

# Synthesis and revision of groups within the Newark Supergroup, eastern North America

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## ABSTRACT

The Newark Supergroup currently includes nine stratigraphic groups, each of which applies to part or all of the rock column of only one or a few basins. Because the group nomenclature within the Newark Supergroup is neither inclusive nor parallel in its concepts, nearly half of the strata within the Newark Supergroup lacks any group placement. A new system is proposed herein that (1) establishes unambiguous group boundaries, (2) places all Newark Supergroup strata into groups, (3) reduces the number of group names from nine to three, (4) creates parallelism between groups and three major successive tectonic events that created the rift basins containing the Newark Supergroup, and (5) coincidentally provides isochronous or nearly isochronous group boundaries. These proposed groups are (1) the Chatham Group (Middle Triassic to basal Lower Jurassic sedimentary rocks), (2) the Meriden Group (Lower Jurassic extrusive volcanic and sedimentary rocks), and (3) the Agawam Group (new name) (Lower Jurassic sedimentary rocks above all early Mesozoic igneous intrusive and extrusive rocks).

This new rock classification system makes use of the fact that a discrete interval of synchronous or nearly synchronous volcanism and plutonism occurred throughout the early Mesozoic rift system of eastern North America. The presence or absence of volcanic rocks provides a powerful stratigraphic tool for establishing regional groups and group boundaries. The presence of sedimentary rocks injected by diabase dikes and sills, in the absence of extrusive volcanic rocks, places Newark Supergroup rocks in the Chatham Group. The presence of extrusive volcanic rocks, interbedded with sedimentary rocks injected by diabase dikes and sills, places Newark Supergroup rocks in the Meriden Group. The presence of sedimentary rocks lacking both extrusive volcanic rocks and diabase dikes and

sills, places Newark Supergroup rocks in the Agawam Group. Application of this new regional group stratigraphy to the early Mesozoic rift basins requires revision of the stratigraphy of several basins to make formation boundaries match group boundaries.

## INTRODUCTION

The Newark Supergroup (Fig. 1) is an inclusive stratigraphic term for all continental sedimentary and extrusive volcanic rocks of Middle Triassic through Early Jurassic age that are preserved in 29 rift basins exposed in eastern North America (Olsen, 1978; Froelich and Olsen, 1984). Age-equivalent rocks lie buried beneath the Atlantic Coastal Plain, but these have not been added to the Newark Supergroup because their age, areal extent, and lithologic composition remain unknown (Luttrell, 1989, p. 2). The Newark Supergroup is bounded by profound regional unconformities, each representing 90 m.y. or more. Although local internal unconformities have been documented, the Newark Supergroup regionally represents nearly continuous deposition from Middle Triassic into Early Jurassic time (Olsen, 1986).

Formational nomenclature within the Newark Supergroup generally is adequate (Luttrell, 1989, Plate 1), but group-level stratigraphy remains disorganized and incompletely applied (Fig. 2). Four group names (Conewago, Lewisburg or Lewisberry, Lisbon or Lisburn, and Manchester) have been proposed and subsequently abandoned (Luttrell, 1989); these are not discussed further. Among groups currently accepted in the literature, two groups occur within one basin (Tuckahoe and Chesterfield Groups in the Richmond basin); one group encompasses the entire column in several basins (Chatham Group in the Crowburg, Wadesboro, Ellerbe, Sanford, and Durham basins; Dan River Group in the Davie County and Dan River–Danville basins; Tuckahoe Group in the Deep Run and Flat Branch basins; Culpeper Group in the Barbourville and Culpeper

basins; and the Fundy Group in various areas of the Fundy basin), one group encompasses the entire column of a single basin (Hartford Group in the Hartford basin), and one group encompasses only part of the sequence in three basins (Brunswick Group in the Newark basin; Meriden Group in the Pomperaug and Hartford basins). In other early Mesozoic basins, no groups have been proposed (Scottsburg, Randolph, Roanoke Creek, Briery Creek, Farmville, Taylorsville, Scottsville, Gettysburg, Cherry Brook, Deerfield, Northfield, and Middleton basins). Thus some groups correspond to one basin, some groups are present in more than one basin, some groups include only part of one basin, and some basins have no group assignment.

This approach to the group concept has unnecessarily fragmented a relatively uniform regional lithostratigraphic and tectonostratigraphic pattern, because the depositional history of the entire Newark Supergroup can be divided into three discrete and successive phases. In the first phase, separate basins formed and clay, silt, sand, and gravel were deposited in fluvial, lacustrine, and alluvial fan environments. This phase persisted about 35 m.y., from the Middle Triassic to the beginning of the Jurassic (Olsen, 1986). A second depositional phase occurred within the Early Jurassic, when large volumes of basaltic magma spread as basalt flows across the basin floors. These flows are interbedded with sedimentary rocks, formed from continental sediments that continued to accumulate between basaltic eruptions. On the basis of analysis of Milankovitch-type cycles, volcanic extrusions began synchronously within 21 k.y., ended synchronously, and lasted for  $580 \pm 100$  k.y. (Olsen and Fedosh, 1988; Olsen et al., 1996). The third phase commenced after volcanism ceased and sedimentation resumed without volcanic interruption in at least two of the rift valleys.

Wherever the middle stage of the Newark Supergroup rock column is fully preserved, the interval of basaltic magmatism is represented by three successive stratigraphic suites of multiple

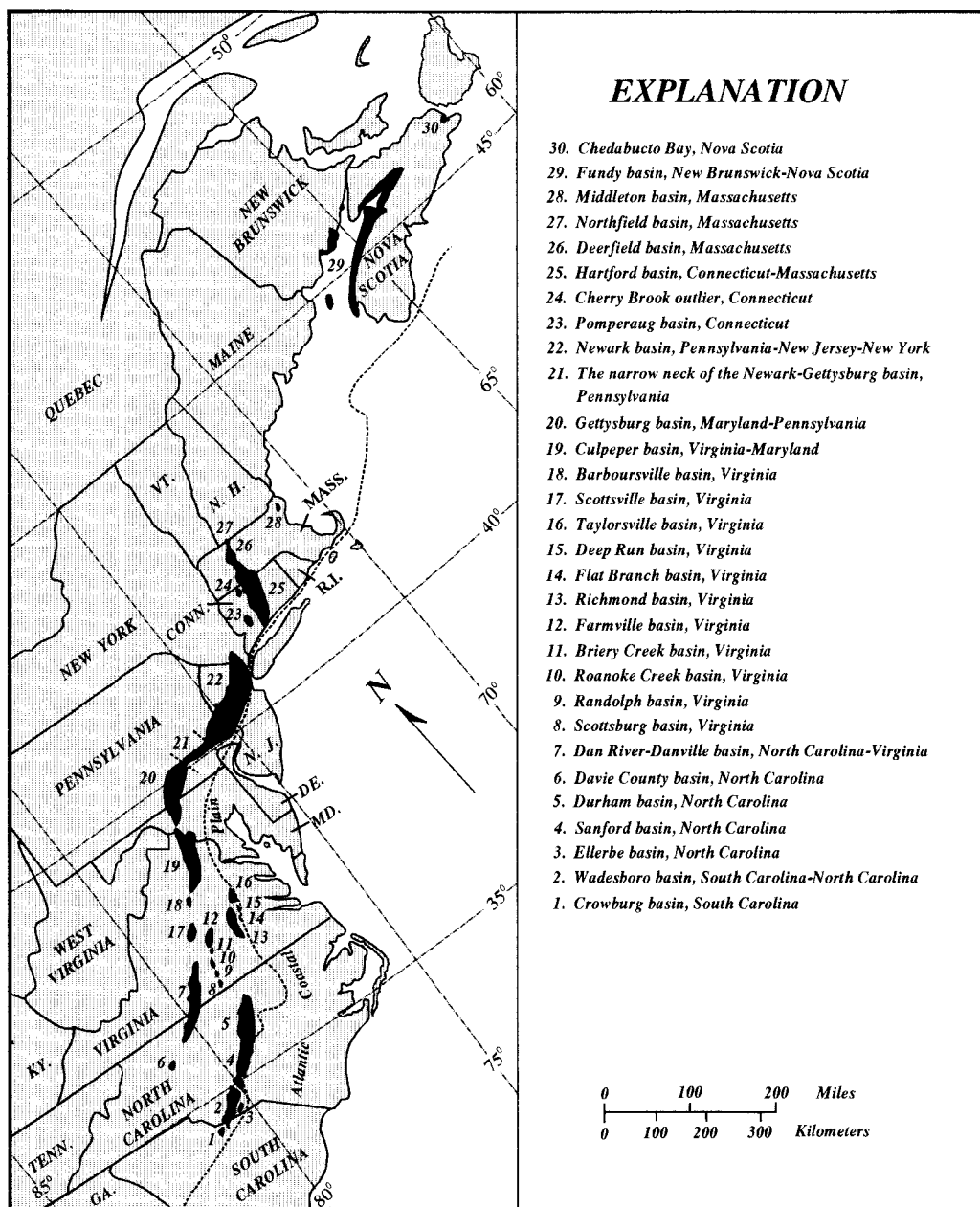


Figure 1. Areal distribution of the Newark Supergroup in eastern North America. Basins in which the Newark Supergroup is preserved are listed by numbers (from Luttrell, 1989).

tholeiitic lava flows. Extensive local and regional mapping throughout the early Mesozoic rift basins has revealed no evidence for any extrusive volcanic rocks below this interval or above it. Thus flow units are found in the northerly and westerly early Mesozoic rift basins that still contain Jurassic rocks (Culpeper, Gettysburg, Newark, Pomperaug, Hartford, Deerfield, and Fundy), and none are found in the southerly and easterly basins where extensive palynological studies show that all preserved strata are Triassic in age (Dunay and Fisher, 1974; Comet, 1977; Schaeffer and McDonald, 1978; Olsen et al., 1982; Cornet

and Olsen, 1985; Traverse, 1986; Litwin et al., 1991). Although Early Jurassic diabase dikes and sills are common in the southerly and easterly rift basins, any flows formerly associated with them have been removed by erosion.

The geochemistry and petrology of the lava flows have been extensively studied in the Culpeper, Gettysburg, Newark, Hartford, Deerfield, and Fundy basins (Smith et al., 1975; Puffer et al., 1981; Philpotts and Reichenbach, 1985; Tollo, 1988; Dostal and Greenough, 1992; Hozik, 1992; Puffer, 1992; Tollo and Gottfried, 1992). The flows in the Pomperaug basin remain

unstudied. Tollo and Gottfried (1992) defined three volcanic intervals, each with a distinctive chemistry probably derived from a separate magma source. The lowest suite of flows (volcanic interval I), which includes the correlative Mount Zion Church, Aspers (named below), Orange Mountain, Talcott, and North Mountain Basalts (Fig. 3), consists of very similar high-titanium quartz-normative (HTQ) basalts (Puffer et al., 1981; Tollo and Gottfried, 1992). The second suite of flows (volcanic interval II), which includes the correlative Sander, Preakness, Holyoke, and Deerfield Basalts and the slightly older

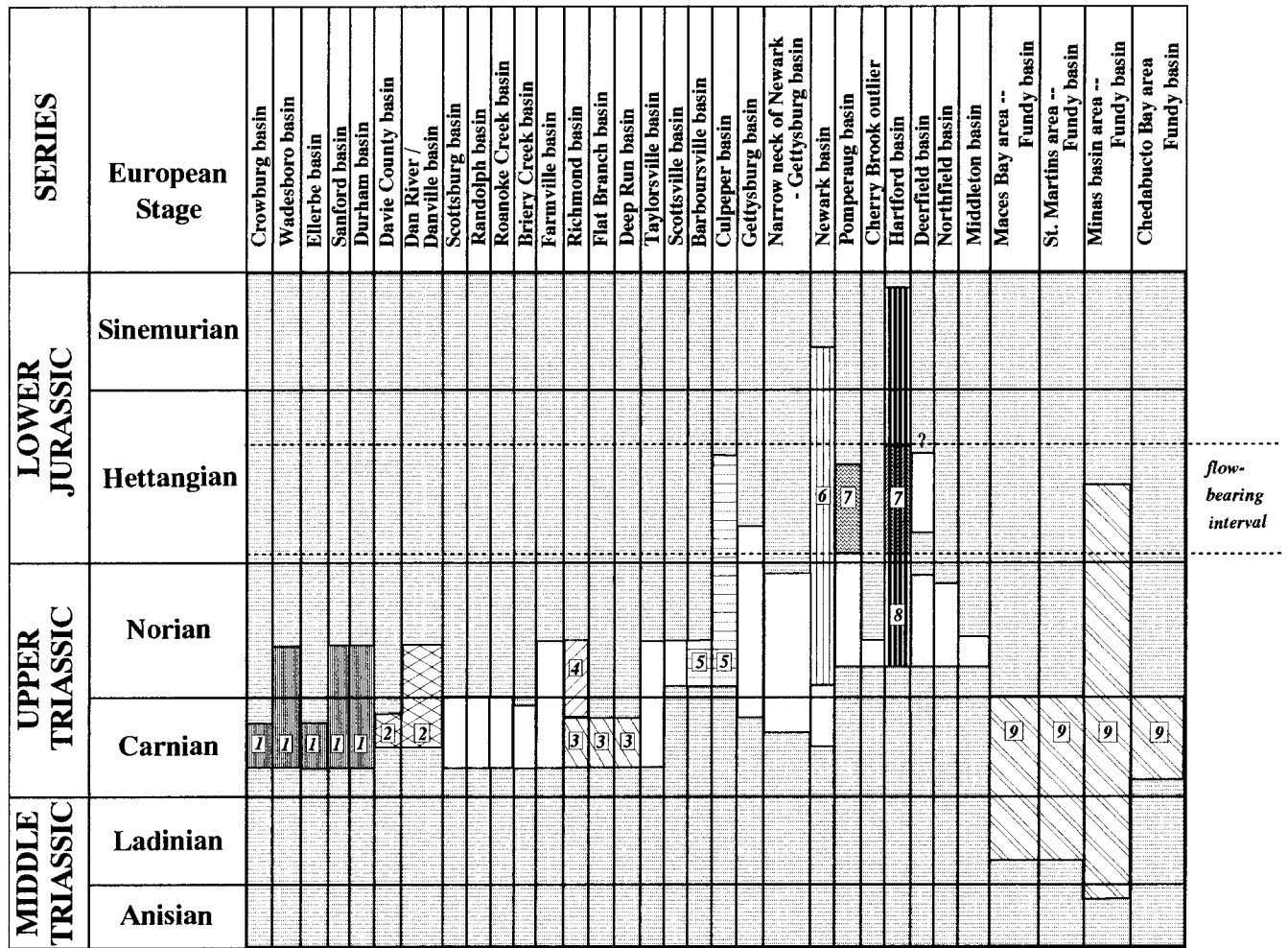


Figure 2. Currently accepted group nomenclature for the Newark Supergroup. Unnumbered portions of stratigraphic columns are not placed in any group. 1—Chatham Group, 2—Dan River Group, 3—Tuckahoe Group, 4—Chesterfield Group, 5—Culpeper Group, 6—Brunswick Group, 7—Meriden Group, 8—Hartford Group, 9—Fundy Group. Data compiled from Luttrell (1989) except as follows: Hartford Group from Lorenz (1988) and Hubert et al. (1992). Jurassic stage assignments based on work by Padian (1989). Work by Litwin and Weems (1992) and Litwin and Ash (1993) take the columns of the Wadesboro, Sanford, Durham, Dan River, and Taylorsville basins well into the Norian; the top of the Richmond basin column is raised to match correlative Taylorsville basin strata. Position of the columns for the Scottsburg, Randolph, Roanoke Creek, Briery Creek, Farmville, and Scottsville basins are based partly on work by Robbins (1985) in the Farmville basin, Olsen (cited in Schaeffer and McDonald, 1978), and on extensive fieldwork by Weems. The base of the Barbourville and Culpeper columns are raised because no direct evidence exists for Carnian strata; the top of the Culpeper column is lowered on the basis of evidence discussed in text. Unconformity at the Norian-Hettangian boundary for the Deerfield basin is based on work by J. P. Smoot, mentioned in text. The top of the Pomperaug and Deerfield columns are lowered on the basis of the work of Huber and McDonald (1992) and evidence discussed in text. Location of column of the Middleton basin is based on similarity with basal rock types in nearby basins.

Hickory Grove Basalt (Fig. 3), consists of high-iron quartz normative/incompatible element-depleted (HFQ/IED) basalts and (in the Culpeper and Newark basins) rarer low-titanium quartz-normative (LTQ) basalts (Puffer et al., 1981; Tollo and Gottfried, 1992). The third and highest suite of flows (volcanic interval III), which includes the correlative Hook Mountain and Hampden Basalts, is characterized by high-iron, high-titanium quartz normative/incompatible element-enriched (HFQ/IEE or HFTQ) basalts

(Puffer et al., 1981; Tollo and Gottfried, 1992). Local variations on these regional geochemical patterns justify different names for flow sequences in different basins, but stratigraphic correlation between basins of these three major extrusive suites (each with a distinctive chemical composition or range of compositions) seems to be firmly established across the entire region (Tollo and Gottfried, 1992).

Available biostratigraphic data from the inter-layered sedimentary strata support geochemical

correlations of basalts. Cornet (1977) and Cornet and Olsen (1985) showed that the lowest HTQ flow in the Culpeper, Gettysburg, Newark, Hartford, and Fundy basins all occur about 50 m above the base of the *Corollina meyeriana* palynofloral zone (after Cornet, 1977). Thus the initiation of basaltic extrusion in all of these basins was essentially synchronous within present limits of stratigraphic resolution. Olsen (1988) showed that the sedimentary cycles from the top of volcanic interval II in the Newark and Hartford

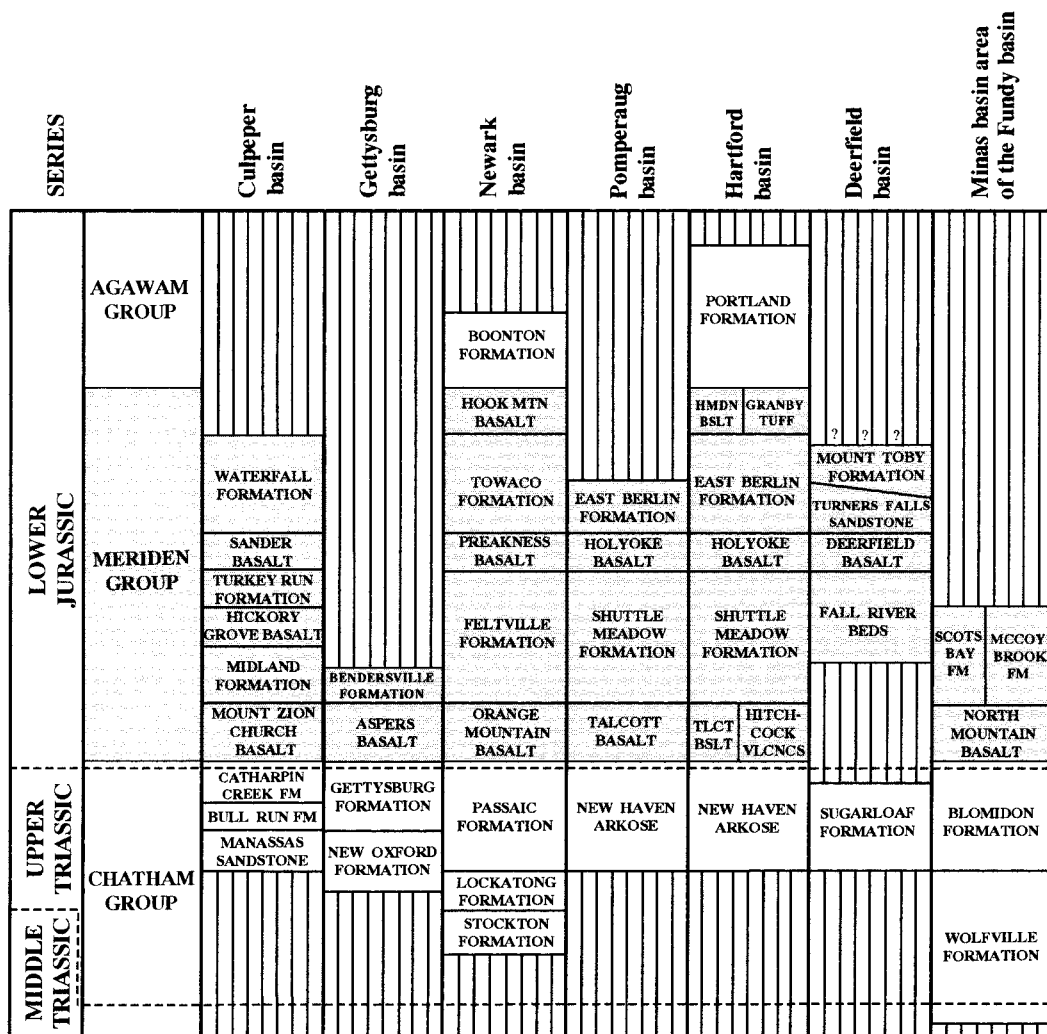


Figure 3. The distribution of formations in basins that include strata higher than the Chatham Group. Formational nomenclature in the Culpeper and Gettysburg basins are shown as modified herein. In other Newark Supergroup basins not shown here, all formations belong to the Chatham Group (Fig. 5). Vertical scale does not reflect relative stratigraphic thicknesses, although horizontal scale does reflect stratigraphic equivalence. HMDN BSLT—Hampden Basalt, GRANBY TUFF—Granby Basaltic Tuff, TLCT BSLT—Talcott Basalt, HITCHCOCK VLCNCS—Hitchcock Volcanics, FM—Formation.

basins (the Preakness and Holyoke Basalts) up to the base of volcanic interval III (the Hook Mountain and Hampden Basalts) are time equivalent. This indicates that the end of the middle flow sequence and the beginning of the upper flow sequence in those basins also were essentially synchronous, despite slight differences between the bulk chemistry of the individual flow units within the second flow sequence in each basin (Puffer et al., 1981). Limited work on the cyclic stratigraphy of the Waterfall Formation in the Culpeper basin (Olsen, 1997, p. 381) suggests correlation of that unit with the Towaco and East Berlin Formations of the Newark and Hartford basins rather than with the Boonton and Portland Formations of the Newark and Hartford basins, as previously assumed (Lee and Froelich, 1989; Luttrell, 1989). Therefore, available biostratigraphic data support the interbasinal correlation of volcanic intervals I through III made on the basis of their geochemical characteristics. Together, both sets

of data indicate that the succession of magmatic compositions and the temporal duration of extrusive volcanism were the same in all early Mesozoic rift basins that still preserve basalt flows. The widespread and unique occurrence within the Newark Supergroup of the volcanic flow-bearing interval makes it a regionally useful rock-stratigraphic marker horizon. The lithic characteristics of the flow-bearing interval, wherever it is preserved, permit a ready and natural division of the entire Newark Supergroup into three regionally recognizable groups, defined by the top and base of the flow-bearing interval and the regional unconformities that mark the top and base of the entire Newark Supergroup. This approach to the group ranking of the Newark Supergroup has numerous advantages. (1) It clusters rocks into entirely sedimentary or sedimentary and volcanic lithostratigraphic groups that formed during each of three major tectonic stages through which the early Mesozoic rift

basins evolved (nonvolcanic-volcanic-nonvolcanic). (2) It provides unambiguous boundaries for these groups throughout the geographic range of the Newark Supergroup. (3) For the first time, it inclusively places all Newark Supergroup strata into groups. (4) It reduces the number of group names from nine to three. (5) Coincidentally, it provides isochronous or nearly isochronous boundaries for these groups, and thus helps make lithostratigraphic and time-stratigraphic concepts parallel and synchronous. The chief disadvantage to the group rankings proposed here is that it would supersede (and thus displace) the existing group nomenclature for the Dan River–Danville, Davie County, Richmond, Deep Run, Flat Branch, Barbourville, Culpeper, Newark, Hartford, and Fundy basins (10 basins). However, extensive literature does not exist for four of these basins (Deep Run, Flat Branch, Barbourville, and Davie County). The proposed group rankings would not change the

group rankings recognized in the Crowburg, Ellerbe, Wadesboro, Sanford, Durham, and Pomperaug basins (6 basins), and would place inclusive group names for the first time in the Scottsburg, Randolph, Roanoke Creek, Briery Creek, Farmville, Taylorsville, Scottsville, Gettysburg, Cherry Brook, Deerfield, Northfield, and Middleton basins (12 basins). We believe that a regionally applicable group nomenclature, integrating global-scale tectonic history with stratigraphic nomenclature, produces positive results that outweigh the changes required. Names and definitions for the three proposed inclusive lithostratigraphic groups of the Newark Supergroup are as follows.

### REVISIONS TO GROUP NAMES WITHIN THE NEWARK SUPERGROUP

#### Chatham Group (Middle Triassic to Lower Jurassic, Anisian to Hettangian Stages)

This name, proposed by Emmons (1857) as the Chatham Series, is the oldest stratigraphic name applied to rocks of the lowest part of the Newark Supergroup. Olsen (1978) was the first to use the term Chatham Group. The type area of the Chatham Group is in the Sanford basin, but Emmons also applied the term to the basal strata in all of the basins known in his day (Emmons, 1857, p. 1–4, 19–98). Figure 4 shows horizons and basins to which Emmons explicitly applied this name. In all cases, the term was applied to rocks below the level of the lowest lava flow. Although Emmons (1857, p. 19–29) guessed the upward extent of this group, he acknowledged that “the upward termination of the series ... is not clearly defined.” (p. 19). Because the distinctions between basalt flows and diabase sills were not well established then, it was not obvious to him that basalt flows could serve as stratigraphic boundaries in the various basins.

Emmons attempted to distinguish his Chatham Series from overlying rocks partly on the basis of plant megafossils. This approach has proven to be inaccurate, because plant megafossils in the Newark Supergroup more often reflect depositional environments than stratigraphic horizons. However, fish, reptile, and footprint remains (with which Emmons also recognized his group), as well as palynomorphs, document fauna and flora in rocks of the Chatham Group that are distinctly different and older than any known from rocks between and above the lava flows in the Culpeper, Newark, Hartford, Deerfield, and Fundy basins. The most sweeping faunal and palynofloral turnover documented within the Newark Supergroup has been placed about 50 m below the lowest lava flows within the Newark

Supergroup (Cornet and Olsen, 1985; Fowell, 1993; Fowell and Olsen, 1993; Fowell et al., 1994). This turnover occurs at or above the highest occurrence of fish and reptiles listed by Emmons (1857, p. 34–96) as characteristic of the Chatham and below the lowest occurrence of fish and reptiles listed by Emmons (1857, p. 99–149) as characteristic of strata above the Chatham. By placing the upward limit of the Chatham Group at the base of the first lava flow, we do not contradict the original lithologic concept which Emmons proposed, and his biostratigraphic concept also remains largely intact.

Olsen (1978) used the name Chatham Group to include all rocks in the Wadesboro, Sanford, and Durham basins, and the North Carolina Geological Survey (1985) added to these the rocks in the Crowburg and Ellerbe basins. These definitions of the Chatham are more restrictive geographically than Emmons intended, but they do not contradict the rock or time stratigraphic concept that Emmons proposed. Similarly, this recent usage is not contradicted by the broader rock stratigraphic sense of the group name as we propose here, nor does the recent usage include any units that would be excluded by the definitions we propose here. The chief difference in recent usage and the usage proposed here is that our terminology is applied to a wider area, including the entire rock-stratigraphic columns preserved in the Crowburg, Wadesboro, Ellerbe, Sanford, Durham, Scottsburg, Randolph, Roanoke Creek, Briery Creek, Farmville, Richmond, Flat Branch, Deep Run, Taylorsville, Davie County, Dan River–Danville, Scottsville, Barboursville, Cherry Brook, Northfield, and Middleton basins (Fig. 5). In addition, the lower units in the Culpeper, Gettysburg, Newark, Pomperaug, Hartford, Deerfield, and Fundy basins are also within the definition of this group as proposed herein (Fig. 3). However, if Lucas and Huber (1993) are correct in suggesting that the Lower Economy beds of the Wolfville Formation (Fundy basin) are separated from the rest of the Wolfville by an unconformity representing about 10 m.y., those beds may deserve to be named as a separate formation and that formation possibly should be excluded from the definition of the Chatham Group. The thickest section of the Chatham Group occurs in the Newark basin, where the Stockton, Lockatong, and Passaic Formations together are about 6000 m thick (Witte et al., 1991).

One stratigraphic problem must be overcome before the term Chatham Group can be applied to the Gettysburg basin. The currently defined Gettysburg Formation mostly includes strata that should be assigned to the Chatham Group as defined here. However, the highest part of the Gettysburg Formation includes the basalt at Aspers

(Cornet, 1977) and an overlying sequence of sedimentary rocks (Luttrell, 1989). These two units (basalt and overlying sedimentary rocks) do not fall within our definition of the Chatham Group (Fig. 3). Therefore the Gettysburg Formation, as currently defined, would cross the boundary between two groups in violation of the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983). For this reason, the term Gettysburg Formation is restricted here to the rocks below the basalt at Aspers. The basalt at Aspers of Cornet (1977) is formalized as the Aspers Basalt, and sedimentary rocks above the Aspers are placed in the Bendersville Formation. These units are defined in the Stratigraphic Revision of the Gettysburg Formation section herein. The Aspers and Bendersville belong in the Meriden Group, which is also defined herein.

#### Meriden Group (Lower Jurassic, Hettangian Stage)

The Meriden Formation was proposed by Krynine (1950) for lava flows and interbedded sedimentary rocks in the Hartford basin. The flows and interbedded sedimentary rocks were named individually by Lehmann (1959), and Sanders (1968) clustered these new units by raising the Meriden to group rank. It is proposed that this group name be applied throughout the basins of the Newark Supergroup for correlative portions of the rock column that include extrusive lava flows and interbedded sedimentary rocks. As here defined, the Meriden Group occurs in the Culpeper, Gettysburg, Newark, Pomperaug, Hartford, Deerfield, and Fundy basins (Fig. 3). The Meriden Group achieves its greatest known thickness (more than 2000 m) in the Culpeper basin (Lee and Froelich, 1989).

Stratigraphic work by Olsen et al. (1996) indicates that the entire Meriden Group was deposited over a time interval of  $550 \pm 50$  k.y. shortly after the beginning of the Jurassic Period. This places the Meriden Group entirely within the Hettangian stage of the Jurassic. Unfortunately, the absolute age of the group is not known precisely. All of the flow basalts have been more or less hydrothermally altered (Seidemann et al., 1984), possibly at about 175 Ma (Sutter, 1988). The alteration has caused the flows to yield a scattering of apparent ages somewhat younger than their true age. The best age estimates obtained so far are U–Pb dates of  $201 \pm 1$  Ma derived from the Palisades and Gettysburg sills (Dunning and Hodych, 1990),  $^{40}\text{Ar}/^{39}\text{Ar}$  plateau dates around  $201 \pm 1$  Ma from diabases in the Culpeper basin (Sutter, 1988), and  $^{40}\text{Ar}/^{39}\text{Ar}$  plateau dates around  $196 \pm 1$  Ma derived from



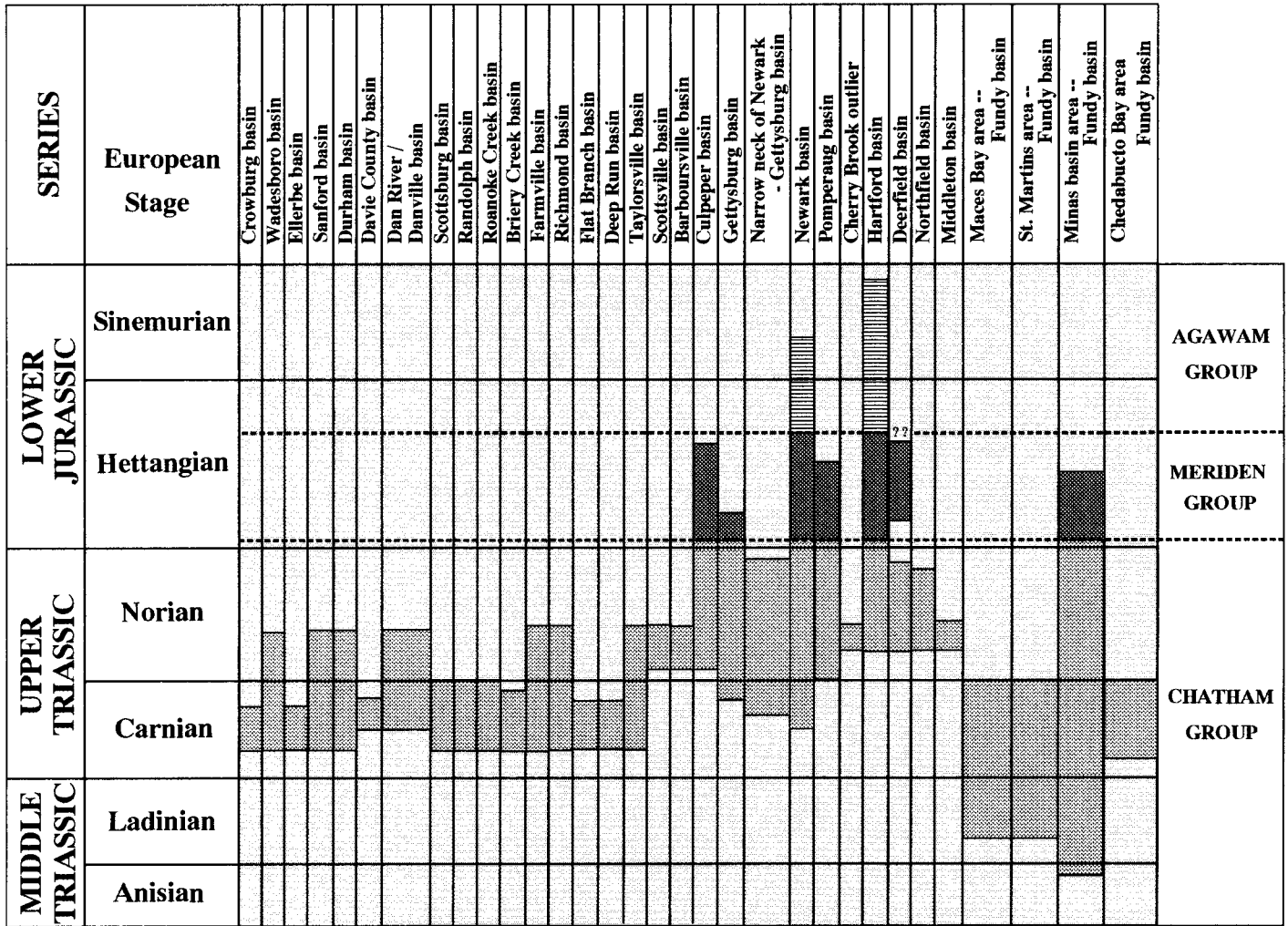


Figure 5. Group terminology proposed here for the Newark Supergroup. Compare with Figure 2 for previous group usages. Shading patterns reflect group placements as defined in this paper.

that no unconformity exists between the two units. The combined thickness of the Turners Falls Sandstone and the Mount Toby Formation may be only about 250 m (Willard, 1951, 1952), and this is less than the thickness of the East Berlin Formation that occupies the same stratigraphic position to the south in the Hartford basin (Colton and Hartshorn, 1966). Because the upper part of the Deerfield column appears to be thin, and because there is no hint of the Hampden Basalt or Granby Tuff, which are well developed only 20 km south of the Deerfield basin, it may be that no Deerfield basin strata are as young as the Portland Formation as suggested by Luttrell (1989). Therefore, both the Turners Falls Sandstone (type area) and the Mount Toby Formation here are retained within the Meriden Group. Above the Turner Falls Sandstone type area, a

covered interval occurs below other cyclic lake strata that are either fault-repeated portions of the Turner Falls Sandstone or strata that correlate with the Portland Formation of the Agawam Group (Olsen, 1997, p. 380). If these strata belong with the Agawam Group, they need to be named and a lower boundary established.

The definition of the Meriden Group cannot include the numerous early Mesozoic dikes and sills within the Newark Supergroup basins or in the country rock around them, because the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983) makes no provision for combining plutonic igneous terminology with extrusive volcanic and/or sedimentary terminology. Therefore, names proposed for different compositions of diabase (York Haven, Rossville, and Quarry-

ville) by Smith et al. (1975) cannot be properly included within the Meriden Group, even though the York Haven type of diabase has been associated strongly with the lavas of volcanic interval I of the Meriden Group, and the Rossville type has been associated strongly with the lavas of volcanic interval II (Puffer, 1992; Tollo and Gottfried, 1992). Although the Quarryville type of diabase does not have a chemistry that matches the chemistry of any flow yet known from an exposed basin (Puffer, 1992), there seems little reason to doubt that all of the early Mesozoic diabase dikes and sills were formed during the same magmatic episode that produced the flows. Therefore, the dikes and sills appear to be genetically connected with and time correlative with the Meriden Group (Olsen et al., 1996), even though they cannot be placed formally within it.

### Agawam Group (New Name) (Lower Jurassic, Hettangian and Sinemurian? Stages)

This name is proposed to include all Newark Supergroup formations stratigraphically above the highest Newark Supergroup lava flows. The included units are the Boonton Formation (Newark basin), and the Portland Formation (Hartford basin) (Fig. 3). No stratigraphic name exists that incorporates the concept of the regional depositional event that occurred after volcanism and plutonism ceased. Therefore, the name Agawam Group is proposed to include the two formations that lie directly above the extrusive volcanic rocks included within the Meriden Group. The Agawam type area is in the northern part of the Hartford basin in Agawam Township, Hampden County, Massachusetts. Only the strata that lie above (east of) the Hampden Basalt are included (Fig. 6). Exposures along the Westfield River east of the Hampden Basalt outcrop, especially the excellent exposures east and west of Bridge Street along the north border of the town of North Agawam, constitute a reference section for this unit. The location of this reference section was shown in Colton and Hartshorn (1966). The top of the Agawam Group is marked everywhere by the modern erosional surface or by a thin cap of surficial Quaternary deposits. The greatest reported thickness of the Agawam Group (about 2500 m) is in the Hartford basin (Hubert et al., 1978), but there could be as much as 5000 m of section present in that basin.

The Agawam Group is Early Jurassic in age. Cornet (1977) suggested that the upper part of this group could be as young as Middle Jurassic (Bathonian), but such an extensive age range was based on very tenuous evidence. A more recent estimate of the age of the Boonton Formation places it entirely within the Hettangian Stage (Olsen and Kent, 1996). Pollen, vertebrate fossils, and ichnofossils from the lower to middle part of the Agawam Group (specifically the Portland Formation) are very similar to fossils from the lower to middle part of the Moenave Formation of the Glen Canyon Group on the Colorado Plateau (Olsen and Padian, 1989). The Kayenta Formation, which probably lies unconformably above the Moenave, so far has yielded no pollen but contains many vertebrate fossils and ichnofossils (such as *Dilophosauripus*, *Hopiichnus*, and *Kayentapus hopii*) (Welles, 1971; Clark and Fastovsky, 1989; Padian, 1989), most of which are unknown from the Agawam Group. Some of these Kayenta fossils clearly are derived in their character states relative to related (but more primitive) fossil forms found in the Agawam Group. Thus there is no compelling evidence for correlating the Agawam Group with strata on the Colorado Plateau any higher than the Moenave For-

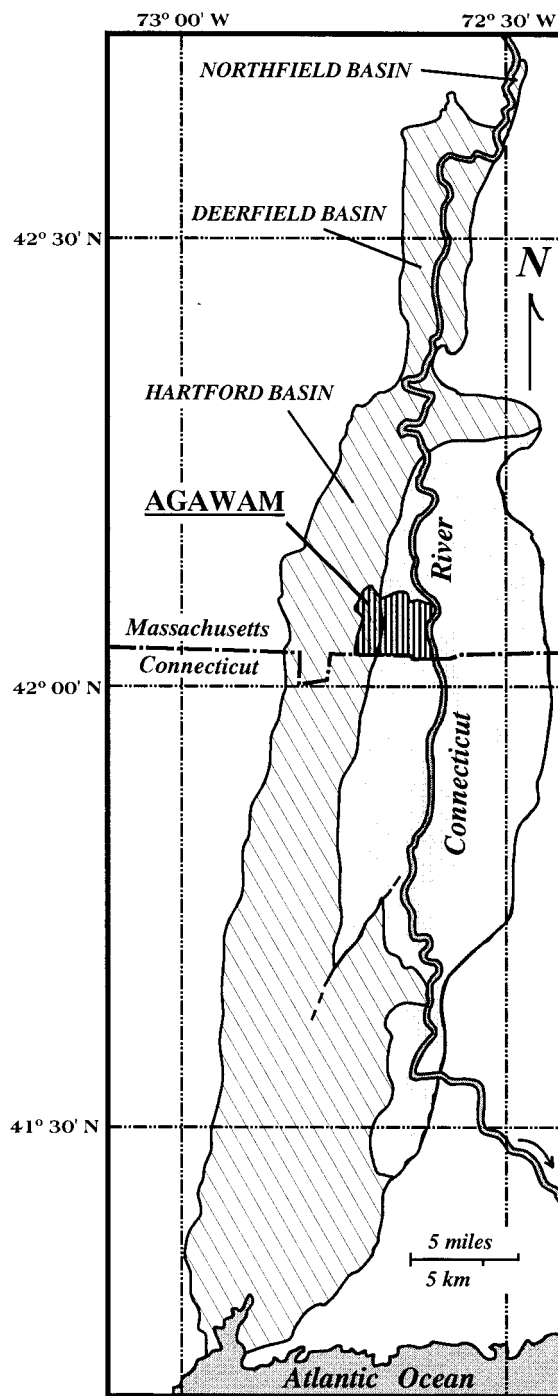


Figure 6. Map of the Newark Supergroup basins in the Connecticut Valley, showing the location of the Northfield, Deerfield, and Hartford basins, Agawam Township, Massachusetts (vertical rule), and the distribution of the Lower Jurassic Agawam Group (light gray). In the Hartford basin, Agawam rocks are the Portland Formation. The type area for the Agawam Group is the light gray dot-patterned portion of Agawam Township east of (stratigraphically directly above) the Hampden Basalt. Obliquely ruled areas are underlain by rocks of the Chatham and Meriden Groups.

matation. Worldwide comparison of vertebrate remains from the overlying Kayenta Formation indicates that it is Sinemurian to Pliensbachian in age (Padian, 1989). This in turn constrains the age of the Moenave Formation (and the Agawam Group) to probably no younger than Sinemurian, as shown in Olsen (1997, p. 341).

The above defined groups and their distribution in the various early Mesozoic rift basins are

shown in Figures 3 and 5. This system of three groups is much simpler to use than the existing system of nine groups; it is fully inclusive of the entire Newark Supergroup and has more precisely and easily defined boundaries than the group nomenclature currently in use. The proposed group nomenclature mirrors the fundamental threefold tectonostratigraphic and lithostratigraphic stages through which the Newark Super-



group evolved, associating a lower package of alluvial fan–fluvial–lacustrine continental deposits that are locally injected by diabase and thermally metamorphosed, a medial package of thin to thick extrusive volcanic basalt flows that are interspersed with volumetrically subordinate packages of alluvial fan–fluvial–lacustrine continental deposits locally injected by diabase and thermally metamorphosed, and an upper package of alluvial fan–fluvial–lacustrine continental deposits unaffected by volcanism. Our proposed system of group names is simple, inclusive, defined by readily observable and mappable boundaries, and accurately reflects one of the most important tectonic events recorded by the Newark Supergroup. Because our group names incorporate the rock columns included in the Dan River Group, Tuckahoe Group, Chesterfield Group, Culpeper Group, Brunswick Group, Hartford Group, and Fundy Group, these terms are abandoned herein.

## STRATIGRAPHIC REVISION OF THE GETTYSBURG FORMATION

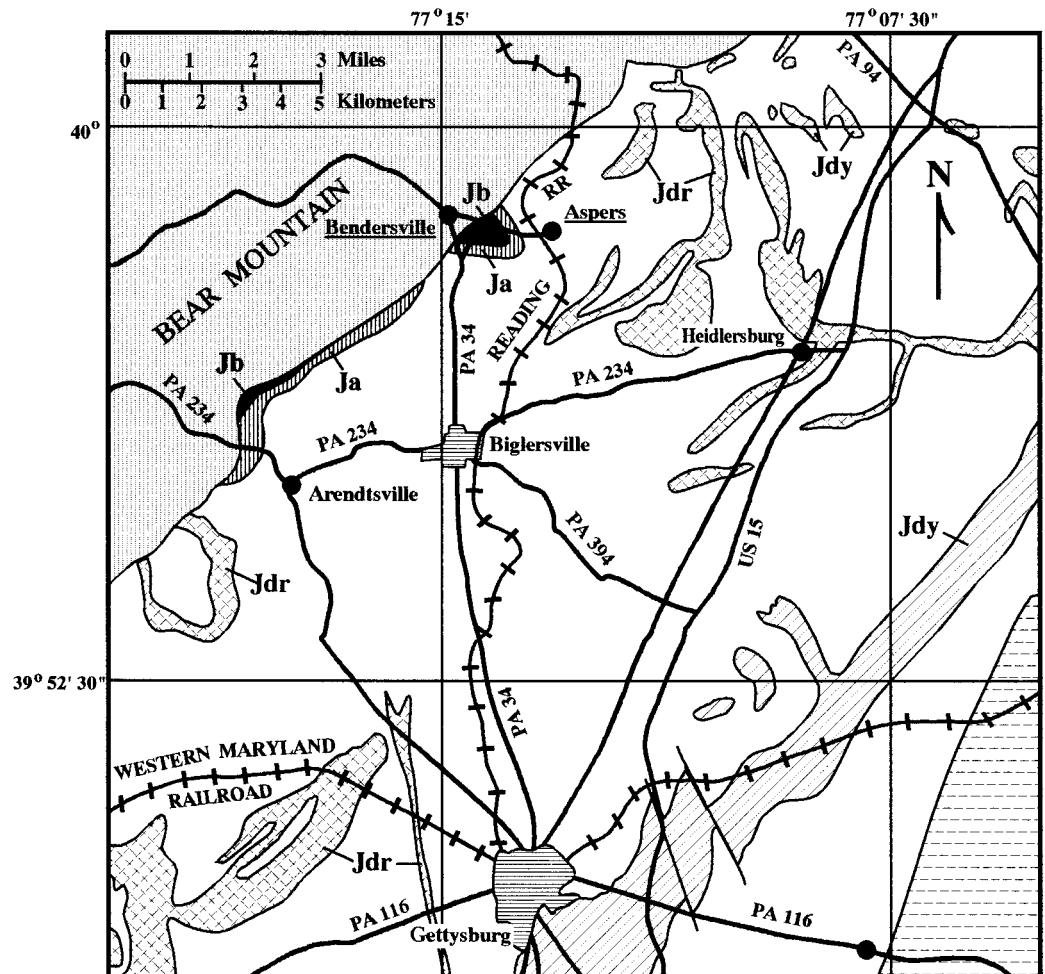
### Gettysburg Formation

The Gettysburg Formation was defined as all strata in the Gettysburg basin from the top of the New Oxford Formation to the top of the preserved basin column (Stose and Bascom, 1929). The upper boundary of the Gettysburg Formation here is moved downward to the base of the basalt at Aspers of Cornet (1977), thereby excluding the basalt and the sedimentary rocks overlying the basalt from the Gettysburg Formation. The lower boundary of the Gettysburg Formation and its composite type section remain unchanged. Strata now excluded from the Gettysburg Formation are named formally below, although they are not yet approved by the North American Commission on Stratigraphic Nomenclature.

### Aspers Basalt (New Name) (Lower Jurassic)

Part of this unit was recognized as a flow by Stose and Bascom (1929), but its full areal extent and geochemistry were not established until the work of Smith et al. (1975, p. 948), who referred this unit to their York Haven type diabase. Although the Aspers Basalt is geochemically equivalent to York Haven diabase, the type locality of the York Haven is a plutonic body. Therefore, although York Haven is the valid name for early Mesozoic diabase dikes and sills that have a high-titanium quartz normative composition, the North American Code of Stratigraphic Nomenclature (North American Commission on Stratigraphic Nomenclature, 1983, p. 848, art. 22, art. 31) does not provide for extending a lithodemic rock name such as York Haven diabase to an extrusive basaltic flow in a sedimentary sequence, even if

Figure 7. Areal distribution of the Aspers Basalt and Bendersville Formation in the Gettysburg basin of Pennsylvania. Type areas of both units lie in the small syncline immediately west of Aspers. Dot pattern—pre-Triassic rocks (Late Proterozoic-lower Paleozoic); dashed horizontal rule—New Oxford Formation (Upper Triassic); white—Gettysburg Formation (Lower Jurassic and Upper Triassic); oblique rule (Jdy)—York Haven type diabase dikes and sills (Lower Jurassic); cross-hatched (Jdr)—Rossville type diabase dikes and sills (Lower Jurassic); vertical rule (Ja)—Aspers Basalt (Lower Jurassic); black (Jb)—Bendersville Formation (Lower Jurassic).



both came from a common magma source. Therefore, the term York Haven is unavailable as a formal stratigraphic name for any basalt flow unit, and the name Aspers Basalt, derived from the informal name "basalt at Aspers" used by Cornet (1977), is here adopted for the basalt-flow remnants west of Heidlersburg. The type area is 1 km west of Aspers, and the unit is estimated to be about 60 m thick (Cornet, 1977). The lower boundary of this unit is defined as the contact between the lowest basalt and the uppermost (thermally metamorphosed) sedimentary rocks of the Gettysburg Formation as restricted above. Its upper boundary is defined as the contact between the highest basalt and the overlying sedimentary rocks of the Bendersville Formation, defined below.

On the basis of its position (about 50 m above the base of the *Corollina meyeriana* palynofloral zone of Cornet, 1977), and on its high-titanium quartz normative composition, the Aspers Basalt is laterally equivalent to the Mount Zion Church Basalt in the Culpeper basin and the Jacksonwald (= Orange Mountain) Basalt in the Jacksonwald syncline of the Newark basin (Fig. 3). It is inadvisable to assign these flow remnants to either the Mount Zion Church or Jacksonwald and/or Orange Mountain Basalts, because of the great distance between the Aspers basalt and its correlatives in adjacent basins and because each basin has a different stratigraphic column for all other units.

#### **Bendersville Formation (New Name) (Lower Jurassic)**

The Bendersville Formation is named for the town of Bendersville, Pennsylvania (Biglerville 7.5-minute quadrangle), which is about 1 km northwest of a small syncline 1.5 km west of Aspers that contains the type area of this unit. The Bendersville Formation includes all sedimentary rocks directly above the Aspers Basalt (defined above), both in the type area syncline near Aspers and along the western basin border fault 9 km to the southwest of Aspers (Arendtsville 7.5-minute quadrangle) (Fig. 7). The top of this unit is truncated by the modern erosional surface. Only about 230 m of stratigraphic section remain (Cornet, 1977). On the basis of its stratigraphic position just above volcanic interval I, the Bendersville Formation is laterally equivalent to the basal Midland Formation in the Culpeper basin and the basal Feltville Formation in the Newark basin. The great distance (>100 km) between this part of the Gettysburg basin and both of the laterally equivalent, previously named units precludes obvious assignment to either one. Near the northwestern border fault of the Gettysburg basin, the Bendersville is

composed of fanglomerates with quartzitic to metarhyolitic clasts. These rock types originally were mapped as part of the Arendtsville Fanglomerate Lentil by Stose and Bascom (1929), but the conglomerates above the Aspers Basalt have been excluded from the definition of the Arendtsville (Luttrel, 1989, Plate 1). We also exclude the Bendersville conglomerates from the Arendtsville Lentil, so that each of these units remains within group boundaries. Away from the border fault, the Bendersville Formation grades southeastward into pollen-bearing, olive-green, thickly bedded, clayey siltstones (Cornet, 1977) that apparently formed in lacustrine to paludal depositional environments.

#### **REINSTATEMENT OF THE BULL RUN FORMATION**

The "Bull Run Shales" were named as a stratigraphic unit in the Culpeper basin by Roberts (1928). He did not map out the areal extent of this unit, but he did establish a type area along "Bull Run, a small stream between Prince William and Fairfax counties. Bull Run battlefield, named from this stream, lies about 9.5 km (6 miles) due west of Manassas. Almost the only rocks outcropping over this region are the Bull Run shales" (Roberts, 1928, p. 39; Fig. 8). Roberts also listed supplementary outcrops for the Bull Run, "the most northern being on the bluffs of the Potomac River 3½ miles [about 5.5 km] east of Leesburg...." Lee (1977) later used the term Bull Run Formation north of its type area, but he also defined a new stratigraphic unit, the Balls Bluff Siltstone, which he named for the same bluff that Roberts listed as the northernmost exposure of the Bull Run shales. Lee (1977) stopped mapping just north and east of the type area of the Bull Run Formation, but projection of his Balls Bluff Siltstone along strike places it across the entire type area of the Bull Run Formation. Because the Balls Bluff Siltstone as mapped by Lee includes the type area of the Bull Run Formation of Roberts, and because Lee only nominally retained the name Bull Run Formation for beds not correlative with the type area of that unit, Lee's stratigraphic revisions were not valid according to the North American Code of Stratigraphic Nomenclature (North American Commission on Stratigraphic Nomenclature, 1983, article 22c). Accordingly, Lindholm (1979) abandoned the Balls Bluff Siltstone and used the term Bull Run Formation for the entire stratigraphic column from the top of the Manassas Sandstone up to the base of the lowest basaltic lava flow exposed in the Culpeper basin (Lindholm, 1979, Fig. 1). Subsequently, Lee and Froelich (1989) abandoned the Bull Run Formation altogether, reinstating the

Balls Bluff Siltstone for the lower part of the Bull Run column and creating the Catharpin Creek Formation to include its upper part.

The rocks included within the Catharpin Creek Formation lie above the type area of the Bull Run Formation and are dominantly sandstones rather than shales or siltstones. Therefore, it was reasonable for Lee and Froelich to exclude these strata from the Bull Run Formation. However, they were not justified in replacing the Bull Run Formation in its type area and outcrop belt with the Balls Bluff Siltstone, because the term Bull Run was applied validly there and has priority by 60 years. Thus abandonment of the Bull Run Formation was unjustified, and the name herein is reinstated as the valid name for the stratigraphic interval between the Manassas Sandstone and the Catharpin Creek Formation (Fig. 9). The Bull Run Formation is composed of the following five members.

#### **Balls Bluff Member**

The Balls Bluff Siltstone of Lee (1977) is retained, but it is reduced in rank to a member and restricted to rocks within the Bull Run Formation that are similar to those of the Balls Bluff type section (Figs. 8 and 9). Because the Balls Bluff Member includes significant volumes of shale and fine-grained sandstone, especially near the western border faults of the Culpeper and Barbourville basins, "siltstone" is not retained as part of the unit name. This member typically is thick-bedded or massive, and probably formed in sluggish fluvial and overbank environments of deposition (Sobhan, 1985). The Balls Bluff is the lowest unit of the Bull Run Formation throughout the Culpeper and Barbourville basins. In most areas it underlies the Groveton Member (defined below), but in the northern part of the Culpeper basin the Balls Bluff intertongues with the Groveton and underlies the Leesburg Member (Fig. 9). The maximum thickness of this unit is about 900 m.

#### **Groveton Member (New Name)**

The Groveton Member, herein named for Groveton in the Manassas National Battlefield Park (Gainesville 7.5-minute topographic map), includes that part of the Bull Run Formation containing prominent, laterally persistent, gray cyclic lacustrine sequences. Its type area is the Manassas National Battlefield Park, excluding areas underlain by intrusive diabase (Fig. 8). Good exposures in the Manassas National Battlefield Park occur along U.S. Highway 50 and Virginia State Road 234, and along the south bank of

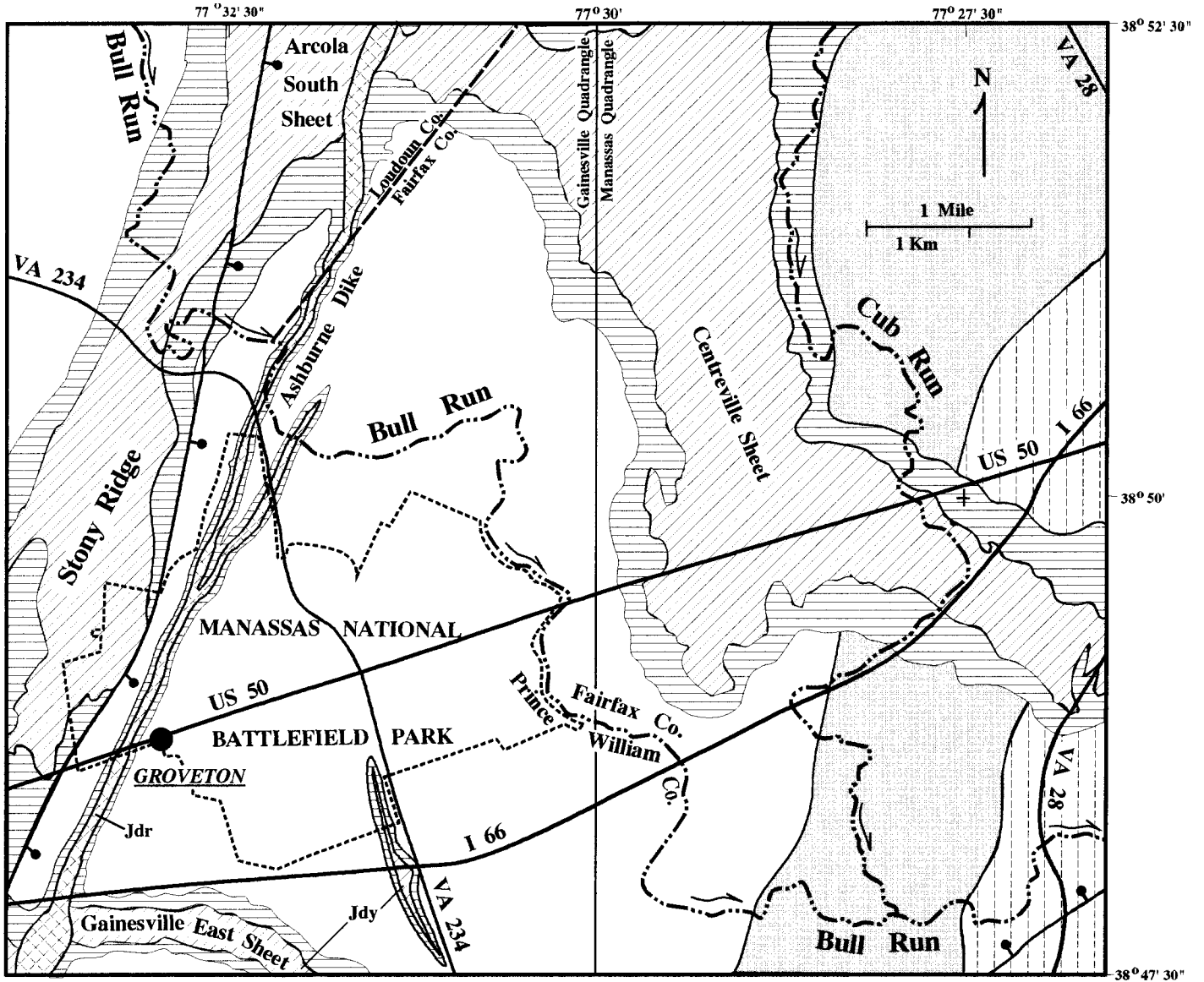


Figure 8. The type area of the Bull Run Formation and the Groveton Member of the Bull Run Formation in the Culpeper basin of Virginia. Dashed vertical rule—Manassas Sandstone, Poolesville Member (Upper Triassic); dot pattern—Bull Run Formation, Balls Bluff Member (Upper Triassic); white—Bull Run Formation, Groveton Member (Upper Triassic); oblique rule—quartz normative, high-titanium diabase (York Haven type, Lower Jurassic); cross-hatched—quartz normative, low-titanium diabase (Rossville type, Lower Jurassic); horizontal rule—Upper Triassic rocks thermally metamorphosed by injected Lower Jurassic diabase.

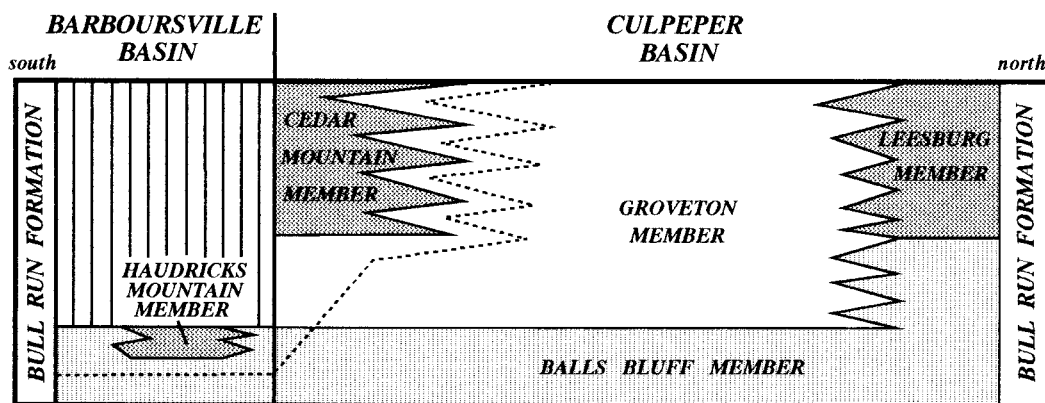
Bull Run Creek along the northern edge of the park. The Groveton Member is characterized by relatively thin (1–10 m) sequences of gray shales interbedded in a highly rhythmic pattern with much thicker (6–60 m) sequences of red shales, siltstones, and occasionally sandstones. These rocks apparently formed in lacustrine to playa flat depositional environments (Sobhan, 1985; Gore, 1988a, 1988b; Smoot and Olsen, 1988). The Groveton Member is dominated by shales

and siltstones, but where it intertongues with fanglomerates along the western border fault of the basin it locally includes sandstones and conglomerates within the red intervals between the gray shales. The base of the Groveton is the base of the lowest cyclic lacustrine red or gray shale present in the Bull Run column; its top is at the top of the highest gray lacustrine shale separated by no more than 60 m of red siltstone from the gray shales below it. Toward the northern end of

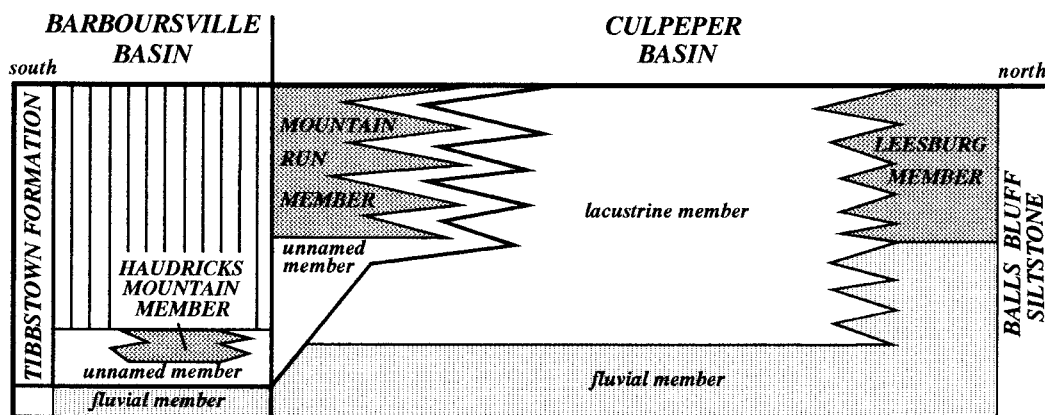
the Culpeper basin, the Groveton grades laterally in its lower part into the Balls Bluff Member and in its upper part into the Leesburg Member (Fig. 9). This unit may be 2500 m thick.

#### Leesburg Member

The Leesburg Limestone Conglomerate Member was defined by Lee (1977), shortened to the Leesburg Conglomerate Member by Lindholm



( THIS REPORT )



( LEE AND FROELICH, 1989 )

Figure 9. Diagrammatic representations of the stratigraphy of strata cropping out within the Culpeper and Barbooursville basins above the Manassas Sandstone and (in the Culpeper basin) below the Catharpin Creek Formation. Nomenclature of Lee and Froelich (1989) is shown at bottom, nomenclature adopted here is shown at top. Conglomeratic members are shown by dark zig-zag pattern. Location of the abandoned Tibbstown-Balls Bluff boundary is shown in the upper column by a dashed line.

(1979), and shortened further to the Leesburg Member by Lee and Froelich (1989). The unit is here retained in the Bull Run Formation as mapped by Lindholm (1979) and Lee and Froelich (1989). The unit only occurs in the northern portion of the Culpeper basin. The Leesburg Member, dominated by clasts of limestone and dolostone, is as thick as 1100 m (Lee and Froelich, 1989); it overlies the Balls Bluff Member and interfingers laterally with the upper part of the Groveton Member (Fig. 9).

#### Cedar Mountain Member

The Cedar Mountain Member of the Bull Run Formation was named by Lindholm (1979) for dominantly greenstone conglomerates that occur in the southwestern portion of the Culpeper basin in the vicinity of Cedar Mountain, 14 km

southwest of Culpeper. This same body of conglomerates was renamed the Mountain Run Member by Lee and Froelich (1989), even though the name Cedar Mountain Member was validly applied by Lindholm (1979) and has priority. Therefore, the name Mountain Run Member is abandoned and the name Cedar Mountain Member is reinstated as a member of the Bull Run Formation. The Cedar Mountain Member is as thick as 640 m.

#### Haudricks Mountain Member

The Haudricks Mountain Member, here placed in the Bull Run Formation, was named by Lee and Froelich (1989) for conglomerates in the Barbooursville basin in the vicinity of Haudricks Mountain that have sandstone, quartzite, and fine-grained metasiltstone clasts interbedded

with fine- to coarse-grained arkosic sandstone. The unit grades laterally into the Balls Bluff Member of the Bull Run Formation (Fig. 9). The Haudricks Mountain Member can be as thick as 500 m (Lee and Froelich, 1989).

#### Tibbstown Formation (Abandoned)

When Lee and Froelich (1989) named the Tibbstown Formation, they assumed that the rocks assigned to this unit had a northerly strike and lay above rocks here assigned to the Bull Run Formation. However, detailed mapping in the Culpeper East quadrangle by R. E. Weems reveals that Tibbstown rock types strike northeast to eastward and grade laterally into rocks typical of the Balls Bluff and Groveton Members of the Bull Run Formation. The outcrop pattern is very complex and impractical to map (Fig. 9). There-

fore, the name Tibbstown Formation is abandoned and its constituent parts are incorporated into the Bull Run Formation.

#### AGE AND GROUP ASSIGNMENT OF THE WATERFALL FORMATION

The Waterfall Formation, highest stratigraphic unit in the Culpeper basin, formerly was correlated with the Boonton and Portland Formations (Lee and Froelich, 1989; Luttrell, 1989) of the Agawam Group. This correlation was based in part on a comment by Cornet (1977, p. 260) that his *Corollina torosa* palynozone (defined from the middle and upper beds of the Portland Formation) "could be represented ... in the youngest strata of the Culpeper Group." Although Cornet (1977, p. 167) had a sample locality in these strata (MBK at Millbrook Quarry), he listed no pollen or spore taxa from this locality and in Appendix I only noted that it "produces poorly preserved palynomorphs" (p. 447). Elsewhere he stated, "particularly significant would be the absence of *Redfieldius* in the Millbrook Quarry fish bed if that part of the section were younger than the highest stratigraphic occurrence of *Redfieldius* spp. Unfortunately, the palynoflorules from the two fish beds do not provide any solution to this problem" (p. 133), and that "the *Corollina torosa* palynoflora, may also be represented in the Culpeper and Greenfield Groups, based on stratigraphic relationships" (p. 247). Thus Cornet provided no palynological evidence to support his suggestion that sample MBK might represent his *Corollina torosa* palynozone and implied in two places that his assignment was based on evidence other than pollen or spores. Therefore, none of the Waterfall Formation has been demonstrated to be as young as the *Corollina torosa* palynozone.

Another argument for correlating the Waterfall Formation with the Agawam Group was based on the assumption that the Sander Basalt (the third flow sequence recognized in the Culpeper basin) correlates with the Hook Mountain and Hampden basalts (the third and highest flow sequences in the Newark and Hartford basins). However, geochemical work on these basalts (Tollo and Gottfried, 1992; Hozik, 1992) demonstrates that the Sander Basalt correlates with the Preakness, Holyoke, and Deerfield Basalts in the Newark, Hartford, and Deerfield basins, and not with the Hook Mountain and Hampden Basalts. This implies that the Waterfall Formation likely correlates with the Towaco Formation, the East Berlin Formation, and the Turners Falls Sandstone and/or Mount Toby Formation (Fig. 3), rather than with the Boonton and Portland Formations as previously assumed. Moreover, preliminary work

on the cyclic stratigraphy of the Waterfall Formation (Olsen, 1997, p. 381) supports this view, because the cyclicity within the Waterfall Formation is most similar to that of the Towaco and East Berlin Formations.

The Waterfall Formation is cut in its lower part by an olivine normative diabase dike (Gottfried et al., 1991, U.S. Geological Survey core hole Opal #1, p. 15 and plate 1), demonstrating that deposition of the lower part of this unit preceded the end of early Mesozoic igneous activity. In addition, Hentz (1985) mapped two fine-grained basaltic bodies along the western basin border fault near Beulah Church and Broad Run (Thoroughfare Gap 7.5-minute quadrangle), which he interpreted as lava flows capping the youngest strata of the Waterfall Formation. The body near Broad Run is stratigraphically discordant (Hentz, 1985, Fig. 2), suggesting that it might be a dike, but either interpretation places volcanic rocks throughout the column of the Waterfall Formation and thus excludes the Waterfall Formation from the definition of the Agawam Group.

An alternative explanation of the two areas of basaltic rock near Thoroughfare Gap was offered by Lee and Froelich (1989, p. 27), who interpreted them as slivers of the Sander Basalt repeated by faulting within the western border fault complex of the Culpeper basin. If this proves to be true, then the highest preserved strata of the Waterfall Formation are not capped by basalts as Hentz thought, and diabase or basalt are not demonstrably present in the highest strata of the Waterfall Formation. Although plausible, this argument requires an impressive throw of 1500 m along the obscure fault that separates the basalt slivers in question from the adjacent upper Waterfall Formation. Such an impressive throw on an obscure fault tends to imply that other such faults probably exist, which in turn implies that the estimated thickness of the Waterfall Formation may be much too great.

In the absence of geochemical data, either interpretation remains plausible. The dike cited by Gottfried et al. (1991) still documents igneous rocks cutting the older parts of the Waterfall Formation, and this still supports correlation of the lower part of the Waterfall Formation with the East Berlin and Towaco Formations. Because Hentz (1985) described angular unconformities near the top of the Waterfall section, it remains possible that the stratigraphic horizon equivalent to the Hampden and Hook Mountain Basalts is lost within one of these unconformities. If so, the highest strata of the Waterfall Formation may belong in the Agawam Group and may need to be mapped and named separately. At our present level of understanding, however, this is speculative. Therefore, we retain all of the Waterfall For-

mation in the Meriden Group until paleontological, geochemical, and/or stratigraphic studies show convincingly that any Agawam-equivalent strata are present in the Culpeper basin.

#### SUMMARY

The rock columns of the early Mesozoic rift basins of eastern North America collectively have been termed the Newark Supergroup, because they share a common tectonic history that is distinctly different from other North American rock sequences. In contrast, disparate parts of this supergroup have been combined into nine groups that neither provide an inclusive stratigraphic framework for the entire supergroup nor cluster the included formations in a manner that optimally reflects their lithic contrasts and similarities. For this reason, we propose a stratigraphic reorganization of the groups within the Newark Supergroup that emphasizes stratigraphic and tectonic elements common to the rock columns of all basins. Two existing group names are retained: the Chatham Group, which is expanded to apply to strata in all basins from the base of each stratigraphic column either to the top of the preserved column, to the base of the lowest preserved lava flow, or to an unconformity encompassing the basal flow horizon; and the Meriden Group, which is retained in its original sense but expanded to apply to all lithologically similar (and age-equivalent) Newark Supergroup lava flows and strata interbedded between flows in other basins. Thus defined, the Meriden Group now includes the lavas and interbedded sedimentary rocks contained in the Culpeper, Gettysburg, Newark, Pomperaug, Hartford, Deerfield, and Fundy basins. The name Agawam Group is proposed here to include all strata higher than the flow-bearing Meriden interval in the two basins where such strata are preserved (Newark and Hartford basins). Seven other group names (Brunswick Group, Chesterfield Group, Culpeper Group, Dan River Group, Hartford Group, Fundy Group, and Tuckahoe Group), previously applied in local areas of the eastern North American early Mesozoic rift basins, are herein abandoned as stratigraphically redundant. As here defined, the Chatham Group ranges in age from Middle Triassic to earliest Early Jurassic. The Meriden Group and the Agawam Group are both Early Jurassic in age.

Unlike the ninefold group nomenclature previously applied to parts of the Newark Supergroup, our threefold group nomenclature places all Newark Supergroup strata into groups and establishes unambiguous boundaries between groups throughout all of the eastern North American early Mesozoic rift basins. Our rock classification system makes use of the fact that a discrete episode of

synchronous or nearly synchronous volcanism occurred throughout this early Mesozoic rift system. Thus the presence or absence of extrusive volcanic rocks (and their genetically related diabase dikes and sills) provides a powerful stratigraphic tool for establishing regionally applicable groups and group boundaries, allows us to create parallelism between stratigraphic groups and some of the major tectonic events that created the eastern North American rift basins, and coincidentally provides isochronous or nearly isochronous group boundaries within the Newark Supergroup.

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