mapped by Farrar (1984), cuts the mutual contacts of the State Farm Gneiss, Sabot Amphibolite, and Maidens Gneiss.

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--Farrar (1984) and Glover and others (1982) suggest that the Goochland terrane is a remobilized slice of Laurentia. Rankin and others (1989) point out that the stratigraphy and structure of the Goochland terrane are different from the adjacent parts of Laurentia. Horton and others (1989a) favor the interpretation that the Goochland terrane is an exotic accreted terrane, rather than a slice of Laurentia. The age (because of the large uncertainty in the determination) and affiliation are unresolved.

The timing of events in the Goochland terrane is too poorly constrained to determine if its accretion was Taconian or later.

REFERENCES--Brown (1937); Farrar (1984, 1985a); Glover and others (1978, 1982); Horton and others (1989a); Poland and others (1979); Rankin and others (1989); Williams and Hatcher (1982, 1983)

NA41: WILMINGTON TERRANE

TERRANE BOUNDARIES--The Wilmington terrane of Horton and others (1989a) appears to be thrust over the James Run Formation of the Chopawamsic terrane on the southwest. Some geologists (Wagner and Srogi, 1987) think that it is thrust over the "Wissahickon Formation" elsewhere along its western contact, but all planar elements in both units dip to the west suggesting that the "Wissahickon" is above the Wilmington. Available mapping (Ward, 1959) suggests that the small area of "Wissahickon" northeast of the Wilmington terrane dips to the east away from the Wilmington, and thereby that the Wilmington lies beneath a thrust sheet, probably of the Potomac terrane.

STRATIGRAPHY--The Wilmington terrane (Fig. 1) in Delaware consists of granulite-facies intrusive, sedimentary, and perhaps volcanic rocks that resemble no other rocks in the central Appalachians. Metasedimentary rocks of the Wilmington terrane are layered, and some appear to be block-in-matrix units.

DEFORMATIONAL AND METAMORPHIC EVENTS--Granulite-facies metamorphism and associated deformation is suggested to be Taconian (Grauert and Wagner, 1975).

IGNEOUS INTRUSIONS--The intrusive rocks are mostly mafic and one body, the Arden pluton, is anorthositic gabbro (Foland and Muessig, 1978). The Arden is Cambrian in age (502±20 Ma) on the basis of whole-rock Rb-Sr dating (Foland and Muessig, 1978). If this is correct the layered rocks must older (Fig. 1), perhaps Late Proterozoic or even Middle Proterozoic.

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--Paleomagnetic data are interpreted to suggest that the Wilmington terrane was nowhere near Laurentia during the Ordovician (Rao and Van der Voo, 1980; Brown and Van der Voo, 1983). The high paleolatitudes, along with similar paleolatitudes from parts of Europe and North Africa, have been considered evidence that the Wilmington terrane was part of an Armerican continent closely associated with Gondwanaland during Ordovician time (Perroud and others, 1984). This interpretation, however, ignores the abundant faulting, isoclinal folding, and granulite-facies metamorphism in the areas that could have reoriented poles that originally had other inclinations. Regional data imply that the Wilmington terrane was amalgamated with the Chopawamsic and Potomac terranes either during the Penobscottian or Taconian events (Horton and others, 1989s).

Because of the Cambrian or older age of the rocks, the granulite-facies metamorphism (suggested to be of Taconian age by Grauert and Wagner, 1975), the presence of anorthositic rocks, and the structural position adjacent to the Chopawamsic terrane (whether above or below), it is possible that the Wilmington terrane might be an extension of the Goochland terrane. The Wilmington terrane could have amalgamated with the Chopawamsic and Potomac terranes either in the Penobscottian or Taconian events.

REFERENCES--Brown and Van der Voo (1983); Grauert and Wagner (1975); Foland and Muessig (1978); Horton and others (1989a); Rao and Van der Voo (1980); Wagner and Srogi (1987); Ward (1959)

NA42: SUSSEX TERRANE

TERRANE BOUNDARIES--The Sussex terrane (Fig. 1), as named by Horton and others (1989a), lies entirely beneath sediments of the Atlantic Coastal Plain in Virginia and Maryland. It is best represented by a north-northeast-trending positive gravity anomaly having about 30 milligals relief (Johnson, 1973). A mixed pattern of magnetic highs and lows coincides with the envelope of the gravity anomaly (Daniels and Leo, 1985). The nature of the terrane boundaries is unknown.

STRATIGRAPHY--Wells that penetrate basement within the limits of the gravity anomaly have recovered foliated mafic metavolcanic rocks, ultramafic rocks, gabbro, metadiorite, and phyllite (Daniels and Leo, 1985).

DEFORMATIONAL AND METAMORPHIC EVENTS--Undetermined.

IGNEOUS INTRUSIONS--The gravity amplitude suggests that dense rock such as gabbro constitutes a major part of the terrane.

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--The mixture of rock types suggests that the Sussex terrane may be a melange complex. Unlike the Jefferson and Potomac terranes, however, the Sussex terrane must contain (because of the amplitude of the gravity anomaly) a predominant fraction of mafic rocks and a smaller fraction of clastic rocks (Horton and others, 1989a). The Sussex terrane may contain substantial amounts of oceanic crustal material.

REFERENCES--Daniels and Leo (1985); Horton and others (1989a); Johnson (1973)

NA43: HATTERAS TERRANE

TERRANE BOUNDARIES--The Hatteras terrane of Horton and others (1989a) was first recognized by Daniels and Zietz (1978). This terrane is nowhere exposed and has no distinct geophysical signature relative to the Roanoke Rapids and Spring Hope terranes that bound it to the northwest. Hence the northwest boundary is bracketed between drill holes. It is distinguished from the Charleston terrane to the east and south by the relatively higher amplitude magnetic anomalies in the Hatteras terrane (Rankin and others, 1991).

STRATIGRAPHY--The Hatteras terrane (Fig. 2) of eastern North Carolina and Virginia is totally covered by Coastal Plain sediments. It is known from drilling to be an amphibolite-facies metamorphic complex containing plutonic rocks (Daniels and Zietz, 1978; Daniels and Leo, 1985).

DEFORMATIONAL AND METAMORPHIC EVENTS--The age of amphibolite-facies metamorphism is undetermined.

IGNEOUS INTRUSIONS--The plutonic rocks, which range in composition from granite to diorite (Daniels and Leo, 1985), have Late Proterozoic Rb-Sr ages of 583 to 685 Ma (Denison and others, 1967; Russell and others, 1981). These ages are similar to those of the lower-grade Carolina terrane and other terranes that have been called Avalonian (Fig. 2).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--The Hatteras terrane may or may not be a higher-grade equivalent of the adjacent Roanoke Rapids terrane. Horton and others (1989a) tentatively named it as a separate terrane.

REFERENCES--Daniels and Leo (1985); Daniels and Zietz (1978); Denison and others (1967); Horton and others (1989a); Rankin and others (1991); Russell and others (1981)

NA44a: SUWANNEE TERRANE

The Suwannee terrane of Horton and others (1989a) is equivalent to the "Tallahassee-Suwannee" terrane of Williams and Hatcher (1982, 1983).

TERRANE BOUNDARIES--Williams and Hatcher (1982, 1983) and Higgins and Zietz (1983) interpret the Brunswick (Altamaha) magnetic anomaly as the northern boundary of the Suwannee terrane. Seismic reflection profiles support the interpretation that this anomaly represents a major terrane boundary or suture deep within the crust. This is complicated, however, by the fact that felsic volcanic rocks similar to those south of the Brunswick anomaly have been recovered by drilling north of the anomaly in eastern Georgia (Chowns and Williams, 1983). The similar rocks on both sides of the Brunswick anomaly suggest that it is not everywhere coincident with a major suture in the upper part of the crust. Secor and others (1986) and Tauvers and Muehlberger (1987) have proposed alternative models in which the Brunswick anomaly is the Alleghanian suture or subsurface limit of pre-Alleghanian North American crust at deeper levels, but that felsic volcanics north of the anomaly are allochthonous parts of the Suwannee terrane thrust over the Charleston terrane.

STRATIGRAPHY--The Suwannee terrane (Fig. 2) contains a sequence of fossiliferous Ordovician to Devonian sandstones and shales, known as the "Suwannee basin" (King, 1961) or "Northern Florida platform sequence" (Chowns and Williams, 1983). These unmetamorphosed, little-deformed rocks contain European or African marine faunas unlike those of similar age in rocks deposited on the Laurentian craton (Pojeta and others, 1976 and references therein).

Low-grade felsic volcanic and epiclastic rocks of uncertain age underlie and extend beyond the Northern Florida platform sequence, and similar rocks are found in the subsurface north of the Brunswick anomaly in eastern Georgia (Chowns and Williams, 1983). Chowns and Williams suggest an age of Late Proterozoic or early Paleozoic for the volcanic rocks because they are overlain by Lower Ordovician strata. Detrital white micas in the overlying Paleozoic sedimentary rocks have $^{40}Ar/^{39}Ar$ plateau ages of about 530 Ma (Dallmeyer, 1986b), suggesting that the sediments were derived from source rocks of Middle Cambrian age. These source rocks could be roughly correlative with part of the volcanic sequence as suggested by Dallmeyer (1986b), although significant amounts of white mica have not been reported in the felsic volcanics.

DEFORMATIONAL AND METAMORPHIC EVENTS--The Northern Florida platform sequence is apparently nonmetamorphosed and little deformed. The age of low-grade metamorphism in underlying volcanogenic rocks is undetermined. Regional amphibolite-facies metamorphism in the "St. Lucie Metamorphic Complex" is thought to be Pan-African (see NA44b decription).

IGNEOUS INTRUSIONS--Mueller and Porch (1983) describe the felsic volcanic rocks as calc-alkaline, and Dallmeyer (1986b) notes that they are associated with hypabyssal granite. Dallmeyer suggests that they are Late Proterozoic on the basis of a proposed direct correlation with calc-alkaline granites in southeastern Senegal, which have Rb-Sr whole-rock isochron ages of 675 to 690 Ma.

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--Wilson (1966) recognized the anomalous character of these rocks and suggested that they might represent a fragment of the west African platform. Chowns and Williams (1983) supported this by demonstrating striking similarities in stratigraphic succession between the Northern Florida platform sequence and several Paleozoic sections in northwest Africa. Villeneuve (1984) has proposed direct sedimentologic and stratigraphic correlations between the Paleozoic sections in northern Florida and in the Bove basin of Senegal and Guinea.

Pre-Grenvillian $^{207}Pb/^{206}Pb$ ages (about 1650 to 1800 Ma) of detrital zircons from the Northern Florida platform sequence also indicate that the Suwannee terrane is exotic with respect to Laurentia (Opdyke and others, 1987). Possible source rocks of this age are known in Africa and South America, but not in southeastern North America. Furthermore, paleomagnetic data for lower Paleozoic rocks of the Northern Florida platform sequence indicate a paleolatitude of 49° (Opdyke and others, 1987). This paleolatitude is substantially higher than paleolatitudes of similar age rocks from Laurentia, but compatible with an interpretation of the Suwannee terrane as a fragment of Gondwanaland.

REFERENCES--Chowns and Williams (1983); Dallmeyer (1986b); Higgins and Zietz (1983); Horton and others (1989a); King (1961); Mueller and Porch (1983); Opdyke and others (1987); Pojeta and others (1976); Secor and others (1986); Tauvers and Muehlberger (1987); Villeneuve (1984); Williams and Hatcher (1982, 1983); Wilson (1966)

NA44b: ST. LUCIE METAMORPHIC COMPLEX (PART OF SUWANNEE TERRANE)

TERRANE BOUNDARIES--The "St. Lucie Metamorphic Complex" is regarded here and by Horton and others (1989a) as part of the Suwannee terrane (Fig. 2). It is shown and labeled separately on the circum-Atlantic terrane map (Horton and others, 1989b), because it may be important for trans-Atlantic correlations and because it suggests that the Suwannee may be a composite terrane (Dallmeyer, 1989a, 1989b).

STRATIGRAPHY--A suite of amphibolite-facies metamorphic rocks in central Florida, termed the "Cowles metamorphic rocks" by Chowns and Williams (1983) and the "St. Lucie Metamorphic Complex" by Thomas and others (1989), is flanked on the north by a large body of granite (Chowns and Williams, 1983, Plate 1), which has been termed the "Osceola Granite" (Dallmeyer and others, 1987; Thomas and others, 1989).

DEFORMATIONAL AND METAMORPHIC EVENTS--Hornblendes from the "St. Lucie Metamorphic Complex" yield $^{40}Ar/^{39}Ar$ plateau ages of 500 to 520 ma (Dallmeyer, 1986a), suggesting that the regional amphibolite-facies metamorphism may have been Pan-African.

IGNEOUS INTRUSIONS--Feldspars from the "Osceola Granite" yield a Rb-Sr age of about 530 Ma (Bass, 1969).

EVIDENCE FOR TERRANE IDENTITY AND TIME OF AMALGAMATION--Similarities in age and metamorphic character suggest that the "St. Lucie Metamorphic Complex" and "Osceola Granite" represent a segment of the western part of the Pan-African Rokelide fold belt (Chowns and Williams, 1983; Dallmeyer, 1986a, 1989a, 1989b). The Suwannee terrane therefore may be a composite terrane.

REFERENCES--Bass (1969); Chowns and Williams (1983); Dallmeyer (1986a, 1989a, 1989b); Dallmeyer and others (1987); Horton and others (1989a); Thomas and others (1989)

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Figure 1. Accretionary-history diagram for the central Appalachian region modified from Horton and others (1989b).

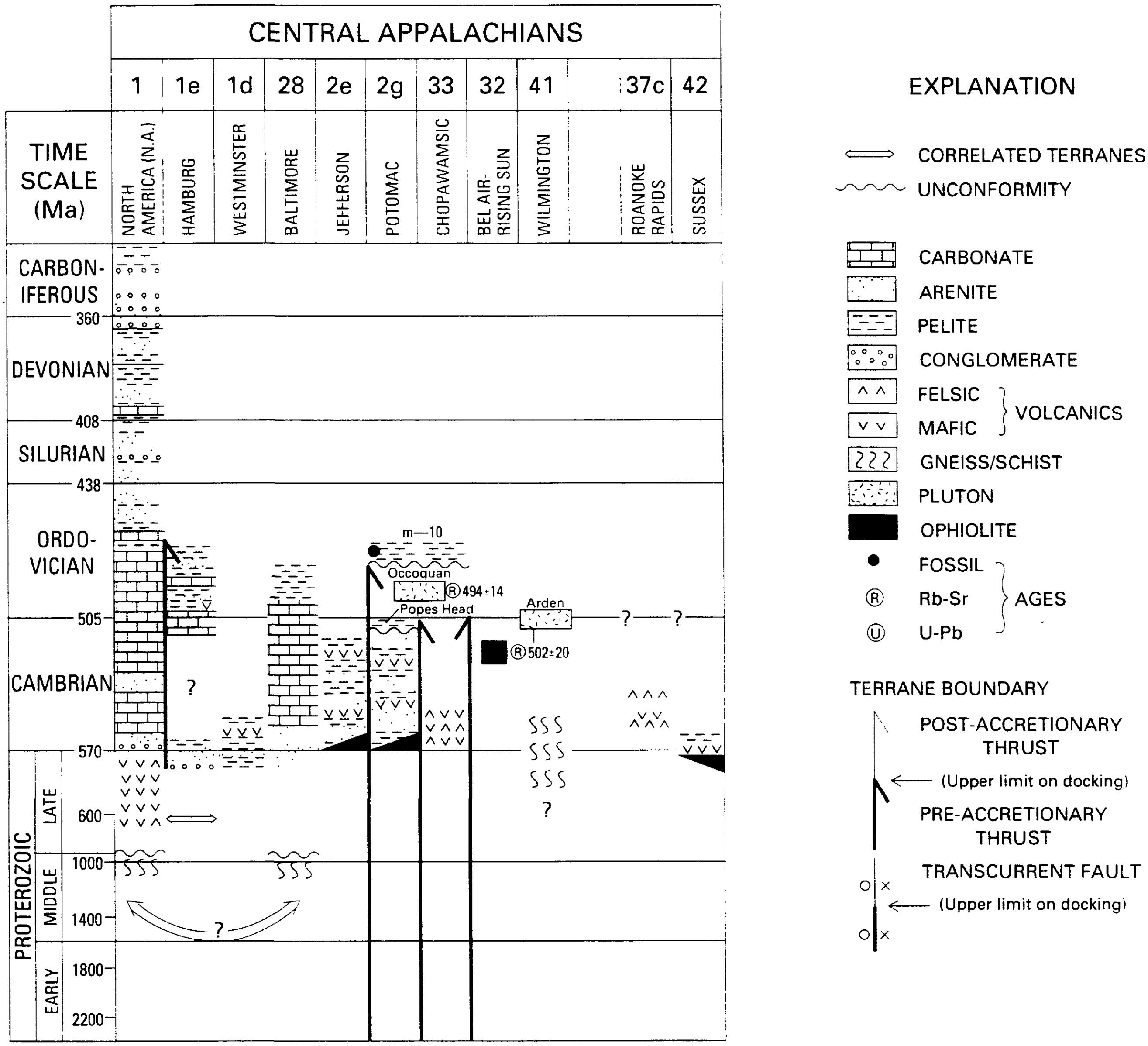

Figure 2. Accretionary-history diagram for the southern Appalachian region modified from Horton and others (1989b). See explanation of symbols in Figure 1.