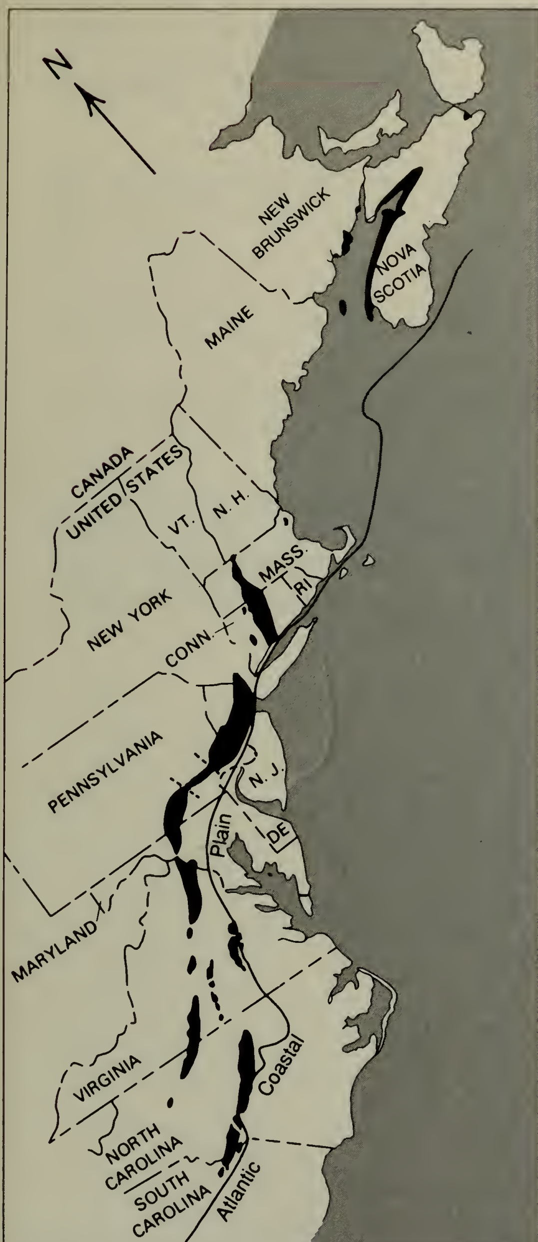

Stratigraphic Nomenclature of the Newark Supergroup of Eastern North America

U.S. GEOLOGICAL SURVEY
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By GWENDOLYN W. LUTTRELL

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A lexicon and correlation chart of Newark Supergroup stratigraphic nomenclature, including a review of the origin and characteristics of the early Mesozoic basins of eastern North America

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METRIC CONVERSION FACTORS

For readers who wish to convert measurements from the inch-pound system of units to the metric system of units, the conversion factors are listed below:

Multiply inch-pound unit	By	To obtain metric unit
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)

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Abstract

The Newark Supergroup includes the lithologically and structurally related continental clastic rocks and interbedded basalt flows of Triassic and Jurassic age that are exposed in discrete elongate basins parallel to the Appalachian orogen in the Piedmont of eastern North America. A brief review of the origin and characteristics of the early Mesozoic basins and summaries of the history, location, and structure of each of the basins provide background for understanding the development of the stratigraphic nomenclature of the basins. The lexicon consists of summaries of papers containing definitions and revisions of the more than 100 formal and informal names used to identify Newark Supergroup rocks. The papers were selected from the literature of the last 135 years. For each unit, the occurrence, lithology, areal distribution, age, and relation to other units are described. Problems in the nomenclature are noted.

INTRODUCTION

The chain of rift basins of early Mesozoic age, which extends from South Carolina to Nova Scotia and follows the grain of the Appalachian Mountains, has fascinated geologists for nearly 200 years. These elongate, half-graben basins are characterized by fluvial red beds, lacustrine deposits, strata containing reptile footprints and fossil fish, diabase intrusions, and volcanic flows. B.S. Lyman (1894) wrote regarding his work in the Newark basin, "There is reason to hope that it may well keep within the not wholly unprecedented New Red [Sandstone] proportions of two bushels of conjecture to two grains of fully ascertained fact." These words may well apply to many of the theories that have been proposed for the origin of the basins.

Manuscript approved for publication April 4, 1989.

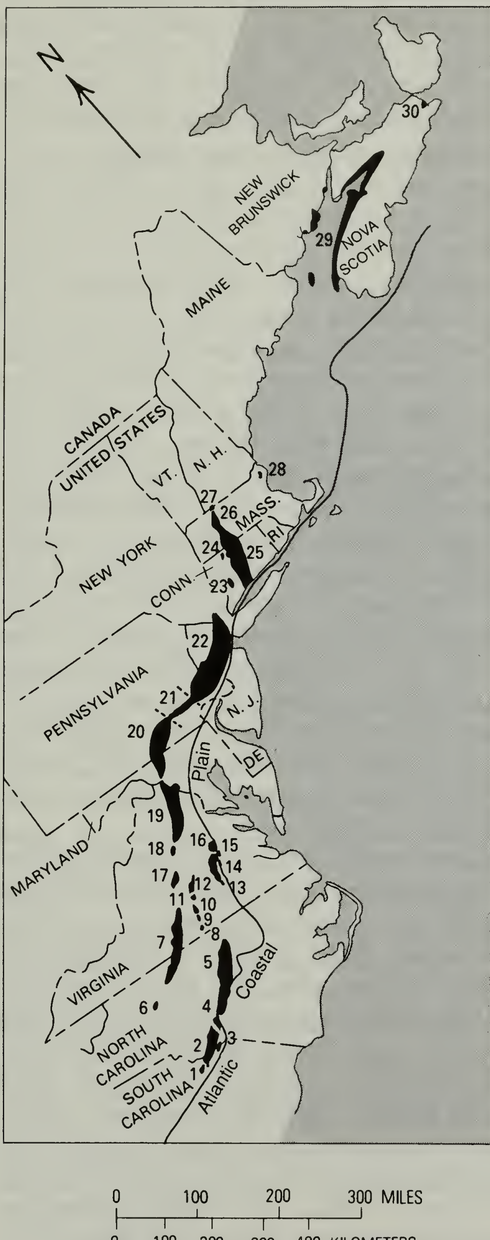
That the basins share a common origin is acknowledged by the assignment of the rocks of all the basins to one all-inclusive lithostratigraphic unit, the Newark Supergroup. The Newark Supergroup, as revised by Froelich and Olsen (1984), includes lithologically and structurally related continental clastic and lacustrine rocks and interbedded basalt flows. These Late (and possibly Middle) Triassic and Early Jurassic rocks are exposed in discrete elongate basins parallel to the Appalachian orogen in the Piedmont province of eastern North America. Similar early Mesozoic subsurface basins lie east of the exposed basins beneath the Atlantic Coastal Plain and Continental Shelf, but, because the relation of these poorly understood subsurface rocks to the exposed early Mesozoic rocks is presently unclear, the name Newark Supergroup is applied only to the rocks in the exposed basins.

EXPOSED BASINS

Rift basins formed during the early phases of the continental rifting that preceded the separation of North America from Africa in the Middle Jurassic. The exposed basins, in the Piedmont and locally along the western margin of the Atlantic Coastal Plain, extend discontinuously from South Carolina to Nova Scotia and are oriented parallel to the Appalachian orogen (fig. 1). The basins are bounded by Precambrian and early Paleozoic metamorphic rocks and by Cretaceous sedimentary rocks. Moderate- to high-angle normal faults of Mesozoic age, which in some cases appear to be reactivated Paleozoic ramp and thrust faults (Ratcliffe and Burton, 1985), border the basins. These fault-bounded troughs, or half grabens, are filled with Triassic and Jurassic continental sedimentary and igneous rocks, collectively known as the Newark Supergroup.

Some of the basins may have extensions in the subsurface. Well data from the Coastal Plain in Maryland and Virginia indicate areas in the subsurface that may be continuations of the Taylorsville basin (Weems, 1980a). The Fundy basin extends in the subsurface beneath the Bay of Fundy.

Several hypotheses have been proposed to explain the origin of the exposed basins. Russell (1878) discussed two hypotheses. The local-basin hypothesis proposes that deposition occurred in detached basins, which formed by erosion or faulting and have not changed much since their filling. The broad-terrane hypothesis proposes that the present detached basins are remnants of much broader terranes; perhaps all the terranes were originally united into one broad depositional terrane that was later subjected to upheaval, faulting, and considerable erosion. Sanders (1963), in his discussion of the origin of the Newark and Hartford basins, modified the broad-terrane hypothesis to include initial graben subsidence of a much smaller area, deposition of nonmarine



EXPLANATION

1. Crowburg basin, South Carolina
2. Wadesboro basin, South Carolina-North Carolina
3. Ellerbe basin, North Carolina
4. Sanford basin, North Carolina
5. Durham basin, North Carolina
6. Davie County basin, North Carolina
7. Dan River-Danville basin, North Carolina-Virginia
8. Scottsburg basin, Virginia
9. Randolph basin, Virginia
10. Roanoke Creek basin, Virginia
11. Briery Creek basin, Virginia
12. Farmville basin, Virginia
13. Richmond basin, Virginia
14. Flat Branch basin, Virginia
15. Deep Run basin, Virginia
16. Taylorsville basin, Virginia
17. Scottsville basin, Virginia
18. Barboursville basin, Virginia
19. Culpeper basin, Virginia-Maryland
20. Gettysburg basin, Maryland-Pennsylvania
21. The narrow neck of the Newark-Gettysburg basin, Pennsylvania
22. Newark basin, Pennsylvania-New Jersey-New York
23. Pomperaug basin, Connecticut
24. Cherry Brook outlier, Connecticut
25. Hartford basin, Connecticut-Massachusetts
26. Deerfield basin, Massachusetts
27. Northfield basin, Massachusetts
28. Middleton basin, Massachusetts
29. Fundy basin, New Brunswick-Nova Scotia
30. Chedabucto Bay, Nova Scotia

FIGURE 1.—Exposed early Mesozoic basins of eastern North America (Powers, 1916; Stevenson, 1960; King and Beikman, 1974).

sediments, crustal arching, erosion, second-generation graben subsidence, and development of transverse folds. Faill (1973) proposed that the origin of the Gettysburg and Newark basins was crustal extension that resulted in downwarping of the basement floor, sediment filling, tilting, faulting, and folding. Klein (1969) proposed the "Dead Sea model" in which the so-called "half-graben" distribution of sedimentary facies found in the Newark-type basins occurs in simple grabens, where structural and physiographic boundaries do not coincide. Hubert and others (1978) described a modified broad-terrane hypothesis for the origin of the Newark and Hartford basins. They suggested the evolution of a single rift valley in which differences in time of deposition and total thickness of deposits are accounted for by irregularity in spacing and timing of normal border faults and associated areal patterns of sediment accumulation. Manspeizer (1981) based his hypothesis on the concept of plate tectonics. At the time of the rifting of the Atlantic continental margin, the basins originated in a strike-slip setting where crustal segments were pulled apart. Sedimentation started in sag ponds that evolved into pull-apart basins and half grabens, as transform segments passed each other during crustal extension and compression. In their fault reactivation model, Ratcliffe and Burton (1985) hypothesized that the overall structure and location of the Newark and Hartford basins were controlled by reactivation of Paleozoic ramps and thrusts that led to a characteristic basin form that has a shallow, wide flange developed over the ancestral thrusts and an axial anticline developed at the point of inflection between thrusts and ramps. The widest parts of the basin occur where extension was normal to the Paleozoic grain, and narrow parts and terminations occur where there was increased oblique slip and consequent decrease in horizontal separation.

Many of the exposed basins are constricted by structurally uplifted and cross-faulted areas of Mesozoic rocks known as narrow necks, or cross structures. These uplifted areas apparently received a thinner load of sediments than adjacent areas, which resulted in the separation and isolation of the deeper parts of the basins. The narrow neck that separates the Newark and Gettysburg basins, described by Glaeser (1963), is parallel to the ancient east-west structural grain and may have resulted from predominant left-oblique normal faulting and minor dip-slip movement (Ratcliffe and Burton, 1985). Other narrow, uplifted structures are the Pekin cross structure at the north end of the Wadesboro basin near the Sanford basin, the Colon cross structure separating the Sanford and Durham basins, the constricted area just north of the North Carolina-Virginia State line in the Dan River-Danville basin, the fault block of uplifted granite near Renan in the Danville basin, "The Ridge" in the southern Culpeper basin, and the narrow neck separating the Hartford and Deerfield basins. Other basins are separated by narrow cross-faulted zones of exposed older rocks that may represent uplifted areas from which all the Mesozoic strata have been removed by erosion. Such zones separate the Crowburg and Wadesboro basins, the Richmond and Taylorsville basins, and the Barboursville, Culpeper, and Gettysburg basins. The Scottsburg, Randolph, Roanoke Creek, Briery Creek, and Farmville basins may have been interconnected during Late Triassic time.

The complexly intertonguing sedimentary lithologies, primary structures, fabrics, and packaging of the strata in the basins reflect a diversity of fluvial and lacustrine depositional environments. The depositional environments have been compared to those of modern arid rift valley basins (Olsen, 1980a; Turner-Peterson, 1980). Smoot (1985) suggested that deposition took place in at least periodically closed basins. Similarly, fluvial and lacustrine environments were present in all the basins but not necessarily at the same time. All of the basins were influenced by a combination of active tectonism and climatic change (Van Houten, 1962, 1964; Bain and Harvey, 1977; Wheeler and Textoris, 1978; Manspeizer, 1981; Olsen, 1984b; Smoot and Olsen, 1985) reflected by the presence of fluvial arkosic sandstones, red beds, and conglomerates and cyclic lacustrine deposits. The lacustrine deposits are characterized by fossiliferous black laminated shale and siltstone, reflecting wet times, and by limestone, chert, and red massive mudstone containing mudcracks and evaporite minerals, formed under relatively arid conditions.

Several of the basins have rock types that appear to be time related. For example, swampy conditions in the Middle(?) to Late Triassic produced coal deposits in the Deep River, Dan River-Danville, Farmville, Richmond, and Taylorsville basins. In basins containing basalt flows, the earliest flows are found just above the Triassic-Jurassic boundary. Diabase sheets and dikes, which are present in nearly all the basins, and the basalt flows are about the same age and crystallized in the time span of about 175–200 Ma (Sutter, 1985), but their specific relations are, in most cases, uncertain. In the Hartford basin, three regional dikes have been correlated, petrographically and chemically, with the basin's three basalt units (Philpotts and Martello, 1986); feeder dikes for two of the basalt units are exposed (Philpotts, 1985). No diabase has been found to cut the sedimentary rocks overlying the highest basalt flows (Philpotts, 1985), which are the Sander Basalt in the Culpeper basin, the Hook Mountain Basalt in the Newark basin, the Hampden Basalt in the Hartford basin, and the Deerfield Basalt in the Deerfield basin.

Correlation of the continental sedimentary rocks of the Newark Supergroup with the classic European marine Triassic and Jurassic type sections is hampered by the incompleteness of the sections, different fauna and flora, and uncertainties in the identification of similar or possibly identical species (R.J. Litwin, U.S. Geological Survey, oral commun., 1988). Intrabasinal correlations and age estimates have been made on the basis of the chemical composition, paleomagnetism, and radiometric ages of basalt and diabase; vertebrate and plant fossils; spores and pollen; and cyclic sequences of sedimentary beds (DeBoer, 1968; Cornet, 1977; Puffer and others, 1981; Olsen and others, 1982; Raymond and others, 1982; Robbins, 1982; Olsen, 1984a; Sutter, 1985; Ediger, 1986; Traverse, 1986, 1987). Paleontological and palynological studies suggest that sedimentation began and ended earlier in the southern basins than in the northern basins. However, sedimentation may have continued longer than the geologic record shows, and younger strata may have been removed by erosion from the southern basins. The ages of the rocks preserved in the southernmost basins are possibly late Middle Triassic and Late Triassic. In the northern basins, ages range from early Late Triassic to Early Jurassic and possibly to late Early Jurassic in the Hartford basin. Fundy, the northernmost basin, however, contains strata ranging in age from possibly late Middle Triassic to Early Jurassic. Newark Supergroup intrabasin correlations and ages are shown on plate 1.

DESCRIPTIONS OF THE EXPOSED BASINS

The exposed basins and their associated outliers, histories, locations, areas, structures, and currently used stratigraphic nomenclature are described in geographical order from the southernmost Crowburg basin in South Carolina to the northernmost Fundy basin in Canada. The basins described herein and shown on figure 1 are the Deep River basin and its subbasins, the Crowburg, Wadesboro, Ellerbe, Sanford, and Durham basins in South and North Carolina; the Davie County basin in North Carolina; the Dan River-Danville basin in North Carolina and Virginia; the Scottsburg, Randolph, Roanoke Creek, Briery Creek, Farmville, Richmond and its Flat Branch and Deep Run outliers, Taylorsville, Scottsville, and Barboursville basins in Virginia; the Culpeper basin in Virginia and Maryland; the Gettysburg basin in Maryland and Pennsylvania; the Newark basin in Pennsylvania, New Jersey, and New York; the Pomperaug basin and Cherry Brook outlier in Connecticut, the Hartford basin in Connecticut and Massachusetts, and the Deerfield and Northfield basins in Massachusetts, all included in the ConnecticutValley basin; the Middleton basin in Massachusetts; and the Fundy basin in New Brunswick and Nova Scotia.

DEEP RIVER BASIN

The Deep River basin is named for the Deep River coal field, which extends along the Deep River in the Sanford subbasin in Chatham, Lee, and Moore Counties, N.C. (Reinemund, 1955). The name Deep River basin was first used by Emmons (1857) to include the entire string of related subbasins extending from Chesterfield County, S.C., through Durham County, N.C. These subbasins were later individually named the Crowburg, Wadesboro, Ellerbe, Sanford, and Durham basins. The name Deep River basin has also been used to include only the Sanford and Durham basins (Reinemund, 1955). The entire Deep River basin is a structural and topographic trough about 240 km long and has a maximum width of 27 km and an area of about 2,700 km^2. The basin trends northeastward from Chesterfield County, S.C., through parts of Union, Anson, Richmond, Montgomery, Moore, Lee, Chatham, Orange, Wake, Durham, and Granville Counties, N.C.

Basal strata unconformably overlie older metamorphic rocks along the locally faulted western margin. Late Triassic strata gradually thicken and dip monoclinally toward the eastern margin, which is faulted against older metamorphic rocks by the west-facing, major, high-angle, normal Jonesboro border fault. The eastern margin is locally overlapped by younger Atlantic Coastal Plain sediments. Northwest-trending cross faults are related to the uplifted Colon cross structure, which separates the Sanford from the Durham subbasin, and to the Pekin cross structure at the northern end of the Wadesboro subbasin. The stratigraphic nomenclature of the Deep River basin is shown in table 1.

CROWBURG BASIN

The Crowburg basin, a subbasin of the Deep River basin, is named for the town of Crowburg in northern Chesterfield County, S.C. The basin, a small wedge-shaped outlier, is located southwest of the Wadesboro basin and is about 6.5 km long, as much as 2 km wide, and about 6 km^2 in area. Most of the border of the basin is marked by a prominent scarp that is 15 to 30 m high. Late Triassic rocks are mainly fanglomerates containing minor amounts of sandstone and shale (Bell and others, 1974). The stratigraphic nomenclature of the Crowburg basin is shown in table 1.

TABLE 1.—*Present stratigraphic nomenclature of the Deep River basin, including the Crowburg, Wadesboro, Ellerbe, Sanford, and Durham basins (Reinemund, 1955; Brown, 1985)*

Stratigraphic Unit	Basin					Age
	Crowburg	Wadesboro	Ellerbe	Sanford	Durham	
Newark Supergroup	×	×	×	×	×	Late-Middle(?) Triassic.
Chatham Group	×	×	×	×	×	Do.
Sanford Formation				×	×	Late Triassic.
Cumnock Formation ...				×	×	Do.
Pekin Formation		×		×	×	Late-Middle(?) Triassic.

WADESBORO BASIN

The Wadesboro basin, a subbasin of the Deep River basin, is named for the town of Wadesboro, Anson County, N.C. The basin extends from Chesterfield County, S.C., northeastward through Union, Anson, and Richmond Counties, N.C., to the village of Candor, Montgomery County. The basin is about 80 km long, has a maximum width of about 16 km, and is about 1,100 km^2 in area.

Newark Supergroup sedimentary rocks unconformably overlie and are faulted against early Paleozoic metamorphic rocks on the west side of the basin. On the east side, the basin is bordered by a northwest-dipping, high-angle, normal fault, which may be a branch of the Jonesboro fault or a continuation of the Governors fault and is overlapped by Cretaceous Atlantic Coastal Plain sediments. The east side of the basin contains also a number of small outliers of Late Triassic rocks, including the named Ellerbe basin. To the southwest, the basin terminates in a series of cross faults that separate it from the Crowburg basin. To the north, the Wadesboro basin is terminated by the Pekin cross structure, a northwest-striking, cross-faulted anticlinal warp similar to the Colon cross structure that separates the Sanford basin from the Durham basin. The overlapping Atlantic Coastal Plain sediments occupy the area between the Wadesboro and Sanford basins. The Late Triassic, and possibly Middle Triassic (Traverse, 1987), sedimentary rocks in the basin are southeast-dipping claystone, siltstone, sandstone, shale, conglomerate, and fanglomerate cut by numerous Early Jurassic diabase dikes. The basin has been described by Randazzo and Copeland (1976) and Randazzo and others (1970). The stratigraphic nomenclature of the Wadesboro basin is shown in table 1.

ELLERBE BASIN

The Ellerbe basin, a subbasin of the Deep River basin, lies 3 km southwest of the town of Ellerbe, Richmond County, N.C. The basin is a small outlier, 10 to 13 km east of the Wadesboro basin, and is 10 km long, 3 km wide, and about 30 km^2 in area. A high-angle, normal fault passes along the western margin of the basin. Late Triassic fanglomerates have been reported by Bell and others (1974). The stratigraphic nomenclature of the Ellerbe basin is shown in table 1.

SANFORD BASIN

The Sanford basin, a subbasin of the Deep River basin, was named for the largest city in the Sanford basin by Prouty (1926). Extending from western Moore County for 51 km through Lee and Chatham Counties, N.C., the Sanford basin has a maximum width of about 22 km and an area of about 740 km^2. The Sanford basin was called the Cumnock basin by Prouty (1928).

The basin is a northeast-trending half graben, bordered on the east by the high-angle, normal Jonesboro fault. There is evidence for a series of western border faults that bring older metamorphic rocks in contact with the Triassic rocks of the basin (Conley, 1962). The basin contains 2,100 to 3,000 m of sedimentary rocks of Late Triassic, and possibly Middle Triassic, age (Traverse, 1987), siltstone, sandstone, conglomerate, claystone, shale, and the Deep River coal beds. The basin rocks are intruded by Early Jurassic diabase dikes and sills. The Sanford basin is separated from the Durham basin to the north by the Colon cross structure (Campbell and Kimball, 1923), a cross-faulted anticlinal fold that forms a constricted area 13 km long and 8 km wide and extends from the village of Colon, 7 km northeast of Sanford, Lee County, north to the Lee-Chatham County line. In the Colon cross structure, the thickness of the Triassic rocks is only 1,200 to 1,500 m. Studies of the Sanford basin have been made by Campbell and Kimball (1923), Reinemund (1955), and Gore (1986). The stratigraphic nomenclature of the Sanford basin is shown in table 1.

DURHAM BASIN

The Durham basin, a subbasin of the Deep River basin, was named for the largest city in the Durham basin by Prouty (1926). The basin extends northward from the Colon cross structure at the Lee-Chatham County line for 83 km through Orange, Wake, Durham, and Granville Counties, N.C., and has a maximum width of 27 km and an area of about 1,700 km^2.

The basin is a northeast-trending half graben bordered on the east by the high-angle, normal Jonesboro fault. On the western border, Triassic rocks unconformably overlie older metamorphic rocks, and there is evidence of minor faulting. The basin contains 2,100 to 3,000 m of Late Triassic, and possibly Middle Triassic (Traverse, 1987), siltstone, sandstone, conglomerate, claystone, shale, and minor amounts of limestone and chert. Diabase dikes and sills of Early Jurassic age intrude the Triassic rocks. Studies of the Durham basin have been made by Campbell and Kimball (1923), Reinemund (1955), Wheeler and Textoris (1978), Bain and Brown (1981), and Gore (1986). The stratigraphic nomenclature of the Durham basin is shown in table 1.

DAVIE COUNTY BASIN

The Davie County basin was named for Davie County, N.C. Located 13 km northwest of Mocksville in northwestern Davie and southern

TABLE 2.—*Present stratigraphic nomenclature of the Davie County and Dan River-Danville basins (Thayer, 1970b, 1977, 1980b; Brown, 1985)*

Stratigraphic unit	Basin			Age
	Davie County	Dan River	Danville	
Newark Supergroup.........	×	×	×	Late Triassic.
Dan River Group............	×	×		Do.
Stoneville Formation		×	×	Do.
Cow Branch Formation....		×	×	Do.
Pine Hall Formation.......		×	×	Do.
Dry Fork Formation			×	Do.

Yadkin Counties, the basin has an irregular shape, of which the maximum length is about 10 km, the width is 4 km, and the area is about 36 km^2. The basin lies on the line of strike of the Dan River-Danville basin 40 km to the northeast and is believed to be an outlier of the Dan River-Danville basin (Brown, 1932). A much smaller outlier southeast of Harmony in Iredell County, N.C., mapped by LeGrand (1954), lies along the same line of strike.

The Davie County basin is a half graben bordered on the east by a steep normal fault, which may be an extension of the Chatham-Stony Ridge fault zone that borders the Dan River-Danville basin (Thayer, 1970b). The Davie County basin contains northwest-dipping, laterally interfingering, Late Triassic basin-margin conglomerate and fluvial sandstone, siltstone, and claystone in the basin center. Early Jurassic diabase dikes intrude the Triassic rocks (Thayer, 1970a). The stratigraphic nomenclature of the Davie County basin is shown in table 2.

DAN RIVER-DANVILLE BASIN

The Dan River-Danville basin is a narrow north-northeast-trending half graben that extends from 16 km north of Winston-Salem through Stokes and Rockingham Counties, N.C. In Virginia, the basin extends through Pittsylvania and Campbell Counties to the southern tip of Appomattox County and extends partially into Halifax and Henry Counties. In North Carolina the basin is named for the Dan River, and in Virginia the basin is named for the city of Danville. The entire basin is about 175 km long and has a maximum width of 13 km and an area of about 1,190 km^2.

The basin is bordered on the northwest by southeast-dipping, high-angle, normal Mesozoic faults that occur along the reactivated Paleozoic Chatham-Stony Ridge fault zone (Thayer, 1970b). The fault zone forms the contact between the northwest-dipping Triassic strata and Paleozoic metamorphic rocks. On the southeast border, the contact between the Triassic strata and the metamorphic rocks is mostly unconformable and has minor faulting (Johnson, Wiener, and Conley, 1985). The basin contains as much as 4,500 m of continental clastic sedimentary rocks, including conglomerate, sandstone, siltstone, claystone, shale, mudstone, and thin coal beds of Late Triassic age. Age determination was based on fossils of fish, reptiles, plants, pollen, and spores (Olsen and others, 1982; Robbins, 1982, 1985). Diabase sheets and dikes that intrude into the Triassic strata are Early Jurassic. Russell (1892) described a profound northwest-trending displacement, located in southern Pittsylvania County, Va., that separates the Dan River and Danville basins. Thayer (1980a, b) shows a cover of Quaternary terrace deposits, which may represent an uplifted and possibly cross-faulted neck similar to the Colon cross structure that separates the Sanford and Durham basins. Near Renan, in northern Pittsylvania County, Va., a fault block of pre-Triassic quartz monzonite about 5 km^2 is enclosed by Triassic strata (Meyertons, 1963). The geology of the basin has been described by Meyertons (1963) and Thayer (1970b, 1977, 1980a, b). The stratigraphic nomenclature of the Dan River-Danville basin is shown in table 2.

SCOTTSBURG BASIN

The Scottsburg basin is named for the town of Scottsburg, Halifax County, Va. The basin forms, together with the Randolph, Roanoke Creek, Briery Creek, and Farmville basins to the northeast, a 65-km-long string of half grabens known in Virginia as the central belt (Johnson, Wilkes, and Zeiler, 1985). The basins lie along the same line of strike, and their western margins are formed by steeply east-dipping normal faults. West-dipping clastic strata lie in unconformable contact with older metamorphic rocks located along the eastern margins of the basins. The Scottsburg basin is about 9.5 km long, is as much as 4 km wide, and has an area of about 25 km^2. The basin contains Late Triassic siltstone, shale, and minor amounts of sandstone and conglomerate (Olsen and others, 1982; Johnson, Wilkes, and Zeiler, 1985).

RANDOLPH BASIN

The Randolph basin is named for the town of Randolph, Charlotte County, Va. The basin is small, about 8 km long and 5 km wide, covers about 36 km^2, and is situated between the Scottsburg and Roanoke Creek basins in Charlotte and Halifax Counties. The basin is a half graben that has a steep normal fault on the west border. Late Triassic siltstone, shale, and minor amounts of sandstone and conglomerate unconformably overlie older metamorphic rocks (Johnson, Wilkes, and Zeiler, 1985).

ROANOKE CREEK BASIN

The Roanoke Creek basin is named for Roanoke Creek, Charlotte County, Va. This small basin, about 14.5 km long and 1 to 3 km wide, covers about 29 km^2 and is situated between the Randolph and Briery Creek basins in Charlotte County. The basin is a half graben bordered on the west by a steep normal fault that occurs in a zone of intensely deformed country rock. Late Triassic rocks, cut by an Early Jurassic diabase dike, are sedimentary breccia and bedded and massive conglomerate that has a muddy sandstone matrix (Johnson, Wilkes, and Zeiler, 1985; Goodwin and others, 1986).

BRIERY CREEK BASIN

The Briery Creek basin is named for Briery Creek, Prince Edward County, Va. This small wedge-shaped basin is about 8 km long, is as much as 1.5 km wide, and has an area of about 8 km^2. The basin, which lies 3.2 km south of the Farmville basin, is fault bounded on the east and west margins and has a wide mylonite border on the west. Late Triassic rocks are composed of siltstone, shale, and minor amounts of sandstone, conglomerate, and coal. Early Jurassic diabase dikes intrude into the Triassic strata (Johnson, Wilkes, and Zeiler, 1985; Goodwin and others, 1986).

FARMVILLE BASIN

The Farmville basin is named for the nearby town of Farmville, Prince Edward County, Va. The basin is about 43 km long, is 6.5 km wide, and occupies a northeast-trending area of about 170 km^2 in Prince Edward, Buckingham, and Cumberland Counties. The basin is a graben bounded on the west and east by normal faults. Late Triassic rocks include sedimentary breccia and conglomerate, arkosic conglomerate, arkosic sandstone, siltstone, and locally important coal measures. Early Jurassic diabase dikes intrude into the sedimentary rocks (Wilkes, 1982; Johnson, Wilkes, and Zeiler, 1985; Goodwin and others, 1986).

RICHMOND BASIN AND OUTLIERS

The Richmond basin lies 19 km west of the city of Richmond, Va., in Amelia, Chesterfield, Powhatan, Henrico, and Goochland Counties. The basin is about 53 km long, is 16 km wide at its maximum width, and has an area of about 500 km^2 (Goodwin and others, 1985). The Richmond basin is a half graben surrounded by Precambrian and Mississippian igneous and metamorphic rocks of the Piedmont province. The Richmond basin and the Taylorsville basin (11 km to the northeast) are bordered on the northwest by the Hylas zone. This late Paleozoic thrust fault zone, composed of cataclastic rocks, was reactivated as a zone of normal faults in the early Mesozoic and Tertiary. On the eastern border of the basin, older plutonic and metamorphic rocks are unconformably overlain by, or are locally in fault contact with, Triassic sedimentary rocks of fluvial and lacustrine origin, including conglomerate, sandstone, siltstone, shale, and bituminous coal. These rocks are Late Triassic and possibly Middle Triassic (Ediger, 1986). Early Jurassic diabase dikes are present but rare.

Five small outliers, east and northeast of the Richmond basin, were possibly once continuous with the Richmond basin. Near Midlothian, coal has been mined from three small outliers: the Stonehenge, Union, and Black Heath basins. The Flat Branch, or Tuckahoe, outlier lies along Flat Branch, Henrico County. This outlier, which is about 3 km long, is as much as 1 km wide, and has an area of about 3 km^2, may be connected to the Richmond basin, but the area between the basins, which varies from 0.16 to 1.6 km wide, is obscured by younger alluvial deposits. Sandstone, shale, and coal deposits of the coal measures are present in this basin and are faulted against the Petersburg Granite on the western border (Goodwin, 1980). The most northerly of the outliers, the Deep Run, or Springfield, basin, is located about 4.5 km east of the Richmond basin and 9 km south of the Taylorsville basin. The basin is 4.5 km long, is as much as 0.6 km wide, and has an area of about 3.5 km^2. The coal measures are composed of sandstone, shale, and coal beds. Along the western border of the basin, the coal measures are in fault contact with the Petersburg Granite; along the eastern border, which is parallel to Deep Run in Henrico County, the coal measures unconformably overlie the granite (Goodwin, 1981). Pollen and spores from coal mine-dump samples in the Deep Run basin, unlike those in basins nearby, are dark brown and have Permian affinities. This basin was possibly subjected to a thermal event such as deeper burial and may be as old as Early Triassic or Permian (Robbins and Weems, 1988). Studies of these basins have been made by Shaler and Woodworth (1899), Goodwin (1970, 1980, 1981), Johnson, Wilkes, and Gwin (1985), and Goodwin and others (1986). The stratigraphic nomenclature of the Richmond, Deep Run, and Flat Branch basins is shown in table 3.

TAYLORSVILLE BASIN

The Taylorsville basin, named for the town of Taylorsville, Hanover County, Va., by Weems (1980a), is a north-northeast-trending half graben lying 11 km northeast of the Richmond basin. The exposed area of the basin in Hanover and Caroline Counties is about 19 km long, is 11 km wide (Johnson, Wilkes, and Gwin, 1985), and has an area of 140 km^2. Geophysical data, supported by the presence of Triassic rocks in wells

TABLE 3.—*Present stratigraphic nomenclature of the Richmond, Deep Run, and Flat Branch basins (Shaler and Woodworth, 1899; Johnson, Wilkes, and Gwin, 1985)*

Stratigraphic unit	Basin			Age
	Richmond	Deep Run	Flat Branch	
Newark Supergroup	×	×	×	Late-Middle Triassic.
Chesterfield Group	×			Late Triassic.
Otterdale Sandstone	×			Do.
Vinita beds	×			Do.
Tuckahoe Group	×	×	×	Late-Middle Triassic.
productive coal measures	×	×	×	Do.
Boscabel boulder beds	×			Do.
lower barren beds	×			Middle Triassic.

drilled along the regional strike to the northeast in Caroline and King George Counties, Va., and Charles County, Md., suggest that the basin may extend to the northeast into southern Maryland for a distance of at least 48 km beneath Tertiary and Quaternary Atlantic Coastal Plain sediments. Correlations by Weems (1980a), based on work by Cornet (1977), show that the Taylorsville and Richmond basins may have been connected by rivers or lowlands during the last half of their preserved depositional history.

The Taylorsville basin is in fault contact with Precambrian gneiss to the northwest, unconformably overlies the Petersburg Granite to the south, and is unconformably overlain by younger Atlantic Coastal Plain sediments to the east. The southern and eastern margins may be, in part, fault contacts. Both the Taylorsville and the Richmond basins are bordered on the northwest by the Hylas zone, a late Paleozoic thrust fault zone composed of cataclastic rocks. The Hylas zone was reactivated and became a normal border fault zone in both early Mesozoic and Tertiary times (Goodwin and others, 1985). Most of the other faults in the basins parallel the Hylas zone and also may represent reactivation of preexisting faults (Weems, 1980a). The basin contains northwestward-dipping sedimentary rocks including fluvial conglomerate and sandstone, lacustrine siltstone and black shale, rare coal beds of Late Triassic and possibly Middle Triassic age (Traverse, 1987), and a few diabase dikes of Early Jurassic age. Palynomorphs, possibly Permian, have been found mixed with a typical Late Triassic assemblage. This mixing suggests that unidentified pre-Late Triassic materials may have been reworked and incorporated into the strata of the Taylorsville basin (Robbins and Weems, 1988). The basin has been studied by Weems (1980a, b, 1981) and Johnson, Wilkes, and Gwin (1985). The stratigraphic nomenclature of the Taylorsville basin is shown in table 4.

TABLE 4.—*Present stratigraphic nomenclature of the Taylorsville basin (Weems, 1980a)*

Stratigraphic unit	Taylorsville basin	Age
Newark Supergroup	×	Late-Middle(?) Triassic.
Doswell Formation	×	Do.
Newfound Member	×	Late Triassic.
Falling Creek Member	×	Do.
Stagg Creek Member	×	Late-Middle(?) Triassic.

SCOTTSVILLE BASIN

The Scottsville basin, named for the town of Scottsville, Albemarle County, Va., lies about 40 km southwest of the Culpeper basin in Albemarle, Buckingham, and Nelson Counties. The basin is about 34 km long, has a maximum width of 6 km, and has an area of about 130 km^2. The basin is a northeast-trending half graben, bounded along the west side by a normal fault. A sequence of slightly metamorphosed lithic breccia and greenstone conglomerate interlayered with metamorphosed greenstone is located on the western side of the basin. In places, this unit is in contact with older metamorphic rocks, and, in other places, the unit is in contact with Late Triassic shale and siltstone. The age of the greenstone conglomerate and breccia unit is uncertain. Along the eastern border of the basin, westward-dipping sandstone, siltstone, shale, and conglomerate of Late Triassic age lie nonconformably on older metamorphic rocks. Diabase dikes of Early Jurassic age are present. The basin has been described and mapped by Johnson, Wiener, and Conley (1985).

BARBOURSVILLE BASIN

The Barboursville basin was named for the town of Barboursville, Orange County, Va., by Lee (1980). Occupying an area of about 51 km^2, the basin is 16 km long and 4 km wide and lies mostly in Orange County but extends south into Albemarle County. The basin is a small fault-bounded trough separated from the Culpeper basin to the northeast by 2.5 km of Precambrian metamorphic rocks. The basin contains Late Triassic continental clastic rocks related to those of the Culpeper basin. The geology of the basin has been studied by Lee (1977) and Lee and Froelich (1989). The stratigraphic nomenclature of the Barboursville basin is shown in table 5.

CULPEPER BASIN

The Culpeper basin was named for the town of Culpeper, Culpeper County, Va., where the rocks are well exposed. The name was first

TABLE 5.—*Present stratigraphic nomenclature of the Barboursville and Culpeper basins (Lee and Froelich, 1989)*

Stratigraphic unit	Basin		Age
	Barboursville	Culpeper	
Newark Supergroup	×	×	Early Jurassic, Late Triassic.
Culpeper Group	×	×	Do.
Waterfall Formation		×	Early Jurassic.
Millbrook Quarry Member		×	Do.
Sander Basalt		×	Do.
Turkey Run Formation		×	Do.
Hickory Grove Basalt		×	Do.
Midland Formation		×	Do.
Mount Zion Church Basalt		×	Do.
Catharpin Creek Formation		×	Early Jurassic, Late Triassic.
Goose Creek Member		×	Do.
Tibbstown Formation	×	×	Late Triassic.
Mountain Run Member		×	Do.
Haudricks Mountain Member	×		Do.
Balls Bluff Siltstone	×	×	Do.
Leesburg Member		×	Do.
Manassas Sandstone	×	×	Do.
Poolesville Member	×	×	Do.
Tuscarora Creek Member		×	Do.
Reston Member		×	Do.
Rapidan Member	×	×	Do.

published in the Tectonic Map of the United States by the National Research Council (1944). The basin occupies a north-northeast-trending half graben, about 185 km long, 15 km wide, and 2,750 km^2 in area. Located in northern Virginia and central Maryland, the basin is generally aligned with the structural grain of the surrounding crystalline rocks of the Piedmont. The basin extends from northwest of the town of Orange through parts of Orange, Madison, Culpeper, Fauquier, Prince William, Fairfax, and Loudoun Counties in Virginia, across the Potomac River into Montgomery and Frederick Counties in Maryland, and terminates southwest of the city of Frederick.

The basin is bordered on the west by a major high-angle, normal fault zone that forms the boundary between west- and northwest-dipping Mesozoic strata and folded and faulted east-dipping Precambrian and lower Paleozoic crystalline and sedimentary rocks. The basin is bordered on the east by a regional unconformity cut by normal faults of relatively minor displacement. Gentle folds, strike-slip faults, and the structurally uplifted cross-faulted area known as "The Ridge" are present within the basin. The basin contains fluvial and lacustrine clastic sedimentary rocks of Late Triassic and Early Jurassic age, intercalated with at least three major flow sequences of basaltic rocks of Early Jurassic age, and is intruded by Early Jurassic diabase dikes and sheets. Studies of the Culpeper basin have been made by Roberts (1928), Cornet (1977), Lee (1977, 1979, 1980), Lindholm (1979), and Lee and Froelich (1989). The present stratigraphic nomenclature of the Culpeper basin is shown in table 5. Figure 2 shows the evolution of the lithostratigraphic nomenclature of the basin.

GETTYSBURG BASIN AND THE NARROW NECK OF THE NEWARK-GETTYSBURG BASIN

The Gettysburg basin is named for the town of Gettysburg, Adams County, Pa. The first published use of the term Gettysburg basin was in the Tectonic Map of the United States (National Research Council, 1944). The Gettysburg basin, separated from the Culpeper basin by a 1.6-km-wide stretch of Paleozoic rocks in a cross-faulted area in southern Frederick County, Md., is a northeast-trending half graben that extends from Frederick County through Carroll County, Md., to Adams, York, and Dauphin Counties, Pa. The basin is about 130 km long, has a maximum width of 35 km, and covers an area of about 2,560 km^2.

Because the Gettysburg and Newark basins are connected, they have been referred to in the literature as the Newark-Gettysburg basin. A 60-km-long by 8- to 16-km-wide structurally uplifted and cross-faulted belt of conglomerate and sandstone, located in Lebanon, Lancaster, and Berks Counties, connects the basins. This belt was described by Glaeser (1963) as the narrow neck of the Newark-Gettysburg basin. The older stratigraphic nomenclature of the Newark basin, first applied to the rocks in New Jersey by Kümmel (1897), had, through the years, been extended southwestward into the narrow neck area. Stose and Bascom (1929) described and named the rocks in the Gettysburg area of Adams County, noting their equivalence to Newark Group rocks in eastern Pennsylvania and New Jersey. The Gettysburg basin nomenclature was subsequently extended eastward in the narrow neck to the Schuylkill River area where the Newark basin nomenclature is used. The traditional separation between the Gettysburg Formation and the Brunswick Formation of the Newark basin was near the Morgantown sheet, an irregularly shaped, northwest-trending diabase body near the Lancaster-Berks County line (Glaeser, 1963). The boundary between the underlying New Oxford and Stockton Formations was in the area of Terre Hill, Lancaster County. Glaeser (1963) defined the boundaries of the narrow neck on the basis of lithologic distinctions used as arbitrary cutoffs at the Dauphin-Lebanon County line to the west and at a line drawn in the vicinity of the Schuylkill River to the east. He renamed the

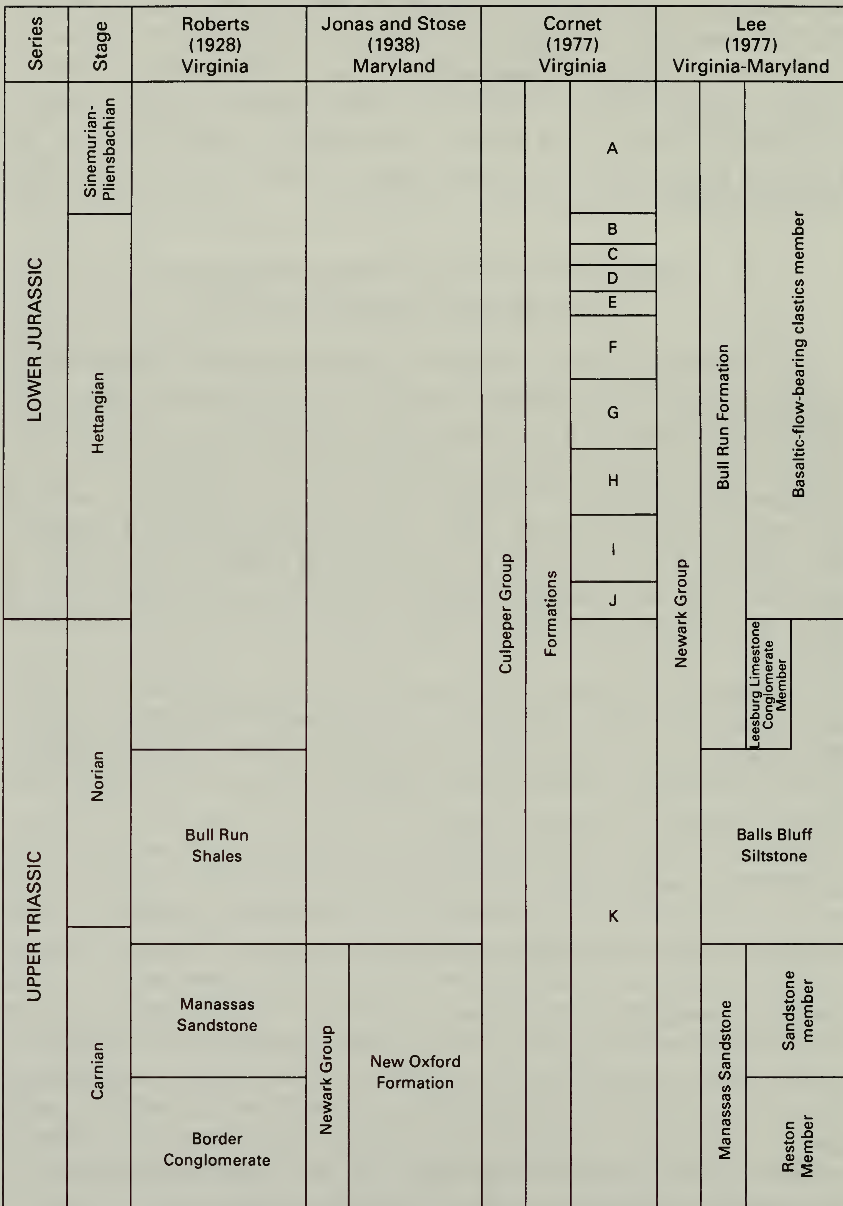


FIGURE 2.—Evolution of the Newark Supergroup lithostratigraphic nomenclature of the Culpeper and Barboursville basins, Virginia and Maryland (modified from Lee and Froelich, 1989).

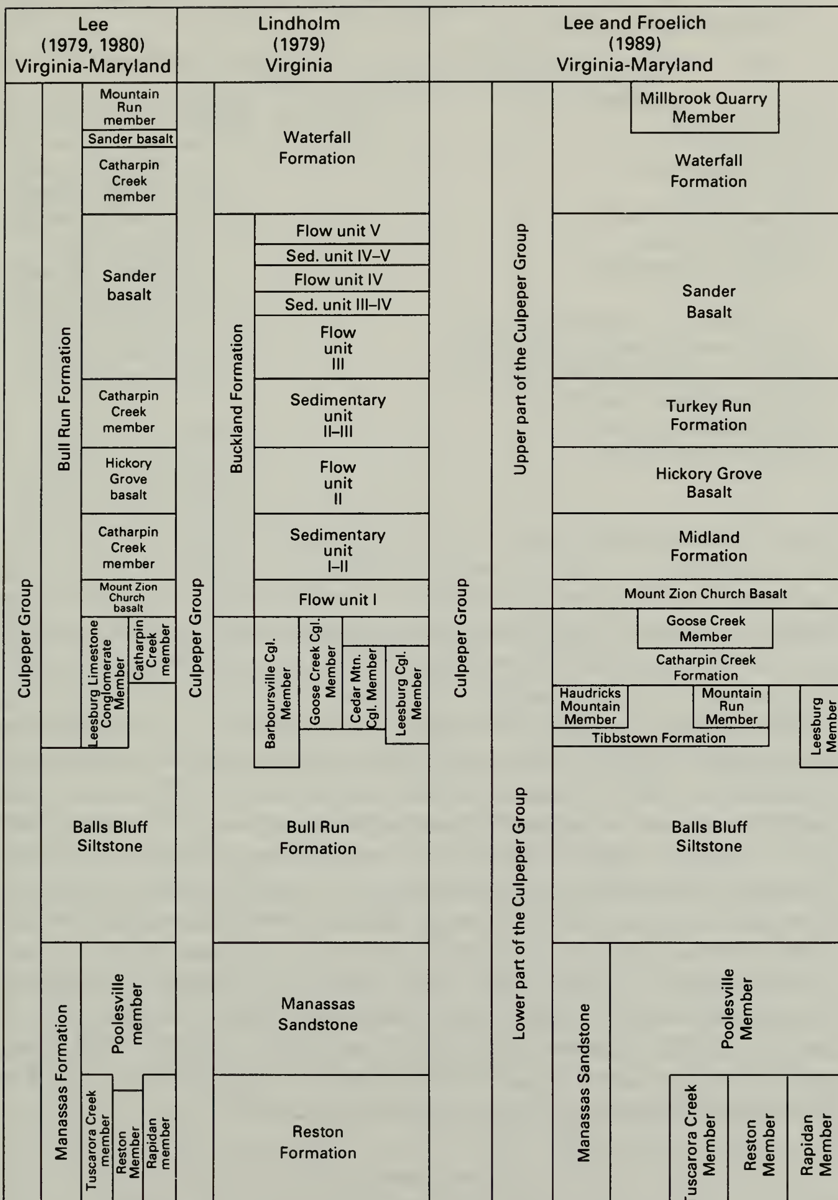


FIGURE 2.—Continued.

TABLE 6.—*Present stratigraphic nomenclature of the Gettysburg basin and the narrow neck of the Newark-Gettysburg basin (Stose and Bascom, 1929; Berg and others, 1983)*

Stratigraphic unit	Basin		Age
	Gettysburg	Narrow neck	
Newark Supergroup	×	×	Early Jurassic, Late Triassic.
Gettysburg Formation	×		Early Jurassic.
Basalt at Aspers	×		Do.
Gettysburg Formation	×		Early Jurassic, Late Triassic.
Arendtsville Fanglomerate Lentil	×		Do.
Heidlersburg Sandstone Member	×		Late Triassic.
Conewago Conglomerate Member	×		Do.
Hammer Creek Formation		×	Do.
New Oxford Formation	×	×	Do.
Stockton Formation		×	Do.

coarse clastic rocks, typical of neither the Gettysburg nor Brunswick Formations in the narrow neck, the Hammer Creek Formation. He restricted the Gettysburg Formation to rocks west of the cutoff at the Dauphin-Lebanon County line and the Brunswick Formation to rocks east of the Schuylkill River cutoff. The New Oxford and Stockton Formations were not changed.

The Gettysburg basin is bordered on the northwest by discontinuous high-angle, normal faults controlled by reactivation of Paleozoic faulting (MacLachlan, 1983). Triassic rocks unconformably overlie Precambrian and Paleozoic rocks on the southeast side of the basin. The Gettysburg basin contains mainly Late Triassic sedimentary rocks cut by Early Jurassic intrusive diabase dikes and sills. A small Early Jurassic basalt flow has been reported at Aspers in Adams County (Stose and Bascom, 1929). Strata above the basalt are dated by palynomorphs as Early Jurassic (Cornet, 1977). The Gettysburg basin has been studied by Stose and Bascom (1929), Stose and Jonas (1939), McLaughlin and Gerhard (1953), Glaeser (1963, 1966), and Cornet (1977). The stratigraphic nomenclature of the Gettysburg basin and the narrow neck of the Newark-Gettysburg basin is shown in table 6.

NEWARK BASIN

The Newark basin is named for the city of Newark, N.J., where the "New Red Sandstone," common to all the Mesozoic basins in eastern North America, was first described and given the name Newark Group by W.C. Redfield in 1856. The Newark basin extends from Lancaster County, Pa., through Berks, Chester, Montgomery, Bucks, and Lehigh Counties, Pa., and Hunterdon, Somerset, Middlesex, Bergen, and

TABLE 7.—*Present stratigraphic nomenclature of the Newark basin (Lyttle and Epstein, 1987)*

Stratigraphic unit	Newark basin			Age
	Pennsylvania	New Jersey	New York	
Newark Supergroup	×	×	×	Early Jurassic, Late Triassic.
Brunswick Group	×	×	×	Do.
Boonton Formation		×		Early Jurassic.
Hook Mountain Basalt		×		Do.
Towaco Formation		×		Do.
Preakness Basalt		×	×	Do.
Feltville Formation		×		Do.
Orange Mountain Basalt		×	×	Do.
Jacksonwald Basalt	×			Do.
Passaic Formation		×	×	Early Jurassic, Late Triassic.
Perkasie Member	×	×		Late Triassic.
Graters Member	×	×		Do.
Lockatong Formation	×	×		Do.
Stockton Formation	×	×	×	Do.

Passaic Counties, N.J., to Rockland County, N.Y. The basin is about 200 km long, has a maximum width of about 50 km along the Delaware River, and has an area of about 7,000 km^2.

The basin is a northeast-trending half graben bordered on the northwest by a series of right-oblique normal faults controlled by the reactivation of Paleozoic ramps and thrusts (Ratcliffe and Burton, 1985). On the southeast side of the basin, Triassic rocks unconformably overlie Precambrian and Paleozoic metamorphic rocks and are unconformably overlain in places by younger Atlantic Coastal Plain sediments. At the southwest end, the Newark basin is connected to the Gettysburg basin by the narrow neck, an uplifted and cross-faulted belt of clastic rocks, which is described in the section on the Gettysburg basin. The sedimentary rocks in the Newark basin range from Late Triassic to Early Jurassic (Olsen, 1980b), are interbedded with three basalt flows of Early Jurassic age, and are intruded by Early Jurassic diabase dikes and sills that may be related to the flows. Major studies of the Newark basin include Kümmel (1897), Darton (1890), McLaughlin (1959), and Olsen (1980b). The stratigraphic nomenclature of the Newark basin is shown in table 7. The evolution of the lithostratigraphic nomenclature of the basin is shown on figure 3.

CONNECTICUT VALLEY BASIN

The term Connecticut Valley basin has been used to describe the entire fault-bounded trough, filled with early Mesozoic rocks, that

<table>
<tr><th>SERIES</th><th>Lyman (1895) Pennsylvania</th><th>Kümmel (1987) New Jersey Bascom and others (1909) Pennsylvania</th><th>Darton and others (1908), Bayley and others (1914) New Jersey-New York</th><th colspan="2">Olsen (1980b), Lyttle and Epstein (1987) New Jersey-New York</th><th colspan="2">Lyttle and Epstein (1987) Pennsylvania</th></tr>
<tr><td rowspan="7">LOWER JURASSIC</td><td rowspan="3">Pottstown Shales</td><td rowspan="8">Brunswick Shale</td><td>Brunswick Formation</td><td rowspan="8">Brunswick Group</td><td>Boonton Formation</td><td colspan="2" rowspan="5"></td></tr>
<tr><td>Third Watchung Basalt</td><td>Hook Mountain Basalt</td></tr>
<tr><td>Brunswick Formation</td><td>Towaco Formation</td></tr>
<tr><td rowspan="3">Perkasie Shales</td><td>Second Watchung Basalt</td><td>Preakness Basalt</td></tr>
<tr><td rowspan="2">Brunswick Formation</td><td rowspan="2">Feltville Formation</td></tr>
<tr><td rowspan="3">Brunswick Group</td><td>Upper part</td></tr>
<tr><td rowspan="2">Lansdale Shales</td><td>First Watchung Basalt</td><td>Orange Mountain Basalt</td><td>Jacksonwald Basalt</td></tr>
<tr><td rowspan="3">UPPER TRIASSIC</td><td>Brunswick Formation</td><td>Passaic Formation</td><td>Lower part</td></tr>
<tr><td>Gwynedd Shales</td><td>Lockatong Formation</td><td>Lockatong Formation</td><td colspan="2">Lockatong Formation</td><td colspan="2">Lockatong Formation</td></tr>
<tr><td>Norristown Shales</td><td>Stockton Formation</td><td>Stockton Formation</td><td colspan="2">Stockton Formation</td><td colspan="2">Stockton Formation</td></tr>
</table>

FIGURE 3.—Evolution of the Newark Supergroup lithostratigraphic nomenclature of the Newark basin, Pennsylvania, New Jersey, and New York.

extends for more than 160 km from Long Island Sound in Connecticut to northern Massachusetts. The basin is divided, from south to north, into the Pomperaug (Southbury) basin, the Cherry Brook outlier, the Hartford basin, the Deerfield basin, and the Northfield basin.

POMPERAUG (SOUTHBURY) BASIN

The Pomperaug (Southbury) basin, first named Pomperaug Valley by Hobbs (1901), extends along the Pomperaug River between South

TABLE 8.—*Present stratigraphic nomenclature of the Pomperaug basin, Cherry Brook outlier, and Hartford basin (Zen and others, 1983; Rodgers, 1985)*

Stratigraphic unit	Pomperaug basin	Cherry Brook outlier	Hartford basin	Age
Newark Supergroup	×	×	×	Early Jurassic, Late Triassic.
Portland Formation	×		×	Early Jurassic.
Hampden Basalt	×		×	Do.
Granby Basaltic Tuff			×	Do.
East Berlin Formation	×		×	Do.
Holyoke Basalt	×		×	Do.
Shuttle Meadow Formation	×		×	Do.
Talcott Basalt	×		×	Do.
Hitchcock Volcanics			×	Do.
New Haven Arkose	×	×	×	Early Jurassic, Late Triassic.

Britain, Southbury, and Woodbury in New Haven and Litchfield Counties, Conn. The basin is about 14 km long, averages about 3.2 km wide, and has an area of about 36 km^2 (Platt, 1957). The basin is a half graben, bordered by a fault along the eastern margin. The basin contains the same stratigraphic sequence of sedimentary and basalt units as the Hartford basin, although corresponding units are much thinner in this basin (Cornet, 1977; Weddle and Hubert, 1983). The present stratigraphic nomenclature of the Pomperaug basin is shown in table 8.

CHERRY BROOK OUTLIER

The Cherry Brook outlier, which has also been called the Cherry Valley or the Canton Center outlier (Kaye, 1983; Weddle and Hubert, 1983), is a small erosional remnant that lies about 1.6 km west of the Hartford basin. Late Triassic rocks crop out along Cherry Brook for a distance of about 0.8 km between Canton Center and North Canton in Hartford County, Conn. The outlier covers an area of about 0.7 km^2 in a depression in older crystalline rocks and is bordered on the east by a fault (Platt, 1957). The present stratigraphic nomenclature of the Cherry Brook outlier is shown in table 8.

HARTFORD BASIN

The Hartford basin is named for the Hartford, Conn., area. The Hartford basin extends through the Connecticut River valley from Long Island Sound through New Haven, Middlesex, and Hartford Counties, Conn., and Hampden and Hampshire Counties, Mass. The basin is about 130 km long, has a maximum width of about 35 km, and has an area of about 3,400 km^2. The Hartford basin is connected to the Deerfield basin to the north by a structurally uplifted 5-km-wide narrow neck of Mesozoic sedimentary rocks in the area of Hadley and South Amherst (Chandler, 1978). An arbitrary cutoff drawn at the neck restricts Hartford basin stratigraphic nomenclature to rocks south of the cutoff and Deerfield basin stratigraphic nomenclature to rocks north of the cutoff.

The Hartford basin is a north-trending half graben unconformably bounded by older igneous and regionally metamorphosed rocks. The basin is bordered on the east by west-dipping normal faults. Although generally an unconformable contact, much of the western margin is also bordered by faults. Erosion has isolated a small outlying basin to the west, the Cherry Brook outlier (Rodgers, 1968). The Hartford basin contains 6.4 to 11 km of continental clastic rocks of Late Triassic and Early Jurassic, and possibly Middle Jurassic, age (Cornet and Olsen, 1985) interbedded with Early Jurassic basalt flows and intruded by Early Jurassic diabase dikes and sills (LeTourneau, 1985). Studies of the geology of the Hartford basin were made by Percival (1842), Davis (1898), Emerson (1891, 1898a, b, 1917), Krynine (1950), and Sanders (1963, 1968). The present stratigraphic nomenclature of the Hartford basin is shown in table 8. The evolution of the lithostratigraphic nomenclature of the Hartford basin is shown on figure 4.

DEERFIELD BASIN

The Deerfield basin, named for the town of Deerfield, Franklin County, Mass., extends from Hadley and South Amherst in Hampshire County north to the area of Gill and Bernardston in Franklin County, Mass. The basin is about 30 km long, is 12 km wide, and has an area of about 350 km^2. The Deerfield basin is connected to the north end of the Hartford basin by a 5-km-wide narrow neck of Mesozoic sedimentary rocks in the area of Hadley and South Amherst. The narrow neck reflects the influence of an uplifted area of early Paleozoic rocks (Chandler, 1978). An arbitrary cutoff restricts Deerfield basin nomenclature to rocks north of the neck.

The basin is a half graben bordered along the eastern margin by a west-dipping normal fault and is unconformably bounded on the west by early Paleozoic metamorphic rocks. The Deerfield basin contains an interrupted sedimentary sequence and one basalt flow sequence, which is correlative with the Holyoke Basalt in the Hartford basin. An unconformity in the Jurassic section (Cornet, 1977) represents a hiatus that is equivalent to a large portion of the Jurassic section in the Hartford basin and includes the time of eruption of the Hampden Basalt and the Granby Basaltic Tuff (Robinson and Luttrell, 1985). The rocks

<table>
<tr><th>SERIES</th><th>Percival (1842) Connecticut</th><th>Davis (1898) Connecticut</th><th>Emerson (1898b, 1917) Connecticut Massachusetts</th><th colspan="2">Krynine (1950) Connecticut</th><th>Lehmann (1959) Connecticut</th><th colspan="2">Sanders (1968) Connecticut</th><th colspan="2">Zen and others (1983) Massachusetts</th><th>Rodgers (1985) Connecticut</th></tr>
<tr><td rowspan="6">LOWER JURASSIC</td><td>Eastern sandstone</td><td>Upper sandstone</td><td>Chicopee Shale
Longmeadow Sandstone
Sugarloaf Arkose</td><td colspan="2">Portland Arkose</td><td>Portland Arkose</td><td colspan="2">Portland Arkose</td><td colspan="2">Portland Formation</td><td>Portland Formation</td></tr>
<tr><td rowspan="5">Middle shale</td><td>Posterior trap sheet</td><td>Hampden Diabase</td><td rowspan="5">Meriden Formation</td><td>Upper lava flow</td><td>Hampden Basalt</td><td rowspan="5">Meriden Group</td><td>Hampden Basalt</td><td>Hamp-den Basalt</td><td>Granby Basaltic Tuff</td><td>Hampden Basalt</td></tr>
<tr><td>Posterior shales</td><td>Longmeadow Sandstone</td><td>Upper sedimentary division</td><td>East Berlin Formation</td><td>East Berlin Formation</td><td colspan="2">East Berlin Formation</td><td>East Berlin Formation</td></tr>
<tr><td>Main trap sheet</td><td>Holyoke Diabase</td><td>Middle lava flow</td><td>Holyoke Basalt</td><td>Holyoke Basalt</td><td colspan="2">Holyoke Basalt</td><td>Holyoke Basalt</td></tr>
<tr><td>Anterior shale and sandstone</td><td>Longmeadow Sandstone
Sugarloaf Arkose</td><td>Lower sedimentary division</td><td>Shuttle Meadow Formation</td><td>Shuttle Meadow Formation</td><td colspan="2">Shuttle Meadow Formation</td><td>Shuttle Meadow Formation</td></tr>
<tr><td>Anterior trap sheet</td><td>Talcott Diabase (Connecticut only)</td><td>Lower lava flow</td><td>Talcott Basalt</td><td>Talcott Basalt</td><td></td><td>Hitch-cock Vol-canics</td><td>Talcott Basalt</td></tr>
<tr><td>UPPER TRIAS-SIC</td><td>Western sandstone</td><td>Lower sandstone</td><td>Longmeadow Sandstone
Sugarloaf Arkose</td><td colspan="2">New Haven Arkose</td><td>New Haven Arkose</td><td colspan="2">New Haven Arkose</td><td colspan="2">New Haven Arkose</td><td>New Haven Arkose</td></tr>
</table>

FIGURE 4.—Evolution of the Newark Supergroup lithostratigraphic nomenclature of the Hartford basin, Connecticut and Massachusetts (modified from Lehmann, 1959).

TABLE 9.—*Present stratigraphic nomenclature of the Deerfield and Northfield basins (Zen and others, 1983)*

Stratigraphic unit	Basin		Age
	Deerfield	Northfield	
Newark Supergroup	×	×	Early Jurassic, Late Triassic.
Mount Toby Formation	×		Early Jurassic.
Turners Falls Sandstone	×	×	Do.
Deerfield Basalt	×		Do.
Sugarloaf Formation	×		Early Jurassic, Late Triassic.

range from Late Triassic to Early Jurassic (Robinson and Luttrell, 1985). The stratigraphic nomenclature of the Deerfield basin is shown in table 9.

NORTHFIELD BASIN

The Northfield basin, named for the town of Northfield, Franklin County, Mass., is about 4.8 km long, is 1.6 km wide, and has an area of about 7.5 km^2. The basin is bordered on the east by a continuation of the border fault of the Deerfield basin, from which the Northfield is separated by about 1.6 km of early Paleozoic metamorphic rocks. Sandstone and conglomerate are the only early Mesozoic rocks present in the basin. A.J. Froelich (U.S. Geological Survey, oral commun., 1988) believes that the age of the rocks may be Late Triassic, rather than Early Jurassic, as mapped by Zen and others (1983). The present stratigraphic nomenclature of the Northfield basin is shown in table 9.

MIDDLETON BASIN

The Middleton basin in Essex County, Mass., was named for the nearby town of Middleton by Kaye (1983). Oldale (1962) described fragments of unmetamorphosed red arkose and shale, probably of Triassic age, in glacial drift in the northern part of the Salem quadrangle. Oldale predicted the presence of a body of Triassic rocks buried beneath the glacial deposits near the northwest corner of the quadrangle. The Middleton basin lies in the northwest part of the Salem quadrangle and the northeast part of the Reading quadrangle. The basin is about 5.7 km long, has a maximum width of 0.5 km, and has an area of about 2.5 km^2. The basin is downfaulted on the southeastern border by a normal fault. Red conglomerate, arkose, and fossiliferous shale of Late Triassic age, intruded by Early Jurassic(?) diabase dikes, are exposed in a quarry at Peabody, Mass. Elsewhere the rocks are covered by glacial drift.

FUNDY BASIN

The Fundy basin is named for the Bay of Fundy, which lies between the Provinces of Nova Scotia and New Brunswick in Canada. The Fundy basin was named by Bell (1958), who included in his definition of the basin a much larger area of Carboniferous deposits that extend northeastward across the Gulf of St. Lawrence and into Newfoundland (Belt, 1968). The part of the Bay of Fundy in which the Mesozoic rocks are found was described as the Acadian area by Powers (1916), who stated that the original form of the area appeared to have been a basin that had a northern limit near the Cobequid Mountains and a southern limit south of Grand Manan and Brier Islands. Tagg and Uchupi (1966) defined the Acadian basin to include the floor of the Bay of Fundy and three narrow troughs separated by Paleozoic basement highs in the Gulf of Maine. The Fundy basin was called the Maritime basin by Ballard and Uchupi (1972).

The Fundy basin contains scattered outcrops of Mesozoic conglomerate, sandstone, shale, mudstone, and basalt flows. Remnants of Middle and Late Triassic sedimentary rocks form small crescent-shaped outcrops, 2 to 5 km long and 2 to 3 km wide, along the New Brunswick shore at Maces Bay, Saint John, St. Martins, Martins Head, and Waterside in Chignecto Bay. In Nova Scotia, Late Triassic and Early Jurassic rocks crop out from Brier Island to Truro, at the northeastern end of the Minas Basin, for a length of about 290 km, a width of as much as 40 km at the mouth of the Minas Basin, and an area of about 3,300 km^2. Sedimentary rocks are found in the Annapolis Valley and on the borders of the Minas Basin. Three small outcrops of Late Triassic sedimentary rocks that occur along the Chedabucto Bay in northeastern Nova Scotia may be related to the Fundy basin. Early Jurassic volcanic rocks are found on Grand Manan Island, New Brunswick, and along the Nova Scotia coast of the Bay of Fundy from Brier Island to the mouth of the Minas Basin.

Seismic profiles taken across the Bay of Fundy show that Mesozoic rocks unconformably overlie Carboniferous rocks and form a broad synclinal structure that has an axis plunging gently southwestward toward the Gulf of Maine (Ballard and Uchupi, 1975). The basin is genetically similar to other early Mesozoic basins in eastern North America and was formed at the edge of a reactivated Paleozoic basement thrust fault (D.E. Brown, Amoco Oil Canada, Ltd., written commun., 1987). Studies of the Fundy basin have been made by Powers (1916), Klein (1962), and Nadon and Middleton (1985). The stratigraphic nomenclature of the Fundy basin is shown in table 10.

TABLE 10.—*Present stratigraphic nomenclature of the Fundy basin at Maces Bay, St. Martins, Nova Scotia, and Chedabucto Bay (Klein, 1962; Donohoe and Wallace, 1982; Nadon and Middleton, 1985)*

Stratigraphic unit	Fundy basin				Age
	Maces Bay	St. Martins	Nova Scotia	Chedabucto Bay	
Newark Supergroup	×	×	×	×	Early Jurassic, Late-Middle Triassic.
Fundy Group	×	×	×	×	Do.
McCoy Brook Formation			×		Early Jurassic.
Scots Bay Formation			×		Do.
North Mountain Basalt			×		Do.
Blomidon Formation			×		Early Jurassic, Late Triassic.
Wolfville Formation			×		Late-Middle Triassic.
Chedabucto Formation				×	Late Triassic.
Lepreau Formation	×				Late-Middle Triassic.
Echo Cove Formation		×			Do.
Melvin Beach Member		×			Late Triassic.
Fownes Head Member		×			Late-Middle Triassic.
Stony Brook Member		×			Do.
Berry Beach Member		×			Middle Triassic.
Quaco Formation		×			Do.
Honeycomb Point Formation		×			Do.
McCumber Point Member		×			Do.
Browns Beach Member		×			Do.

DEVELOPMENT OF THE NOMENCLATURE

The term Newark Group was proposed by W.C. Redfield in 1856 as a convenient name for the New Jersey sandstones, as well as the "New Red Sandstone" (Rogers, 1842), of the Connecticut valley, Pennsylvania, Maryland, Virginia, and North Carolina. Merrill and others (1902) revised the Newark Group to include basalt flows interbedded with the sedimentary rocks. The rank of the Newark was raised to Supergroup by Van Houten (1977), redefined by Olsen (1978), and revised by Froelich and Olsen (1984) as a formal assemblage of related groups and formations (North American Commission on Stratigraphic Nomenclature, 1983, North American Stratigraphic Code, art. 29). Close lithologic and structural relations are implied through the use of the supergroup designation, and the usage is restricted to rocks that crop out in the exposed early Mesozoic basins. In basins containing basalt flows, the Late Triassic and Early Jurassic clastic rocks beneath the lowest basalt flow have been informally designated as the lower Newark Supergroup; the overlying Early Jurassic basalt flows and interbedded clastic rocks have been designated as the upper Newark Supergroup (Lyttle and Epstein, 1987; Lee and Froelich, 1989).

Groups are defined as expressing the natural relations of associated formations and are useful in small-scale mapping (North American Commission on Stratigraphic Nomenclature, 1983, North American Stratigraphic Code, art. 28). The group rank has been used in two ways in Newark Supergroup basins. Groups have been used to emphasize the common origin and relations of all the Mesozoic rocks in one basin or in several closely related basins. Examples of this usage are the Chatham Group in the Deep River basin, which includes the Wadesboro, Sanford, and Durham subbasins, the Dan River Group in the Dan River-Danville basin, the Culpeper Group in the Culpeper and Barboursville basins, and the Fundy Group in the Fundy basin. The group rank also has been used to set apart some of the more closely related formations within a basin from other formations in the same basin. Examples are the Tuckahoe and Chesterfield Groups in the Richmond basin, separating the rocks of the lower coal-bearing units from the overlying barren units, and the Brunswick Group in the Newark basin, including and setting apart the younger sedimentary units and interbedded basalt flows from the older sedimentary units.

The fundamental lithostratigraphic unit is the formation, which is identified and mapped on the basis of lithic characteristics and stratigraphic position. A member is the lithostratigraphic unit next in rank below a formation and is recognized as a named entity within a formation possessing characteristics distinguishing it from adjacent parts of the formation (North American Commission on Stratigraphic Nomenclature, 1983, North American Stratigraphic Code, arts. 24, 25). Recent studies and reinterpretations of the origin, structure, and relations of the sedimentary and basalt units of the Newark Supergroup have resulted in revisions of the nomenclature at the formation and member levels. In the Newark and Culpeper basins, where sedimentary rocks are interbedded with basalt flows, the rocks of each class were originally described as single, large units. In the Newark basin, the Brunswick Formation of Kümmel (1897) included all the sedimentary rocks above the Lockatong Formation but excluded the interbedded basalts. The basalts were grouped together into one basalt unit, the Watchung Basalt of Darton (1890). Recent work by Olsen (1980b) has led to the revision of the Brunswick and Watchung into seven formations, each having a distinctive lithology. Recent mapping in the Culpeper and Barboursville basins by Lee and Froelich (1989) has produced similar revisions of the nomenclature. This work has resulted in the recognition and naming of three basalt units and three interbedded sedimentary units. The stratigraphic usage of these correlative parts of the section in the Culpeper and Newark basins is now consistent with the usage in the Hartford and Deerfield basins in Connecticut and

Massachusetts (Zen and others, 1983; Rodgers, 1985). Lee and Froelich (1989) also studied the problem of the age and stratigraphic position of conglomerates, many of which are found along the margins of the basins. The conglomerates bordering the Culpeper basin originally were assigned to a single conglomerate unit, the Border Conglomerate of Roberts (1928). The conglomerates are now recognized to be of different ages and have been remapped as members of several different formations by Lee and Froelich (1989).

PROBLEMS IN THE NOMENCLATURE

This study of Newark Supergroup stratigraphic nomenclature has revealed several problems, which are briefly described here in the hope that they may be addressed by workers in the future. The problems include the use of dual nomenclature across political boundaries (Newark, Dan River-Danville basins), differences in the manner of representing the absence of a marker bed (Dan River-Danville basin), inconsistencies in the rank of units (Taylorsville, Gettysburg basins), possible misnaming of previously described rocks (Hitchcock Volcanics, Turners Falls Sandstone), and application of a name in a manner contrary to its definition (Hammer Creek Formation).

Problems of dual nomenclature arise where artificial or political boundaries divide basins. In 1895, B.S. Lyman of the Pennsylvania Geological Survey proposed a fivefold nomenclature for the Newark sedimentary rocks in eastern Pennsylvania, and, in 1897, H.B. Kümmel of the New Jersey Geological Survey proposed a different threefold nomenclature for the Newark sedimentary rocks east of the Delaware River in New Jersey. Around 1900, U.S. Geological Survey (USGS) geologists started mapping quadrangles on both sides of the Delaware River. N.H. Darton was using Kümmel's nomenclature in the Passaic quadrangle, and Florence Bascom was using Lyman's nomenclature in the Philadelphia quadrangle (Bascom, 1904). Darton and others (1908) used the New Jersey nomenclature for the Passaic folio. Bascom and others (1909) then used the New Jersey nomenclature in the Philadelphia folio, thus averting much future confusion. Even though the Pennsylvania nomenclature was described earlier, the New Jersey nomenclature was found to be more applicable to the rocks and has withstood the test of time. Similar nomenclatural problems across State lines presently exist in the Newark and Dan River-Danville basins. Recent mapping in New Jersey (Olsen, 1980b; Lyttle and Epstein, 1987) has resulted in the division of the Brunswick Formation of Kümmel (1897) into four formations and in the elevation of the Brunswick to group rank. The Brunswick has been redefined to include four sedimentary and three interbedded basalt units (the Watchung Basalt of

Darton, 1890), and this usage is widely accepted. The terms Brunswick Group undivided or Brunswick Formation are used in Pennsylvania.

In the Dan River-Danville basin, the nomenclature of Meyertons (1963) for the Danville basin in Virginia was revised and extended by Thayer (1970b) into the Dan River basin in North Carolina. Thayer (1977) later used this revised nomenclature in Virginia, but he neglected to abandon the parts of Meyertons' nomenclature that he did not use. Specific problems are the Leakesville Formation and its Cascade Station Member, mapped by Thayer (1980b) as the siltstone facies of the Pine Hall and Stoneville Formations. A discrepancy in the usage of the Pine Hall and Stoneville Formations, where the Cow Branch Formation is absent, is noted between the North Carolina and Virginia parts of the basin. In Virginia, the Dry Fork Formation has been defined as a name for the Pine Hall and Stoneville Formations undivided where the Cow Branch is absent, and no basis exists for distinguishing more than a single unit. In North Carolina, where the Cow Branch is absent, an arbitrary contact is drawn between the Pine Hall and Stoneville Formations. Another problem of Dan River-Danville basin nomenclature is that the name Dan River Group is applied only to the Newark Supergroup rocks in the North Carolina part of the basin, while the Newark rocks in Virginia are not assigned to a group.

An inconsistency in rank exists in the Taylorsville basin, where the entire Triassic section is assigned to a single formation. The extensive Taylorsville basin occurs in the subsurface probably for many kilometers to the northeast. The Taylorsville strata are thousands of meters thick and contain the same divisions of fluvial and lacustrine rocks that have been mapped as groups and formations in other Newark basins. The Doswell Formation is equivalent to a group in other basins, and its members are equivalent to formations.

In the Gettysburg basin, the informal basalt at Aspers is equivalent to formal basalt units in the Culpeper, Newark, and Hartford basins. Sedimentary rocks underlying and overlying the basalt at Aspers are assigned to the Gettysburg Formation and are equivalent to separately named underlying and overlying formations in the other basins. A usage consistent with that of other basins would be the division of the Gettysburg into two sedimentary units separated by the basalt unit.

A study of Hitchcock Volcanics literature (Emerson, 1898b, 1917; Bain, 1941; Balk, 1957; Brophy and others, 1967) shows that the Hitchcock, in the Hartford basin, has been described and mapped as extrusive volcanic cones related to the Holyoke Basalt and as intrusive diabase breccia. As now defined and mapped (Zen and others, 1983), the Hitchcock appears to be a hybrid of the two different rock types lumped into a single unit (A.J. Froelich, USGS, oral commun., 1988).

Barren conglomerate and sandstone units in the Northfield basin, mapped as Jurassic Turners Falls Sandstone by Zen and others (1983), may actually be Triassic Sugarloaf Formation. The structural configuration of the basin, which includes beds dipping steeply into the border fault, and the absence of the Deerfield Basalt suggest that faulting, subsidence, and deposition began in the Triassic.

Conglomerate units in the Passaic Formation in the Newark basin in New Jersey and New York have been called the Hammer Creek Formation or Conglomerate by Van Houten (1969, 1980). As now defined, the Hammer Creek includes rocks only in a specific area in the narrow neck of the Gettysburg and Newark basins in Pennsylvania.

LEXICON

The lexicon is an alphabetical list of all Newark Supergroup lithostratigraphic nomenclature, including formal names in current usage, abandoned names, and informal names. Informal nomenclature is included because it has been much used in the literature and contributes to a better understanding of the development of the nomenclature. The following information is given for each name:

- Unit name and affiliated unit of next higher rank. Bold print indicates usage accepted by the U.S. Geological Survey (USGS). A dagger, †, preceding a unit name indicates that the name is obsolete or has been abandoned.
- Most recent age assignment.
- State or province and Mesozoic basin(s) in which the unit has been mapped.
- Type section, locality, or area. Canadian geographic coordinates are shown in parentheses. Distances have been taken from original references, and so different systems of measurement have been used throughout the lexicon (see the metric conversion factors table at the end of the table of contents).
- Subunit(s).
- History, including references to papers containing original definition, revisions, redefinitions, age, usage, and other significant studies that are summarized in the lexicon. Synonyms and equivalences are noted. Data in brackets, [ ], are comments or explanatory notes by the lexicographer. Summaries of papers included in the history section are then listed chronologically. Summaries include information on original definition, revisions, redefinitions, formal and informal subdivisions, geographic distribution, lithology, adjoining units, boundaries, thickness, paleoenvironment, and age.

†Annapolis Formation of the Newark Group

Late Triassic

Nova Scotia, Fundy basin

Type locality: Outcrops on the shore of Annapolis Basin (Powers, 1916).
Subunits: Wolfville Sandstone [Member], Blomidon Shale [Member].
History: Named (Powers, 1916). Abandoned, Wolfville and Blomidon Members raised to formation rank (Klein, 1962).

Powers (1916) named sandstone exposed on the north shore of Annapolis Basin, Nova Scotia, the Annapolis Formation of the Newark Group. Consists of calcareous red beds and contains the Wolfville Sandstone [Member] at the base and the Blomidon Shale [Member] at the top. Unconformably overlies Paleozoic or older rocks; underlies North Mountain Basalt. Interbedded with the Annapolis near its top are tuff and agglomerate beds of the Five Islands Volcanics. Outcrops of red sandstone at Quaco (St. Martins), Martin Head, and Waterside, New Brunswick, were correlated with the Annapolis. At Quaco there is a conglomerate bed, the Quaco Conglomerate, in the center of lower and upper red sandstone members correlated with the Annapolis because of the basal unconformity of the Newark rocks at West Quaco. Age is Triassic.

Klein (1962) abandoned the Annapolis Formation. The Wolfville and Blomidon Members, which are lithologically distinct mappable units, were raised to formation rank.

Arendtsville Fanglomerate Lentil of the **Gettysburg Formation**

Late Triassic
Early Jurassic

Pennsylvania, Gettysburg basin

Type locality: Exposures near the town of Arendtsville, Adams County (Stose and Bascom, 1929).
History: Named, USGS usage (Stose and Bascom, 1929). Age (Berg and others, 1983).

Stose and Bascom (1929) named the Arendtsville Fanglomerate Lentil of the Gettysburg Shale. This lens of loosely cemented conglomerate near the top of the Gettysburg extends for 32 km along the border fault at the foot of South Mountain in northern Adams and York Counties, Pa. Consists of rounded cobbles and boulders of quartzite, quartz, sandstone, and aporhyolite in a matrix of red sand. Maximum thickness is 150 m.

Berg and others (1983) showed the age of unnamed fanglomerate members near the top of the Gettysburg as Late Triassic and Early Jurassic.

Balls Bluff Siltstone of the **Culpeper Group**

Late Triassic (late Carnian, Norian)

Virginia-Maryland, Barboursville and Culpeper basins

Type section: Exposures in a gully 412 m N. 4° E. from the flag pole at the Balls Bluff National Cemetery, Waterford quadrangle, Loudoun County, Va. (Lee, 1977).
Subunit: **Leesburg Member**.

History: Named Balls Bluff Siltstone of the Newark Group, USGS usage, previously mapped as Bull Run Shales by Roberts (1928) (Lee, 1977). Revised in Culpeper Group, includes rocks mapped as New Oxford Formation by Jonas and Stose (1938), formation K by Cornet (1977), and Bull Run Formation by Lindholm (1979) (Lee and Froelich, 1989).

Lee (1977) named the Balls Bluff Siltstone of the Newark Group in the Culpeper basin. [These rocks were first mapped as Bull Run Shales by Roberts (1928).] Consists of interbedded laminated siltstone, limestone, dolomite, and sandstone. Overlies the Manassas Sandstone; underlies and intertongues with the Leesburg Limestone Conglomerate Member of the Bull Run Formation. Measured thickness at type section (incomplete) is 39 m. Age is Late Triassic.

Lee and Froelich (1989) revised the Balls Bluff Siltstone and assigned it to the Culpeper Group. Constitutes the bulk of the Upper Triassic rocks in the central Barboursville and Culpeper basins and contains rocks previously mapped as New Oxford Formation by Jonas and Stose (1938), formation K by Cornet (1977), and Bull Run Formation by Lindholm (1979). Includes the redefined Leesburg Member in the northwestern Culpeper basin. Consists of grayish and dusky-red calcareous siltstone and thin layers of gray limestone, dolomite, and fossiliferous and palyniferous gray to black mudstone and greenish-gray shale. Freshwater invertebrates, fish teeth and scales, and dinosaur tracks and bones are present locally. Gradationally overlies the Manassas Sandstone; gradationally underlies the Catharpin Creek Formation on the west side of the Culpeper basin and the Tibbstown Formation in the Barboursville basin. Thickness ranges from 80 to 1,690 m. Age is late Carnian to late Norian based on palynoflora.

†Balls Mill (or Balls Mills) Formation

Early Jurassic (Hettangian)

Virginia, Culpeper basin

Type locality: None designated.
History: Name used informally (Olsen, 1984a). [These rocks are now assigned to the Turkey Run Formation of Lee and Froelich (1989).]

Olsen (1984a) showed the Balls Mill (or Balls Mills) Formation, overlying the Hickory Grove Basalt and underlying the Sander Basalt, in a preliminary chart of formations of the Culpeper basin, Virginia. This informal name, attributed to A.J. Froelich, has been superseded by the formal name Turkey Run Formation of Lee and Froelich (1989) and should not be used for this interval of rocks.

†Barboursville Conglomerate Member of the Bull Run Formation

Late Triassic

Virginia, Barboursville basin

Type locality: None designated. Named for exposures near the original Barbour Estate (Barbour Ruins) south of Barboursville, Orange County (Lindholm, 1979).
History: Named Barboursville Conglomerate Member, previously mapped as Border Conglomerate by Roberts (1928) (Lindholm, 1979).

Abandoned, rocks assigned to Rapidan Member of the Manassas Sandstone and Haudricks Mountain Member of the Tibbstown Formation (Lee and Froelich, 1989).

Lindholm (1979) named isolated masses of conglomerate, scattered throughout the southern part of the Culpeper basin south of the Robinson River, the Barboursville Conglomerate Member of the Bull Run Formation. These rocks were included by Roberts (1928) in his schist conglomerates of the Border Conglomerate. Consists of silicate and quartzose-feldspathic clasts in a grayish-maroon matrix. Maximum thickness is 150 m. Age is Late Triassic.

Lee and Froelich (1989) abandoned the Bull Run Formation and the Barboursville Conglomerate Member, the rocks of which are assigned to two units, the Rapidan Member of the Manassas Sandstone and the Haudricks Mountain Member of the Tibbstown Formation.

Basalt at Aspers

Early Jurassic (Hettangian)

Pennsylvania, Gettysburg basin

Type locality: None designated. Exposed in a road cut 0.8 km south of Bendersville, Biglerville quadrangle, Adams County (Stose and Bascom, 1929). Named for nearby town of Aspers (Cornet, 1977).
History: Basalt near Bendersville described (Stose and Bascom, 1929). Described (Smith and others, 1975). Informally named Aspers basalt [basalt at Aspers] (Cornet, 1977). Stratigraphic position (Berg and others, 1983).

Stose and Bascom (1929) described a small sheet of basalt exposed in the road south of Bendersville, Adams County, Pa. Consists of a mixture of rounded diabase boulders in a red sandy matrix at the base, overlain by fine-grained diabase, decomposed but finely amygdaloidal in part. Believed to be a small lava flow associated with the Gettysburg diabase sill, which intrudes the Gettysburg Formation.

Smith and others (1975) described two small basalt flows of the York Haven type, 30 m thick, which occur within the northwest prong of the Gettysburg diabase sheet along the northwest border of the Gettysburg basin northwest of Heidlersburg.

Cornet (1977) named a thin basalt flow near the top of the Gettysburg Formation in the vicinity of Aspers, Pa., the informal Aspers basalt [correct informal usage is basalt at Aspers]. Above the Aspers, which may be as thick as 60 m, are strata dated as Early Jurassic on the basis of palynomorphs.

Berg and others (1983) placed the basalt at Aspers in the [informal] upper member of the Gettysburg Formation.

Berry Beach Member of the Echo Cove Formation

Middle Triassic (Ladinian)
Late Triassic (Carnian)

New Brunswick, Fundy basin

Type section: Exposures at the west end of Berry Beach on the Bay of Fundy, from the contact with the Quaco Formation to the break in the

exposure at Berry Brook, St. Martins area, Saint John County (NTS 21 H/6W) (Nadon and Middleton, 1985).
History: Named, previously mapped as upper red sandstone of Powers (1916) (Nadon and Middleton, 1985).

Nadon and Middleton (1985) named the lowest member of the Echo Cove Formation the Berry Beach Member. Equivalent to the upper red sandstone of Powers (1916) and to the entire Echo Cove Formation of Klein (1962). Consists of red sandstone, conglomerate, and shale, gradually decreasing in the redness of the sandstone. Gradationally overlies the Quaco Formation; gradationally underlies the Fownes Head Member of the Echo Cove. Thickness is 170 m. Age is Ladinian to Carnian based on palynomorphs in the Fownes Head Member.

†Black Rock Diabase

Early Jurassic

Massachusetts, Hartford basin

Type locality: Black Rock, south of Mount Holyoke, Mount Holyoke quadrangle, Hampshire County (Emerson, 1898b).
History: Named Black Rock Diabase (Emerson, 1898a). Mapped as Blackrock Diabase (Emerson, 1898b). Abandoned, rocks mapped as Hampden Diabase (Emerson, 1917). Described as Black Rock diabase breccia in Granby Tuff (Balk, 1957). [Mapped in part as Hitchcock Volcanics by Zen and others (1983).]

Emerson (1898a) named the 11th core of the newer series of volcanic cores and short dikes, exposed at Black Rock, the Black Rock Diabase. The name was used to designate the whole series of newer trap intrusions and included 12 or more cores.

Emerson (1898b) mapped the line of volcanic cores parallel with, and 1.6 km southeast of, the Holyoke Range as Blackrock Diabase. One plug is quartz diabase, the others are similar to bedded trap rock but are fresher and form domes. Intrusive into Hampden Diabase.

Emerson (1917) abandoned the Black Rock Diabase, an apparent core that had been made the type of a series of such supposed plugs, because it was found to be connected with the Hampden Diabase sheet and not an isolated intrusive plug as first described.

Balk (1957) described the Black Rock diabase breccia in the Granby Tuff. Includes a diabase breccia dike [the Blackrock Diabase of Emerson, 1898b], which extends from Dry Brook into the upper portion of the Holyoke Range south of Taylor Notch, and innumerable small scattered ledges of diabase breccia that interrupt the smooth till cover on the north slope of the Holyoke Range 1.6 km to the northeast. [The outcrops on the north slope of the Holyoke Range at Mount Hitchcock were mapped as Hitchcock Volcanics by Zen and others (1983).] The cliffs of the Black Rock dike display a complex of vesicular, irregularly cemented diabase fragments, ash, and foreign fragments penetrated by lenses of diabase that have imperfect columnar jointing. The diabase breccia contains fragments of Sugarloaf Arkose [now New Haven Arkose], apparently unconsolidated at the time of eruption (Bain, 1941), and cuts basal sediments above the Holyoke Diabase and basal members of the Granby Tuff. The diabase breccia is probably a large dike emplaced at about the same time as the pipes and dikes that cut the Granby Tuff and may mark the location of an important fissure feeder for the late [Hampden] diabase.

Blomidon Formation of the Fundy Group

Late Triassic (Norian)
Early Jurassic (Hettangian)

Nova Scotia, Fundy basin

Type locality: The section exposed between Cape Blomidon and Paddy Island, west shore of the Minas Basin, Kings County (NTS 21 H/1) (Klein, 1962).

History: Named Blomidon Shale [Member] of the Annapolis Formation (Powers, 1916). Revised Blomidon Formation of the Fundy Group, includes rocks previously mapped as Five Islands Volcanics of Powers (1916) and Tennycape Formation of Weeks (1948) (Klein, 1962). Age (Hubert and Mertz, 1980, 1984). Revised, areal restriction, partly reassigned to McCoy Brook Formation (Donohoe and Wallace, 1982).

Powers (1916) named the Blomidon Shale [Member] as the upper unit of the Annapolis Formation. Overlies the Wolfville Sandstone [Member] of the Annapolis; underlies the North Mountain Basalt. Thickness is 150 to 300 m. Age is Triassic.

Klein (1962) raised the Blomidon Shale [Member] of the abandoned (Klein, 1962) Annapolis Formation to formation rank and assigned it to the Fundy Group. Exposed only in the Annapolis-Cornwallis Valley and on the north shore of the Minas Basin, Nova Scotia. Includes a basal basalt conglomerate near McKay Head, which was mapped as Five Islands Volcanics by Powers (1916). At Glenholme, Colchester County, outcrops mapped by Weeks (1948) as the Tennycape Formation of Mississippian age, are Blomidon. Consists of interbedded reddish-brown and greenish-gray medium- to fine-grained sandstone, claystone, and siltstone. Laterally persistent beds of claystone, siltstone, and sandstone at the type locality are designated the Del Haven facies; channel-stratified beds are designated the Digby facies. Overlies the Wolfville Formation or the McKay Head Basalt; underlies the North Mountain Basalt. Age is Late Triassic (Norian) based on plant fossils.

Hubert and Mertz (1980, 1984) placed the Triassic-Jurassic boundary near the top of the Blomidon Formation on the basis of palynological biozones reported by Bruce Cornet (Columbia University, N.Y., written commun., 1980).

Donohoe and Wallace (1982) assigned rocks on the north shore of the Minas Basin at McKay Head, which had previously been mapped as the Blomidon Formation by Powers (1916) and Klein (1962), to the McCoy Brook Formation.

Boonton Formation of the **Brunswick Group**
Boonton Formation of the **Newark Supergroup**

Early Jurassic (Sinemurian, Pliensbachian)

New Jersey, Newark basin

Type section: Exposures along Rockaway River, Boonton, Morris County (Olsen, 1980b).

History: Informally named Boonton beds of Smith (1900) (Schaeffer and McDonald, 1978). Named Boonton Formation, previously mapped as part of the Brunswick Formation (Olsen, 1980b). Age (Olsen, 1984a). Revised in Brunswick Group, USGS usage (Lyttle and Epstein, 1987).

Schaeffer and McDonald (1978) described the Boonton beds of Smith (1900), which lie 360 m above the Third Watchung Basalt in the upper Brunswick Formation. Fossil fish occur in a 1-m-thick bed of flaggy to fissile, microlaminated, calcareous light-gray shale. The fish horizon was buried during construction of the dam for the Jersey City Reservoir.

Olsen (1980b) abandoned the Brunswick Formation of Kümmel (1897) and named the upper part, described as the Boonton beds of Smith (1900), the Boonton Formation of the Newark Supergroup. Consists of red, brown, gray, and black, fine to coarse clastics and minor evaporite beds. Overlies the Hook Mountain Basalt and is the uppermost unit of the Newark basin. Thickness at type section is 180 m. Age is Early Jurassic.

Olsen (1984a) gave the age of the Boonton Formation as Sinemurian and Pliensbachian on the basis of age determinations of pollen, spore, and footprint assemblages by Cornet (1977).

Lyttle and Epstein (1987) accepted for USGS usage the Boonton Formation of Olsen (1980b) and assigned it to the revised Brunswick Group in New Jersey.

†Border Conglomerate

Late Triassic
Early Jurassic

Virginia, Barboursville and Culpeper basins

Type locality: None designated. Applicable to conglomerates exposed along the east and west borders of Triassic basins in Virginia from the Potomac River at Point of Rocks to the [North] Carolina State line (Roberts, 1928). [Although Roberts' definition applies to all the Virginia basins, the name has been used only for the conglomerates in the Barboursville and Culpeper basins.]

History: Named (Roberts, 1928). Assigned to other units (Lindholm, 1979). Abandoned, assigned to other units (Lee and Froelich, 1989).

Roberts (1928) proposed the term Border Conglomerate for all conglomerates exposed along the east and west borders of Triassic basins in Virginia. In the Potomac area the conglomerates are divided into six classes depending on clast composition: (1) limestone conglomerate, also known as Potomac marble and calico marble, derived from Cambrian limestone; (2) quartz conglomerate, derived from granites and quartz lenses in Piedmont crystalline rocks; (3) arkose conglomerate, derived from granites, granite gneisses, and quartz; (4) schist conglomerate, derived from Catoctin schist; (5) trap conglomerate, derived from diabase; (6) quartz arkose conglomerate, derived from Precambrian granites and gneisses. The conglomerates are easily traced by their hilly topography, flat exposures, boulders, fertile soil, and abundant pebbles on the surface.

Lindholm (1979) included as members of the Bull Run Formation conglomerate bodies above the Manassas Sandstone and below the lowest basalt flow, described by Roberts (1928) as Border Conglomerate. Limestone conglomerate was named the Leesburg Conglomerate Member Lee's (1977) Leesburg Limestone Conglomerate Member, the schist conglomerate was named the Barboursville Conglomerate Member, the trap conglomerate was named the Cedar Mountain Conglomerate Member, and the arkose conglomerate was named the Goose Creek Conglomerate Member and the Waterfall Formation.

Lee and Froelich (1989) abandoned the Border Conglomerate of Roberts (1928) because it spans the entire Triassic-Jurassic section in the Culpeper basin and the entire time interval from late Carnian to possibly Pliensbachian. The conglomerates are lenticular and isolated and are separable into geographically and lithologically distinct members of several different formations. The two limestone conglomerates were named the Leesburg Member of the Balls Bluff Siltstone and the Tuscarora Creek Member of the Manassas Sandstone; the arkose conglomerate was subdivided and named the Millbrook Quarry Member of the Waterfall Formation and the Goose Creek Member of the Catharpin Creek Formation; the schist conglomerate was subdivided and named the Reston Member of the Manassas Sandstone and the Haudricks Mountain Member of the Tibbstown Formation; and the trap conglomerate was subdivided and named the Rapidan Member of the Manassas Sandstone and the Mountain Run Member of the Tibbstown Formation.

Boscabel boulder beds of the Tuckahoe Group

Late Triassic (early Carnian)

Virginia, Richmond basin

Type locality: None designated. Named for exposures at Boscabel Ferry on the James River near Manakin, Goochland County (Shaler and Woodworth, 1899).

History: Named (Shaler and Woodworth, 1899). Stratigraphic position (Goodwin and Farrell, 1979). Age (Cornet, 1977, 1989; Ediger, 1986).

Shaler and Woodworth (1899) named conglomerate deposits mapped at two places west of Boscabel and north of the James River along the western margin of the Richmond basin the Boscabel bowlder [sic] beds of the Tuckahoe Group. Consist of large, angular blocks and fragments of gneiss and granite randomly oriented in a matrix of gritty red sandstone. Located near the base of the Newark section and time equivalent to the lower barren beds on the eastern margin of the basin. Thickness ranges from 0 to 15 m. Age is Late Triassic.

Cornet (1977) gave the age of strata in the Richmond basin as middle to late Carnian on the basis of palynoflora.

Goodwin and Farrell (1979) stated that the Boscabel boulder beds probably are not a basal Triassic unit across the entire basin but were deposited locally as talus deposits at the base of fault scarps along the western margin and grade eastward into finer grained sediments. Conglomerates are found locally along the eastern and southern margins of the basin.

Ediger (1986) mapped the Boscabel boulder beds as laterally intertonguing, especially with the Vinita beds. Their age was not determined, but he dated the lower barren beds as Cornet (1989) dated the Boscabel as early(?) to middle(?) Carnian on the basis of biostratigraphy.

Browns Beach Member of the Honeycomb Point Formation

Middle Triassic (Ladinian)

New Brunswick, Fundy basin

Type section: Cliff exposures at Browns Beach along the Bay of Fundy coast between Honeycomb Point and Quaco Head, near St. Martins, Saint John County (NTS 21 H/6W) (Nadon and Middleton, 1985).

History: Named (Nadon and Middleton, 1985).

Nadon and Middleton (1985) named the Browns Beach Member of the Honeycomb Point Formation. Consists of coarse breccias interbedded with well-sorted, medium-grained, crossbedded red sandstones, and is restricted to the western part of the Honeycomb Point. Unconformably overlies Carboniferous or older rocks; is partly coeval with the McCumber Point Member of the Honeycomb Point; the top is eroded. Thickness cannot be determined because of limited vertical exposures and the presence of numerous faults of undetermined magnitude. Age is Middle Triassic based on Ladinian(?) to Carnian palynomorphs in the overlying Fownes Head Member of the Echo Cove Formation.

†Brunswick Conglomerate of the Newark Group

Late Triassic

Pennsylvania, Newark basin

Type locality: None designated. Described in Lehigh, Montgomery, Berks, and Bucks Counties (Jonas, 1917).
History: Named (Wherry, 1914). Described (Jonas, 1917). Included in Brunswick Formation (Bascom and Stose, 1938). Mapped as Robeson Conglomerate (McLaughlin, 1939).

Wherry (1914) named the Brunswick Conglomerate underlying the Brunswick Shale. Consists of pebble rocks, breccias, and conglomerate deposited at the mouths of rivers.

Jonas (1917) described the Brunswick Conglomerate as a coarse-grained, variegated, reddish-purple conglomerate underlying the Brunswick Shale. Crops out in irregular areas in the Boyertown and Quakertown quadrangles in Montgomery, Berks, Lehigh, and Bucks Counties, Pa.

Bascom and Stose (1938) mapped quartzose conglomerate in red sand matrix in northern Honeybrook and Phoenixville quadrangles, Berks, Lancaster, and Chester Counties, as Brunswick Formation.

McLaughlin (1939) mapped the Robeson Conglomerate in Robeson Township, Berks County, and to the west, where it occupies Furnace Ridge west of the Schuylkill River.

Brunswick Group of the **Newark Supergroup**
Brunswick Formation of the **Newark Supergroup**

Late Triassic (late Carnian, Norian)
Early Jurassic (Hettangian, Sinemurian, Pliensbachian)

Pennsylvania-New Jersey-New York, Newark basin

Type locality: None designated. Exposed in the Raritan River valley near New Brunswick, Middlesex County, N.J. (Kümmel, 1897). Composite section lies along the Delaware River from Stockton north to Spring Mills, Hunterdon County, N.J. (Johnson and McLaughlin, 1957).
Subunits:

Brunswick Group: **Passaic Formation** and its **Graters** and **Perkasie Members**; **Orange Mountain Basalt**; **Jacksonwald Basalt**; **Feltville Formation**; **Preakness Basalt**; **Towaco Formation**; **Hook Mountain Basalt**; **Boonton Formation.**

Brunswick Formation and its Graters, Perkasie, and Jacksonwald Basalt Members.

History: Named Brunswick Series of the Newark System (Kümmel, 1897). Equivalent to Lansdale, Perkasie, and Pottstown Shales of Lyman (1895) in Pennsylvania (Bascom, 1904). Redefined Brunswick

Formation of the Newark Group in New Jersey, USGS usage (Darton and others, 1908). Extended to Pennsylvania as Brunswick Shale (Bascom and others, 1909). Brunswick Formation, members named (McLaughlin, 1933, 1943). Composite section (Johnson and McLaughlin, 1957). Redefined Lithofacies, member named (McLaughlin, 1959). Extended to New York (McKee and others, 1959). Brunswick lithosome, geographic restriction, revised in part as Hammer Creek Formation (Glaeser, 1963). Abandoned, rocks mapped as Passaic, Feltville, Towaco, and Boonton Formations (Olsen, 1980b). Jacksonwald Basalt Member named (MacLachlan, 1983). Age (Olsen, 1984a). Revised Brunswick Group, including rocks previously mapped as Brunswick Formation of Kümmel (1897) and Watchung Basalt of Darton (1890) (Lyttle and Epstein, 1987).

Kümmel (1897) named the upper unit of the Newark System in New Jersey the Brunswick Series. Consists of thick, soft, argillaceous shale and sandstone and flagstone beds. The beds are mostly red but are also purple, green, yellow, and black. Conglomerate beds occur along the northwest border of the Newark basin and some are correlative with the Brunswick. Crops out in three belts repeated by faulting. Gradationally overlies the Lockatong Series. Thickness is 3,600 m. Age is Late Triassic.

Bascom (1904) followed the usage of the Pennsylvania Geological Survey in the Philadelphia district, where the Triassic series is represented by the Norristown, Gwynedd, Lansdale, Perkasie, and Pottstown Shales of Lyman (1895). A footnote states that N.H. Darton divided the Triassic into the Stockton Formation, corresponding to the Norristown; the Lockatong Formation, corresponding to the Gwynedd; and the Brunswick Shale, corresponding to the Lansdale, Perkasie, and Pottstown.

Darton and others (1908) divided the sedimentary rocks of the Newark Group in New Jersey along the Hudson River at the foot of the Palisades into the Stockton, Lockatong, and Brunswick Formations. They are not separately mapped in this area owing to the heavy drift cover and apparent absence of the distinctive Lockatong black slates, which are represented by an unknown thickness of light-brownish-red sandstone and shale not distinct from the Brunswick Formation, which becomes much more sandy to the north.

Bascom and others (1909) extended to Pennsylvania the classification of the Newark Group established in New Jersey. Comprises the Stockton and Lockatong Formations and the Brunswick Shale, which are approximately equivalent to the Norristown, Gwynedd, and Lansdale Shales of Lyman (1895), respectively, the names of which have not been found acceptable as distinct units because of their indefinite application.

McLaughlin (1933) named the dark shale belts in the lower part of the Brunswick Formation in Bucks and Montgomery Counties, Pa. In ascending order, the members are C, D, E, Graters (F, G, H), and Sanatoga.

McLaughlin (1943) recognized gray shale members C through M of the Brunswick Formation in northern Bucks County, Pa., and members C through H on the New Jersey side of the Delaware River.

Johnson and McLaughlin (1957) compiled a composite section of the Brunswick along the Delaware River, abridged from sections previously published by McLaughlin. Section includes the Perkasie Member [Perkasie Shales of Lyman (1895)].

McLaughlin (1959) used the terms Stockton, Lockatong, and Brunswick Lithofacies because these units are intertonguing lithologic facies rather than distinct time stratigraphic units. [This hypothesis was proposed by McLaughlin and Willard (1949).]

McKee and others (1959) extended the Brunswick Formation of the Newark Group to New York.

Glaeser (1963) designated the Lockatong and Brunswick as lithosomes, which are intertonguing, mutually exclusive lithostratigraphic bodies that can be repeated in a vertical succession of strata. Isolated outcrop units may join downdip with their respective main bodies or were once part of the main bodies. Coarse clastics in the narrow neck area of the Newark-Gettysburg basin were named the Hammer Creek Formation. The eastern arbitrary cutoff of the Hammer Creek, a line west of the Schuylkill River, was so placed that it restricted the Brunswick to the originally defined, fine red sandstone, siltstone, shale, and locally exposed uppermost conglomerate bodies at the northern margin of the outcrop belt, all of which occur principally east of the Schuylkill River.

Olsen (1980b) abandoned the Brunswick Formation of Kümmel (1897), which consists of a heterogeneous mix of lithologically distinct major units underlying and interbedded with basalt units of the Watchung Basalt of Darton (1890), also abandoned. The Brunswick was subdivided to form four new formations: the Passaic, Feltville, Towaco, and Boonton Formations, all of the Newark Supergroup.

MacLachlan (1983), in the Birdsboro quadrangle, Berks County, Pa., divided the Brunswick Formation into a lower member, the Jacksonwald Basalt Member, and an upper member. Fossil pollen and spores place the Triassic-Jurassic boundary more than 15 m but less than 40 m below the basalt. The lower and upper members are reddish-brown mudstone and shale.

Olsen (1984a) gave the ages of the units replacing the Brunswick Formation as late Carnian to Pliensbachian on the basis of pollen, spore, and reptile assemblages (Cornet, 1977).

Lyttle and Epstein (1987) revised the Brunswick Formation of Kümmel (1897) as the Brunswick Group of the Newark Supergroup. Includes the Watchung Basalt of Darton (1890), abandoned and subdivided (Olsen, 1980b). In New Jersey the Brunswick was divided into the seven units proposed by Olsen (1980b): the Passaic Formation, the Orange Mountain Basalt, the Feltville Formation, the Preakness Basalt, the Towaco Formation, the Hook Mountain Basalt, and the Boonton Formation. In Pennsylvania the Brunswick Group was divided into the lower part, equivalent to the Passaic; the Jacksonwald Basalt, equivalent to the Orange Mountain Basalt; and the upper part, equivalent to the Feltville Formation. [In New York the Brunswick Group is represented by the Passaic Formation, the Orange Mountain Basalt, and the Preakness Basalt.]

†Buckland Formation of the **Culpeper Group**

Early Jurassic

Virginia, Culpeper basin

Type locality: Outcrops along U.S. Highway 29–211 near Buckland, Prince William County (Lindholm, 1979).

History: Named Buckland Formation of the Culpeper Group; previously mapped as formations J through B by Cornet (1977) and the lower part of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977) (Lindholm, 1979). Abandoned, rocks assigned to Mount

Zion Church Basalt, Midland Formation, Hickory Grove Basalt, Turkey Run Formation, and Sander Basalt (Lee and Froelich, 1989).

Lindholm (1979) named the Buckland Formation of the Culpeper Group. Crops out in an arcuate belt on the west side of the Culpeper basin from the Rappahannock River north to a point 5 km south of Leesburg, Va., and consists of fine- to medium-grained, locally pegmatitic and columnar jointed basalt flows and interbedded sandstone, mudstone, and shale units. The basaltic flow units are designated, from oldest to youngest, I through V, and the sedimentary units are designated by the flows between which they occur as I–II through IV–V. Lacustrine beds and conglomerates lie in sedimentary unit I–II. The Buckland was mapped as formations J through B by Cornet (1977) and as the lower part of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977). Overlies the Bull Run Formation; underlies the Waterfall Formation. Thickness is 1,670 m. Age is Early Jurassic.

Lee and Froelich (1989) abandoned the Buckland Formation of Lindholm (1979). The basalt and sedimentary units were given formation rank and were named the Mount Zion Church Basalt, Midland Formation, Hickory Grove Basalt, Turkey Run Formation, and Sander Basalt.

†Bull Run Formation of the **Culpeper Group**

Late Triassic
Early Jurassic

Virginia-Maryland, Barboursville and Culpeper basins

Type locality: None designated. Named for Bull Run, a small stream in the Bull Run Battlefield, 9.5 km west of Manassas, Prince William and Fairfax Counties, Va. (Roberts, 1928).

Subunits: Listed by reference.

Leesburg Limestone Conglomerate Member, basaltic-flow-bearing clastics member (Lee, 1977).

Leesburg Limestone Conglomerate Member, informal Catharpin Creek, Mount Zion Church basalt, Hickory Grove basalt, Sander basalt, and Mountain Run members (Lee, 1979).

Leesburg, Goose Creek, Cedar Mountain, and Barboursville Conglomerate Members (Lindholm, 1979).

History: Named Bull Run Shales (Roberts, 1928). Revised Bull Run Formation of the Newark Group [equivalent to the upper part of formation K through formation A of Cornet (1977)] (Lee, 1977). Revised, members named (Lee, 1979). Revised as Bull Run Formation of the Culpeper Group, previously mapped as the upper half of formation K by Cornet (1977), members named (Lindholm, 1979). Abandoned, rocks assigned to Balls Bluff, Tibbstown, Catharpin Creek, Mount Zion Church, Midland, Hickory Grove, Turkey Run, Sander, and Waterfall Formations (Lee and Froelich, 1989).

Roberts (1928) named the Bull Run Shales, exposed at Bull Run, Va. Includes all of the closely related red shales and sandstones of Late Triassic age that occur in belts up to 6.5 km wide from north to south in the Potomac area and in the other Triassic areas of Virginia. [The name has been used only in the Barboursville and Culpeper basins.] Color varies from red to gray, blue, and black and is decolorized near igneous rock contacts. This youngest Triassic formation in Virginia overlies the Manassas Sandstone.

Lee (1977) revised the Bull Run Shales of Roberts (1928) to Bull Run Formation of the Newark Group and divided it into the lower Leesburg Limestone Conglomerate Member and the overlying and intertonguing basaltic-flow-bearing clastics member. This member forms the bulk of the formation in the west-central part of the basin, where it consists of a heterogeneous mixture of conglomerate, sandstone, siltstone, shale, and locally, coal and limestone interbedded with three basalt flows. Thickness ranges from 190 to 7,930 m. Age is Triassic and Jurassic(?).

Lee (1979) retained the Leesburg Limestone Conglomerate Member for the lower part of the Bull Run Formation and subdivided the basaltic-flow-bearing clastics member into informal members including the Catharpin Creek, Mount Zion Church basalt, Hickory Grove basalt, Sander basalt, and uppermost Mountain Run members.

Lindholm (1979) revised the Bull Run Shales of Roberts (1928) to Bull Run Formation of the Culpeper Group. Includes the sequence of rocks that conformably overlies the Manassas Sandstone, underlies the lowermost basalt flow of the Buckland Formation, and corresponds to the upper part of formation K of Cornet (1977) and Roberts' (1928) Bull Run Shales and his conglomeratic units below the lowermost basalt flow. Consists of massive, crossbedded, laminated red mudstones and siltstones and intercalated shale, sandstone, and conglomerate lenses. The Bull Run Formation was divided into the Leesburg, Goose Creek, Cedar Mountain, and Barboursville Conglomerate Members. Maximum thickness is 5,100 m. Age is Late Triassic and Early Jurassic.

Lee and Froelich (1989) abandoned the Bull Run Formation because in all previous definitions this heterogeneous unit lacked distinctive boundaries. The Cedar Mountain and Barboursville Conglomerate Members of Lindholm (1979) were abandoned and the Leesburg and Goose Creek Conglomerate Members were revised. The basalt and interbedded sedimentary units equivalent to or included in the Bull Run by Roberts (1928), Cornet (1977), Lee (1977, 1979, 1980), and Lindholm (1979) were assigned to the Culpeper Group and named the Balls Bluff Siltstone and its Leesburg Member, the Tibbstown Formation and its Haudricks Mountain and Mountain Run Members, the Catharpin Creek Formation and its Goose Creek Member, the Mount Zion Church Basalt, the Midland Formation, the Hickory Grove Basalt, the Turkey Run Formation, the Sander Basalt, and the Waterfall Formation and its Millbrook Quarry Member. The Buckland Formation of Lindholm (1979), equivalent to part of the Bull Run, was abandoned also.

Cascade Station Member of the Leakesville Formation

Late Triassic

Virginia, Danville basin

Type section: Exposures on State Road 856, 0.3 km south of State Road 622, Pittsylvania County. Named for Cascade Station on the Carolina and Northwestern Railway (Meyertons, 1963).

History: Named (Meyertons, 1963). Equivalent to the siltstone facies of the Pine Hall and Stoneville Formations in the Dan River basin (Thayer, 1970b). Pine Hall and Stoneville Formations extended to

Danville basin (Thayer, 1980b). [The names Cascade Station Member and Leakesville Formation have been replaced and should be abandoned.]

Meyertons (1963) named the Cascade Station Member of the Leakesville Formation in the Danville basin, Virginia. Consists of discontinuous and intergrading beds, lenses, and tongues of maroon, red, and brown shale and sandstone and minor amounts of conglomerate, claystone, and siltstone. Crossbedding, ripple marks, and worm trails are common. Intertongues with the Cow Branch Member of the Leakesville and with the arkosic facies of the Dry Fork Formation. Disconformably underlies the Cedar Forest Formation. Thickness at type section is 25 m. Age is Late Triassic.

Thayer (1970b) proposed new stratigraphic nomenclature for the Dan River basin because the rocks of the Dan River basin are interfingering lithologic facies and not time-stratigraphic units as Meyertons (1963) described in the Danville basin. The Cascade Station Member of the Leakesville Formation is equivalent to the siltstone facies of the Pine Hall and Stoneville Formations of the Dan River basin.

Thayer (1980b) extended the Pine Hall and Stoneville Formations of the Dan River basin into the Danville basin. [No reference is made to Meyertons' (1963) earlier name for part of these rocks, the Cascade Station Member of the Leakesville Formation, or to its equivalence to the siltstone facies of the Pine Hall and Stoneville Formations.]

Catharpin Creek Formation of the **Culpeper Group**

Late Triassic (late Norian)
Early Jurassic (early Hettangian)
Virginia, Culpeper basin

Type section: Exposures along Catharpin Creek north and northwest of Haymarket, Prince William County (Lee and Froelich, 1989).
Subunit: **Goose Creek Member.**
History: Named, USGS usage, previously mapped as part of formation K by Cornet (1977), part of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977), and part of the informal Catharpin Creek member of the Bull Run Formation by Lee (1979) (Lee and Froelich, 1989).

Lee and Froelich (1989) named the Catharpin Creek Formation of the Culpeper Group. The formation is part of the informal Catharpin Creek member of Lee (1979) of the Bull Run Formation, which included the entire sequence of sedimentary rocks enclosing and intercalated with the basalt flow units. The name Catharpin Creek is retained for the lowest sedimentary unit of Lee's member; the upper sedimentary units were named the Midland, Turkey Run, and Waterfall Formations. Catharpin Creek consists of micaceous, pebbly, feldspathic red sandstone and clayey siltstone and has local conglomerate lenses. Includes the Goose Creek Member at the top. Gradationally overlies and intertongues with the Balls Bluff Siltstone; underlies, and is separated from, the Mount Zion Church Basalt by a sharp disconformity. Thickness is as much as 500 m. The Triassic-Jurassic boundary is in the upper part of the unit.

†Cedar Forest Formation

Late Triassic

Virginia, Danville basin

Type section: Outcrops along the Virginian Railway, 0.8 km northwest of Long Island Station, Campbell County. Named for the town of Cedar Forest at the junction of State Roads 761 and 639, Pittsylvania County (Meyertons, 1963).
History: Named (Meyertons, 1963). Equivalent to the conglomerate facies of the Pine Hall and Stoneville Formations in the Dan River basin (Thayer, 1970b). Abandoned, rocks assigned to the Dry Fork Formation (Thayer, 1977).

Meyertons (1963) named the Cedar Forest Formation along the east and west borders of the Danville basin, Virginia. Consists of narrow exposures of red and maroon conglomerate containing fragments of older crystalline rocks and interbedded siltstone and shale. Disconformably overlies the Leakesville and Dry Fork Formations. Thickness at type section is 26 m. Age is Late Triassic.

Thayer (1970b) stated that the rocks of the Dan River basin are intertonguing lithologic facies and not time-stratigraphic units as Meyertons (1963) described in the Danville basin. Thayer proposed new stratigraphic units for the Dan River basin. The Cedar Forest Formation does not disconformably overlie the Leakesville and Dry Fork Formations but intertongues with them and is equivalent to the conglomerate facies of the Pine Hall and Stoneville Formations in the Dan River basin.

Thayer (1977) abandoned the Cedar Forest Formation and assigned basin margin conglomerates of the Cedar Forest to the Dry Fork Formation. Detailed mapping shows that the conglomerates are interbedded and intertongue with sandstone of the Dry Fork and that the Dry Fork and Cedar Forest are lateral facies equivalents.

†Cedar Mountain Conglomerate Member of the Bull Run Formation

Late Triassic
Early Jurassic

Virginia, Culpeper basin

Type locality: None designated. Named for exposures on Cedar Mountain, 14 km southwest of Culpeper, Culpeper County (Lindholm, 1979).
History: Named, previously mapped as trap conglomerate of the Border Conglomerate by Roberts (1928) and lower sedimentary unit of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977) (Lindholm, 1979). Abandoned, rocks assigned to the Mountain Run Member of the Tibbstown Formation (Lee and Froelich, 1989).

Lindholm (1979) named the Cedar Mountain Conglomerate Member of the Bull Run Formation. Mapped as trap conglomerate of the Border Conglomerate by Roberts (1928) and occupies a 31-km-long and 3-km-wide belt along the western margin of the Culpeper basin. Consists of greenstone pebbles and boulders in a matrix that is red when fresh and gray when weathered or metamorphosed. Thickness ranges from 240 to 1,400 m. Age is Late Triassic and Early Jurassic.

Lee and Froelich (1989) abandoned the Cedar Mountain Conglomerate Member and the Bull Run Formation. Rocks were assigned to the Mountain Run Member of the Tibbstown Formation.

Chatham Group of the **Newark Supergroup**

Late Triassic (Carnian)

South Carolina-North Carolina, Deep River basin, including Crowburg, Wadesboro, Ellerbe, Sanford, and Durham subbasins

Type locality: None designated. Named for Chatham County, N.C., "* * * in which it makes so distinguished a figure * * *" (Emmons, 1857).
Subunits: **Pekin Formation, Cumnock Formation, Sanford Formation** (North Carolina).
History: Named Chatham series (Emmons, 1857). Revised as Chatham Group of Newark Supergroup, comprising the Pekin, Cumnock, and Sanford Formations (Olsen, 1978; Olsen and others, 1982). Chatham Group, undivided, extended in North Carolina [usage adopted by USGS] (Brown, 1985). Age (Cornet, 1977; Traverse, 1987).

Emmons (1857) defined the Chatham series as the series of rocks well exposed in Chatham County and also at Pekin in the Deep River area of Montgomery County, N.C. The members consist of gray blue-grit conglomerate; brown and red sandstone, including gray sandstone and bituminous slate; slate and green calcareous shale that has coal seams, carbonaceous iron ore, and magnesian carbonate of lime; gray sandstone; conglomerate; blue shale; gray sandstone; and a second series of red and mottled sandstone. Emmons gave the age of the series as Permian up to or near the second conglomerate and Triassic above that.

Cornet (1977) gave an age of late middle and late Carnian to the Chatham on the basis of palynoflora in the Pekin and Cumnock Formations.

Olsen (1978) assigned the Chatham Group in the Deep River basin to the Newark Supergroup, which was revised as an inclusive term. The revision emphasized the close lithologic and structural relations of the basins and allowed the formations of individual basins to be included in specific groups while remaining in a strictly rock-stratigraphic hierarchy.

Olsen and others (1982) assigned the Pekin, Cumnock, and Sanford Formations of Campbell and Kimball (1923) to the Chatham Group in the Wadesboro, Sanford, and Durham basins.

Brown (1985) extended the usage of Chatham Group, undivided, to Upper Triassic rocks in the Wadesboro and Ellerbe basins.

Traverse (1987) extended the age of the Deep River basin sediments to at least earliest Carnian and possibly late Ladinian.

Chedabucto Formation of the Fundy Group

Late Triassic

Nova Scotia, Fundy basin

Type locality: Outcrops along Chedabucto Bay, north of McCaul Island, Guysborough County (NTS 11 F/6) (Klein, 1962).

History: Named (Klein, 1962).

Klein (1962) named the Chedabucto Formation of the Fundy Group in the Chedabucto Bay area, Nova Scotia. Consists of reddish-beige agglomerate, conglomerate, sandstone, siltstone, and shale. Sharpstone conglomerate composed of boulders of Paleozoic rocks in a red-brown silty sandstone matrix is similar to the Gerrish facies of the Wolfville Formation. Unconformably overlies Paleozoic rocks; unconformably underlies Pleistocene gravel. Thickness is 60 m. Age is Late Triassic based on worm trails and fossil reptiles.

Chesterfield Group of the **Newark Supergroup**

Late Triassic (Carnian)

Virginia, Richmond basin

Type locality: None designated. Occurs in Chesterfield County (Shaler and Woodworth, 1899).

Subunits: Vinita beds, Otterdale Sandstone.

History: Named (Shaler and Woodworth, 1899). Revised in Newark Supergroup (Olsen, 1978). Age (Cornet, 1977; Ediger, 1986).

Shaler and Woodworth (1899) named the upper division of the Newark series in the Richmond basin the Chesterfield Group. Includes the Vinita beds and the Otterdale sandstones. Overlies the Tuckahoe Group. Thickness is more than 760 m. Age is Late Triassic.

Cornet (1977) gave the age of the Chatham-Richmond-Taylorsville palynoflora as probably late middle to early late Carnian.

Olsen (1978) assigned the Chesterfield Group to the Newark Supergroup, which was revised as an inclusive term. The revision emphasized the close lithologic and structural relations of the basins and allowed the formations of individual basins to be included in specific groups while remaining in a strictly rock-stratigraphic hierarchy.

Ediger (1986) interpreted the Vinita beds as lacustrine deposits of early Carnian age (including middle Carnian of earlier classification) on the basis of cyclic strata, dispersed organic matter, sedimentology, palynology, and stratigraphy. The unconformably overlying Otterdale Sandstone is the youngest unit of the Richmond basin.

†Chicopee Shale of the Newark Group

Late Triassic

Connecticut-Massachusetts, Hartford and Deerfield basins

Type locality: None designated. Exposed along the railroad cut near Holyoke dam and at the mouth of the Chicopee River, Springfield North quadrangle, Hampden County, Mass. (Emerson, 1898b).

History: Named (Emerson, 1891). Redefined (Emerson, 1898a, b). USGS usage, rocks previously mapped as Longmeadow Sandstone (Emerson, 1917). Areal restriction, partly replaced by Turners Falls Sandstone (Willard, 1951). Abandoned, replaced by Portland Formation (Hartshorn and Koteff, 1967).

Emerson (1891) named the Chicopee shale in the middle of the Triassic basin in Massachusetts where the basin widened so greatly that fine silts and marls were deposited.

Emerson (1898a, b) mapped the Chicopee Shale in the central part of the Connecticut Valley [in the Hartford basin] in Massachusetts and Connecticut. Consists of thin, gray and red shale and shaly sandstone, is coaly, and contains casts of salt and gypsum crystals and nodules of concretionary limestone. Partly contemporaneous with the Mount Toby Conglomerate, Sugarloaf Sandstone, and Longmeadow Sandstone. Extends from Holyoke southward and appears at the mouth of the Chicopee River, in the bed of the Connecticut River at Mittineague, and in beds of brooks at Agawam, Mass., and Thompsonville, Conn. Age is Juratrias [Triassic-Jurassic].

Emerson (1917) mapped the Chicopee Shale of the Newark Group in the area near Greenfield, Mass. [in the Deerfield basin]. These rocks were previously mapped by Emerson (1898a) as Longmeadow Sandstone. The Chicopee consists of thin, coaly, calcareous shale and shaly sandstone. Age is Late Triassic.

Willard (1951) renamed the Chicopee Shale as mapped by Emerson (1917) in the Greenfield and Mount Toby quadrangles the Turners Falls Sandstone because the Chicopee cannot be traced into this area [Deerfield basin] from its type area.

Hartshorn and Koteff (1967) abandoned the name Chicopee Shale and assigned the rocks to the Portland Arkose. Shaly beds mapped by Emerson (1917) as Chicopee Shale at Agawam and Thompsonville are finer grained facies of the Portland that are exposed in the eastern part of the Springfield South quadrangle.

Conewago Conglomerate Member of the **Gettysburg Formation**

Late Triassic

Pennsylvania, Gettysburg basin

Type locality: None designated. Exposed on Conewago Mountain, south of Andersontown, York County (Stose and Jonas, 1939).

History: Named, USGS usage (Stose and Jonas, 1939). Not recognized (Glaeser, 1963). Stratigraphic position (Berg and others, 1983).

Stose and Jonas (1939) named the Conewago Conglomerate Member of the Gettysburg Shale. Extends from southwest of Airy Hill School in western York County, Pa., northeast through Harmony Grove and Conewago Mountain to northwest of Strinestown. The Conewago is a thick lenticular zone of hard, pebbly, arkosic red sandstone and conglomerate near the base of the Gettysburg. Maximum thickness is 2,200 m. Age is Late Triassic.

Glaeser (1963) reported that the part of the Gettysburg designated Conewago Conglomerate Member by Stose and Jonas (1939) was examined at seven exposures and was not separable from typical Gettysburg lithologies. Glaeser did not recognize the name Conewago. Rocks that had been designated Conewago were included as part of the undifferentiated lower unnamed member of the Gettysburg Formation.

Berg and others (1983) placed the Conewago Conglomerate in the [informal] lower member of the Gettysburg Formation.

†Conewago Group

Late Triassic

Pennsylvania, Gettysburg basin

Type locality: None designated. Occurs in Dauphin and York Counties (Ashley, 1931).

History: Named (Ashley, 1931). [Replaced by Gettysburg Shale on Geologic Map of Pennsylvania (Stose and Ljungstedt, 1931).]

Ashley (1931) named the Conewago Group, credited to Bissell (1921), in Dauphin and York Counties, Pa. Consists of alternating hard, purplish, or pinkish-red sandstone and red shale. Overlies the Manchester Group; underlies the Lewisburg (apparently a misprint for Lewisberry) Group. Thickness is 2,400 m. Age is Late Triassic.

Cow Branch Formation of the **Dan River Group** (North Carolina) **Cow Branch Formation** of the **Newark Supergroup** (Virginia)

Late Triassic (middle and late Carnian)

North Carolina-Virginia, Dan River-Danville basin

Type section: Exposures on State Road 856, 0.3 km north of the Virginia-North Carolina State line, Pittsylvania County, Va. Named for Cow Branch, a tributary of Cascade Creek near Leakesville Junction (Meyertons, 1963). Reference sections (Thayer, 1970b).

History: Named Cow Branch Member of Leakesville Formation in Danville basin (Meyertons, 1963). Revised Cow Branch Formation of Dan River Group in Dan River basin (Thayer, 1970b). Cow Branch Formation used in Danville basin (Thayer, 1980b). Age (Robbins, 1982). [Usage adopted by USGS (Brown, 1985).]

Meyertons (1963) named the Cow Branch Member of the Leakesville Formation in the Danville basin, Virginia. Consists of discontinuous lenses, beds, and tongues of black and dark-gray claystone, shale, siltstone, and sandstone containing organic debris. Intertongues laterally with red beds of the Cascade Station Member of the Leakesville and with the arkosic facies of the Dry Fork Formation. Disconformably underlies the Cedar Forest Formation. Thickness at type section is 165 m. Age is Late Triassic.

Thayer (1970b) extended the Cow Branch Member into the Dan River basin, North Carolina, as the revised Cow Branch Formation of the Dan River Group, where it consists of thinly laminated to massive dark-gray siltstone, claystone, and shale containing thin lenticular layers of coal in the lower 60 m. Crops out in a narrow belt along the southeast side of the basin. Gradationally overlies the Pine Hall Formation and conformably underlies the Stoneville Formation. At the north end of the basin, near the town of Leaksville, N.C., the Cow Branch is separated into two laterally overlapping and vertically offset tongues; the lower intertongues northeastward with the Pine Hall Formation and the upper intertongues southwestward with the Stoneville Formation. Thickness averages 180 m. Reference sections are given.

Thayer (1980b) extended the Pine Hall, Cow Branch, and Stoneville Formations from the Dan River basin into the southwestern part of the Brosville quadrangle, Virginia, in the Danville basin. The Cow Branch Formation forms the reference beds for this division of rocks and where it is absent there is no basis for distinguishing more than one unit, the Dry Fork Formation, which is equivalent to the Pine Hall and Stoneville Formations, undivided. [No reference is made to Meyertons' (1963) usage of the Cow Branch Member of the Leakesville Formation in the Danville basin.]

Robbins (1982) gave the age of the Cow Branch as late middle to late Carnian on the basis of pollen and spore assemblages.

Culpeper Group of the Newark Supergroup

Late Triassic (middle and late Carnian, Norian)
Early Jurassic (Hettangian, Sinemurian, Pliensbachian)

Virginia-Maryland, Barboursville and Culpeper basins

Type locality: None designated. Named for the Culpeper basin, Virginia and Maryland (Cornet, 1977).

Subunits: Listed by basin.

Barboursville basin—**Manassas Sandstone** and its **Rapidan** and **Poolesville Members; Balls Bluff Siltstone; Tibbstown Formation** and its **Haudricks Mountain Member**

Culpeper basin—**Manassas Sandstone** and its **Rapidan, Tuscarora Creek, Reston,** and **Poolesville Members; Balls Bluff Siltstone** and its **Leesburg Member; Tibbstown Formation** and its **Mountain Run Member; Catharpin Creek Formation** and its **Goose Creek Member; Mount Zion Church Basalt; Midland Formation; Hickory Grove Basalt; Turkey Run Formation; Sander Basalt; Waterfall Formation** and its **Millbrook Quarry Member**

History: Informally named (Cornet, 1977). Named (Lindholm, 1979). Age (Traverse, 1987). Revised, USGS usage (Lee and Froelich, 1989).

Cornet (1977) designated the formations of rock contained within the Culpeper basin, which extends from northeastern Virginia into Maryland to the Gettysburg basin, as formations K through A of the informal Culpeper group. Formation K, the lowest unit, 3,900 m thick, is composed mostly of fluvial sandstone and siltstone. [Formation K is equivalent to Roberts' (1928) Border Conglomerate, Manassas Sandstone, and Bull Run Shales.] Formation J, 72 m thick, is a basalt unit. Formation I, 508 m thick, is composed of fluvial sandstone and siltstone and two lacustrine units that contain fish beds. Formation H, 92 m thick, is a basalt unit. Formation G, 114 m thick, is composed of fluvial sandstone and siltstone. Formation F, 577 m thick, contains four basalt flows interbedded with sedimentary rocks. Formation E, 186 m thick, is a poorly exposed sedimentary unit. Formation D, 60 m thick, is a basalt unit. Formation C, 65 m thick, is a sedimentary unit. Formation B, 53 m thick, is a basalt unit. Formation A, 1,000 m thick, is composed mostly of conglomerate lenses. Age of the Culpeper is late Carnian to Pliensbachian based on palynoflora. Formation K is late Carnian to Hettangian; formations J to A are Hettangian to Pliensbachian.

Lindholm (1979), by following the informal usage of Cornet (1977), formally named the Culpeper Group for the sedimentary and extrusive igneous rocks of the Culpeper basin. Lindholm included in the Culpeper, in ascending order, the Reston Formation, the Manassas Sandstone, the Bull Run Formation and its Leesburg Limestone, Goose Creek, Cedar Mountain, and Barboursville Conglomerate Members, the Buckland Formation, and the Waterfall Formation.

Traverse (1987) extended the age of the oldest rocks of the Culpeper basin downward to the middle Carnian on the basis of palynomorphs.

Lee and Froelich (1989) revised the Culpeper Group to include the complete lithostratigraphic sequence of Upper Triassic and Lower Jurassic sedimentary and extrusive igneous rocks of the Newark Supergroup in the Barboursville and Culpeper basins in Virginia and Maryland. The lower part of the Culpeper Group comprises the mostly Upper Triassic sequence of continental sedimentary rocks that occupies the entire Barboursville basin and the southern quarter and eastern half of the Culpeper basin and includes the Manassas Sandstone and its Rapidan, Tuscarora Creek, Reston, and Poolesville Members, the Balls Bluff Siltstone and its Leesburg Member, the Tibbstown Formation and its Haudricks Mountain and Mountain Run Members, and the Catharpin Creek Formation and its Goose Creek Member. The Triassic-Jurassic boundary is in the Catharpin Creek. The upper part of the Culpeper Group comprises the Lower Jurassic sequence of tholeiitic basalt flows and interbedded sedimentary rocks in the west-central Culpeper basin and includes the Mount Zion Church Basalt, the Midland Formation, the Hickory Grove Basalt, the Turkey Run Formation, the Sander Basalt, and the Waterfall Formation and its Millbrook Quarry Member. Thickness varies from 330 m to 7,900 m.

Cumnock Formation of the **Chatham Group**

Late Triassic (late Carnian)

North Carolina, Deep River basin, including Sanford and Durham subbasins

Type section: Cumnock (formerly Egypt) coal mine shaft and four boreholes nearby, near Cumnock, Sanford basin, Lee County (Campbell and Kimball, 1923).

History: Named in Newark Group (Campbell and Kimball, 1923). USGS usage (Reinemund, 1955). Age (Cornet, 1977). Assigned to Chatham Group (Olsen and others, 1982). Age (R.J. Litwin, USGS, oral commun., 1989).

Campbell and Kimball (1923) named the Cumnock Formation of the Newark Group for exposures in the shaft of the Cumnock coal mine in the Deep River coal field, North Carolina. Consists of light-colored, coal-bearing slate, shale, and sandstone at the type section but varies greatly in thickness and composition. Includes rocks described as calcareous and bituminous shales and drab-colored sandstones of the Chatham series by Emmons (1857). Gradationally overlies the Pekin Formation; underlies the Sanford Formation.

Reinemund (1955) accepted the Cumnock Formation for use by the USGS. Crops out in a narrow belt along the northwest side of the Sanford basin and at the southern end of the Durham basin. The contact with the gradationally underlying Pekin Formation is drawn at the top of the highest persistent red or brown beds below the coal beds, and the contact with the gradationally overlying Sanford Formation is drawn at the base of the lowest persistent red or brown beds above the coal beds.

Cornet (1977) assigned an age of late middle Carnian to the Cumnock Formation on the basis of palynoflora in the Pekin and Cumnock.

Olsen and others (1982) assigned the Cumnock Formation to the Chatham Group of the Newark Supergroup.

R.J. Litwin (USGS, oral commun., 1989) identified palynomorphs of late Carnian age from the Carolina coal mine in the upper part of the Cumnock.

Cuttalossa Member of the **Stockton Formation**

Late Triassic

Pennsylvania-New Jersey, Newark basin

Type locality: None designated. Exposed in quarries along the Delaware River near Cuttalossa Inn, 1.6 km southeast of Lumberville, Bucks County, Pa. (McLaughlin, 1945).

History: Named (McLaughlin, 1945). Delaware River section (Johnson and McLaughlin (1957).

McLaughlin (1945) named the Cuttalossa Member of the Stockton Formation along the Delaware River in Pennsylvania and New Jersey. Consists of gray, massive, coarse, arkosic sandstone. Overlies and underlies red sandstone of the Stockton. Thickness is 130 m in the Delaware River section. Age is Late Triassic.

Johnson and McLaughlin (1957) described the Cuttalossa Member in the Delaware River section from Stockton to Milford, N.J. Consists of medium to coarse, thick-bedded arkose containing interbeds of fine red-brown sandstone. Lies 110 m above the Upper Prallsville Member; lies 240 m below the Raven Rock Member of the Stockton.

Dan River Group of the Newark Supergroup

Late Triassic (middle and late Carnian, early Norian)

North Carolina, Davie County and Dan River basins

Type area: Dan River basin, Stokes and Rockingham Counties, (Thayer, 1970b).

Subunits: **Pine Hall Formation, Cow Branch Formation, Stoneville Formation.**

History: Named (Thayer, 1970b). Revised in Newark Supergroup (Olsen, 1978). Extended to Davie County basin, [usage adopted by USGS] (Brown, 1985). Age (Robbins, 1982; R.J. Litwin, USGS, written commun., 1987).

Thayer (1970b) proposed new stratigraphic nomenclature for the Dan River basin, the continuation in North Carolina of the Danville basin of Virginia, because the rocks of the Dan River basin are intertonguing lithologic facies and not time-stratigraphic units as Meyertons (1963) described in the Danville basin. The term Dan River Group was used rather than Newark Group because Klein (1962) argued that the term Newark Group had been misused outside its type area in New Jersey where it was originally applied in a time-stratigraphic sense. The Dan River Group consists of as much as 4,500 m of nonmarine clastic strata composed of red, tan, and gray conglomerate, sandstone, and mudrock. The Group is divided into the Pine Hall, Cow Branch, and Stoneville Formations, which unconformably overlie and locally are in fault contact with older metamorphic rocks on the southeast side of the basin and are truncated by the Chatham fault zone on the northwest side. Age is Late Triassic.

Olsen (1978) assigned the Dan River Group [and its Pine Hall, Cow Branch, and Stoneville Formations] to the Newark Supergroup, which was revised as an inclusive term. The revision emphasized the close lithologic and structural relations of the basins and allowed the formations of individual basins to be included in specific groups while remaining in a strictly rock-stratigraphic hierarchy.

Robbins (1982) gave the age of the Cow Branch Formation as late middle to late Carnian on the basis of pollen and spore assemblages. The underlying Pine Hall Formation is middle Carnian, and the overlying Stoneville Formation is late Carnian.

Brown (1985) assigned the rocks of the Davie County basin to the Dan River Group, undivided, of the Newark Supergroup.

R.J. Litwin (USGS, written commun., 1987) found palynomorph assemblages in the Stoneville Formation comparable to assemblages believed to be early Norian in the

Manassas, Gettysburg, and Passaic Formations, which indicates that deposition in the Dan River-Danville basin continued at least into the early Norian.

Deerfield Basalt of the **Newark Supergroup**

Early Jurassic (Hettangian)

Massachusetts, Deerfield basin

Type locality: None designated. Forms the core of Deerfield Mountain, Greenfield quadrangle, Franklin County (Emerson, 1898b).

History: Named Deerfield diabase bed, previously mapped as the main trap sheet by Percival (1842) [and by Davis (1898)] (Emerson, 1891). Redefined (Emerson, 1898a). Abandoned, mapped as Deerfield sheet of the Holyoke Diabase (Emerson, 1898b, 1917). Revised as Deerfield Diabase of the Newark Group, USGS usage (Willard, 1951). Redefined Deerfield Basalt, correlated with Talcott Basalt (Zen and others, 1983). Age (Olsen, 1984a). Redefined in Newark Supergroup (Robinson and Luttrell, 1985). [Because of geochemical similarities to the Holyoke Basalt and the Holyoke-equivalent Hickory Grove Basalt in the Culpeper basin (O'Toole, 1981; Puffer and others, 1981; Richard Tollo, The George Washington University, oral commun., 1987) and because it is closer to the Buttress-Ware dike that feeds the Holyoke Basalt than to the Higganum dike that feeds the Talcott Basalt (Philpotts, 1985), the Deerfield Basalt is correlated in plate 1 with the Holyoke Basalt rather than with the older Talcott Basalt.]

Emerson (1891) named the Deerfield diabase bed in the Triassic basin of Massachusetts. The north and south ends of the Deerfield overlie the Mount Toby conglomerate and the middle of the Deerfield overlies sandstones and shales [Longmeadow brownstone and Chicopee shale]. Near Greenfield the Deerfield underlies sedimentary rocks. Age is Late Triassic.

Emerson (1898a) described the Deerfield sheet as the most northerly occurrence of eruptive rock in the Triassic of Massachusetts. Extends from Gill in the north, southwest through Greenfield and Deerfield, to end in Mount Toby.

Emerson (1898b, 1917) described the Deerfield sheet as a trap bed similar to the main sheet of the Holyoke Diabase. Is a vesicular, fine-grained dark trap made up of three sheets full of steam holes, which indicate three immediately successive flows. Mapped as Holyoke Diabase by Emerson (1898b) and as undifferentiated diabase flows and dikes by Emerson (1917). [The name was abandoned by the USGS in 1914.]

Willard (1951) revised the Deerfield trap by removing it from the Holyoke Diabase and renaming it the Deerfield Diabase of the Newark Group. There is no evidence that the Deerfield and Holyoke Diabases came from a common conduit or were contemporaneous. Consists of fine-grained black diabase and is exposed on the west and south slopes of Mount Toby and west of the Connecticut River in the Pocumtuck Range. Overlies the Sugarloaf Formation; underlies the Turners Falls Sandstone.

Zen and others (1983) mapped the Deerfield Basalt in the Deerfield basin, where it is a well-jointed quartz tholeiite, locally vesicular, and locally pillowed near the base. The Triassic-Jurassic boundary is arbitrarily drawn immediately below the Deerfield in gray mudstone of the Sugarloaf Formation. The Deerfield is correlated with the Hitchcock Volcanics [and, by implication, with the Talcott Basalt in Connecticut].

Olsen (1984a) described the Deerfield Basalt as a single flow of tholeiitic basalt of Early Jurassic age on the basis of the presence of Jurassic palynoflorules in the uppermost part of the underlying Sugarloaf Formation and on K-Ar dates.

Robinson and Luttrell (1985) redefined the Deerfield Basalt of the Newark Supergroup to reflect its extrusive origin, which is shown by pillows and pillow breccias at the base and by vesicular pahoehoe flows at the top.

Doswell Formation of the **Newark Supergroup**

Late Triassic (Carnian)

Virginia, Taylorsville basin

Type section: Exposures along Stagg Creek, a tributary of the South Anna River, from Hanover Country Club, 0.3 km north of State Highway 54, south to the contact with Petersburg Granite, Hanover Academy quadrangle, Hanover County. Named for the village of Doswell (Weems, 1980a).

Subunits: **Stagg Creek Member, Falling Creek Member, Newfound Member.**

History: Named, USGS usage (Weems, 1980a). Age (Traverse, 1987; Robbins and Weems, 1988).

Weems (1980a) named the Doswell Formation of the Newark Group in the Taylorsville basin, Virginia. Includes all the Triassic strata of the basin and consists of sandstone, conglomerate, and siltstone and minor amounts of shale, limestone, and coal. Coal measures, confined to an interval from 244 to 610 m above the base of the unit, are the basis for dividing the formation into three members, in ascending order, the Stagg Creek, Falling Creek, and Newfound Members. Unconformably overlies Mississippian Petersburg Granite; unconformably underlies Miocene to Holocene unconsolidated strata. Thickness is 1,524 m at the type section. Age is Late Triassic (middle and late Carnian).

Traverse (1987) extended the age of the Taylorsville basin to at least earliest Carnian, possibly late Ladinian, on the basis of work by Ediger (1986) in the Richmond basin, which contains a palynomorph subzone also recognized by Cornet (1977) in the Taylorsville basin.

Robbins and Weems (1988) stated that the Doswell contains both in situ, middle Carnian palynomorphs and older, darker palynomorphs that suggest a reworked origin, possibly as old as Permian.

Dry Fork Formation of the **Newark Supergroup**

Late Triassic (middle and late Carnian, early Norian)

Virginia, Danville basin

Type section: Cuts along the Southern Railway on Whiteoak Mountain, 0.8 km south of the town of Dry Fork on State Road 718, 0.8 km west of U.S. Highway 29, Mount Hermon quadrangle, Pittsylvania County (Meyertons, 1963).

History: Named in Danville basin (Meyertons, 1963). Equivalent to sandstone facies of the Pine Hall and Stoneville Formations in Dan River basin (Thayer, 1970b). Revised to include conglomerates of the Cedar Forest Formation (abandoned) (Thayer, 1977). Equivalent to the Pine Hall and Stoneville Formations, undivided, in Danville basin, wherever the Cow Branch Formation is absent [usage adopted by USGS] (Thayer, 1980b). Age (Robbins, 1982; R.J. Litwin, USGS, written commun., 1987).

Meyertons (1963) named the Dry Fork Formation in the central and south-central parts of the Danville basin, Virginia. Consists of gradational and intertonguing facies of graywacke and arkose. The graywacke facies is poorly sorted, gray-green conglomerate and sandstone; the arkose facies, which composes most of the unit, consists of sandstone, shale, and conglomerate. Overlies older crystalline rocks. The Dry Fork is laterally contiguous with and time equivalent to the Leakesville Formation and intertongues with both the Cascade Station and Cow Branch Members of the Leakesville. Disconformably underlies the Cedar Forest Formation. Thickness is 1,800 to 2,400 m. Age is Late Triassic.

Thayer (1970b) proposed new stratigraphic nomenclature for the Dan River basin because the rocks of the Dan River basin are intertonguing lithologic facies and not time-stratigraphic units as Meyertons (1963) described in the Danville basin. The Dry Fork and Leakesville Formations of the Danville basin are contemporaneous, mutually intertonguing lithosomes, and the Cedar Forest Formation intertongues with the Dry Fork and the Leakesville. Thayer correlated the Cedar Forest with the conglomerate facies of the Pine Hall and Stoneville Formations in the Dan River basin. The Dry Fork Formation of the Danville basin is equivalent to the sandstone facies of the Pine Hall and Stoneville Formations.

Thayer (1977) revised the Dry Fork Formation to include conglomerate exposed along the basin margins previously assigned by Meyertons (1963) to the Cedar Forest Formation, which Thayer (1977) abandoned. The conglomerate does not disconformably overlie the Dry Fork but is interbedded with sandstone of the Dry Fork, and the Dry Fork and Cedar Forest are lateral facies equivalents. The Dry Fork is divided into intertonguing sandstone, mudrock, and conglomerate facies. Unconformably overlies or is in fault contact with older rocks on both margins of the basin.

Thayer (1980b) extended the Pine Hall, Cow Branch, and Stoneville Formations from the Dan River basin into the southwestern part of the Brosville quadrangle in the Danville basin. The Cow Branch forms the reference beds for this division of rocks and where it is absent there is no basis for distinguishing more than a single unit, the Dry Fork Formation, which is equivalent to the Pine Hall and Stoneville Formations, undivided. Only the Dry Fork is recognized in the northeastern part of the quadrangle.

Robbins (1982) gave the age of the Dry Fork Formation as middle and late Carnian on the basis of pollen and spore assemblages in the Cow Branch Formation.

R.J. Litwin (USGS, written commun., 1987) found palynomorph assemblages in the Stoneville Formation [Dry Fork equivalent], comparable to assemblages believed to be early Norian in the Manassas, Gettysburg, and Passaic Formations, which indicates deposition into at least the early Norian.

East Berlin Formation of the **Newark Supergroup**

Early Jurassic (Hettangian)

Connecticut-Massachusetts, Pomperaug and Hartford basins

Type locality: Road cuts on Connecticut Highway 72, northeast of Berlin and west of the village of East Berlin, Middletown quadrangle, Hartford County, Conn. (Lehmann, 1959).

History: Named in Newark Group, previously mapped as middle shale (in part) of Percival (1842), posterior shales of Davis (1898), and upper sedimentary division of the Meriden Formation of Krynine (1950) (Lehmann, 1959). USGS usage in Connecticut (Schnabel, 1960). Extended to Massachusetts, previously mapped as Longmeadow Sandstone of Emerson (1898a, b) (Colton and Hartshorn, 1966). Revised in Meriden Group (Sanders, 1968). Age (Cornet, 1977). Revised in Newark Supergroup (Rodgers, 1985).

Lehmann (1959) named the upper sedimentary division of the Meriden Formation of Krynine (1950) the East Berlin Formation of the Newark Group in the Hartford basin in Connecticut. Consists of fine-grained arkosic shale and mudstone, mostly grayish-red, and contains some grayish-black shale. Conformably overlies the Holyoke Basalt; conformably underlies the Hampden Basalt.

Schnabel (1960) accepted the East Berlin Formation for use by the USGS in the Avon quadrangle, Connecticut.

Colton and Hartshorn (1966) extended the East Berlin Formation to Massachusetts, where it includes rocks mapped by Emerson (1898a, b) as Longmeadow Sandstone.

Sanders (1968) assigned the East Berlin Formation to the Meriden Group in Connecticut. The term Newark Group was not used. Thickness varies from 457 m in southern Connecticut to 183 m in central Connecticut.

Cornet (1977) gave the age of the East Berlin Formation as Hettangian on the basis of pollen and spores in gray mudstone.

Rodgers (1985) assigned the East Berlin Formation to the Newark Supergroup on the Bedrock Geological Map of Connecticut. Present in the Pomperaug and Hartford basins and shown as equivalent to part of the Meriden Formation of Krynine (1950).

Echo Cove Formation of the Fundy Group

Middle Triassic (Ladinian)
Late Triassic (Carnian)
New Brunswick, Fundy basin

Type locality: Outcrops at Echo Cove on the Bay of Fundy, St. Martins area, Saint John County (NTS 21 H/6W) (Klein, 1962).
Subunits: Berry Beach Member, Fownes Head Member, Melvin Beach Member, Stony Brook Member.
History: Named, previously mapped as upper red sandstone of Powers (1916) and Quaco Formation by Hayes and Howell (1937) (Klein, 1962). Revised, members named (Nadon and Middleton, 1985).

Klein (1962) named the Echo Cove Formation of the Fundy Group in the St. Martins area, New Brunswick. The Echo Cove was informally named the upper red sandstone of Powers (1916) and was mapped as the Quaco Formation by Hayes and Howell (1937). Consists of crudely stratified, lenticularly crossbedded, pale-red conglomerates interbedded with pale-red and grayish-red sandstone and claystone. Overlies and intertongues with the Quaco Formation. Thickness is more than 300 m. Age is Triassic.

Nadon and Middleton (1985) subdivided the Echo Cove Formation into four members, two of which include rocks stratigraphically above those included by Klein (1962) in the Echo Cove. The basal Berry Beach Member gradationally overlies the Quaco

Formation and is equivalent to the upper red sandstone of Powers (1916) and the entire Echo Cove Formation of Klein (1962). The Berry Beach Member is gradationally overlain by the Fownes Head Member, which is gradationally overlain by the Melvin Beach Member. The Stony Brook Member overlies the Quaco Formation at an exposure 10 km inland. Age of the Echo Cove is Middle and Late Triassic based on Ladinian(?) and Carnian palynomorphs in the Fownes Head Member.

†Elizabeth Furnace Conglomerate Member of the **Gettysburg Formation**

Late Triassic

Pennsylvania, Gettysburg basin

Type locality: None designated. Forms a prominent ridge named Elizabeth Furnace Hill, Lititz quadrangle, Lancaster County (Jonas and Stose, 1930).
History: Named, USGS usage (Jonas and Stose, 1930). Replaced by Hammer Creek Formation (Glaeser, 1963). [Also mapped as Robeson Conglomerate by McLaughlin (1939) and Furnace Ridge Conglomerate Member of the Gettysburg by McLaughlin and Gerhard (1953).] Hammer Creek Formation adopted by USGS [Elizabeth Furnace Member abandoned] (Wood, 1980).

Jonas and Stose (1930) named the Elizabeth Furnace Conglomerate Member of the Gettysburg Shale. The conglomerate begins west of Mount Hope in the Lancaster 15-minute quadrangle, forms the ridge of Elizabeth Furnace Hill [Furnace Ridge], which is cut through by the gorge of Hammer Creek, and passes northeastward beyond the quadrangle boundary. Consists of a lenticular mass of conglomerate and hard sandstone. Maximum thickness is 760 m. Age is Late Triassic.

Glaeser (1963) defined the Hammer Creek Formation in the area between the Dauphin-Lebanon County line on the west and the Schuylkill River on the east and included rocks previously defined as the Elizabeth Furnace Conglomerate Member of the Gettysburg Formation. The Elizabeth Furnace Member is not utilized in the Hammer Creek Formation.

Wood (1980) adopted for USGS usage the Hammer Creek Formation as defined by Glaeser (1963). [It is implied that the Elizabeth Furnace Member of the Gettysburg Formation, which had been mapped only in the area of the Hammer Creek, is abandoned.]

Falling Creek Member of the **Doswell Formation**

Late Triassic (middle Carnian)

Virginia, Taylorsville basin

Type section: Exposures along Stagg Creek, a tributary of the South Anna River, from Hanover Country Club, 0.3 km north of State Highway 54, south to the contact with Petersburg Granite, Hanover Academy quadrangle, Hanover County. Named for Falling Creek, a tributary of the South Anna River, 3.4 km northwest of Ashland (Weems, 1980a).
History: Named, USGS usage (Weems, 1980a).

Weems (1980a) named the Falling Creek Member as the middle member of the Doswell Formation in the Taylorsville basin in Virginia. Consists of laminated, well-bedded, flaggy sandstone, green siltstone, and green, gray, and black shale and contains minor amounts of limestone and coal. Black shale and sandstone are dominant in the lower half of the member, in which fish and reptile bones occur in lenses. Thin beds of coal are at the top of the member near the center of the basin and about 150 m above the base near the western edge of the basin. Conformably overlies the Stagg Creek Member where the base of the Falling Creek is placed below the first limestone, coal, or black shale in the Doswell. Conformably underlies the Newfound Member where the top of the member is placed at the top of the youngest clay, siltstone, or laminated sandstone. Thickness is 385 m. Age is Late Triassic (middle Carnian) based on palynomorphs studied by Cornet (1977).

Feltville Formation of the **Brunswick Group**
Feltville Formation of the **Newark Supergroup**

Early Jurassic (Hettangian)

New Jersey, Newark basin

Type section: Exposure along ravine at Blue Brook, 1 km south of the dam at Lake Surprise, village of Feltville, Watchung Reservation, Union County (Olsen, 1980b).
Subunit: Informal Washington Valley member.
History: Named, previously mapped as part of the Brunswick Formation (Olsen, 1980b). Member named (Olsen, 1980a). Age (Olsen, 1984a). Revised in Brunswick Group, USGS usage (Lyttle and Epstein, 1987).

Olsen (1980b) named the Feltville Formation of the Newark Supergroup in New Jersey as part of the abandoned (Olsen, 1980b) Brunswick Formation of Kümmel (1897). The Feltville is preserved in the Watchung, New Germantown, Sand Brook, and possibly the Jacksonwald synclines. Originally it may have occupied the whole area of the Newark basin as a wedge-shaped deposit, thickest along the western border. Consists of red siltstone and sandstone; buff, gray, and white feldspathic sandstone; and laminated limestone. Overlies the Orange Mountain basalt; underlies the Preakness Basalt. Measured thickness is 18 m at the type section, which represents about 15 percent of the total thickness. Age is Early Jurassic.

Olsen (1980a) named the informal Washington Valley member of the Feltville Formation. Consists of a single limestone sequence bearing a gross resemblance to a single Lockatong detrital cycle and consists of gray, black, and red siltstone and limestone containing fossil fish, reptile footprints, carbonized plant fossils, and root zones, representing transgressive and deep water facies of lake bed deposits. Occurs in the southern Watchung and New Germantown synclines.

Olsen (1984a) reported a Hettangian age for the Feltville determined by Cornet (1977) on the basis of spore and pollen assemblages.

Lyttle and Epstein (1987) accepted the Feltville Formation of Olsen (1980b) for USGS use and assigned it to the revised Brunswick Group in New Jersey. The Feltville is equivalent to strata that overlie the Jacksonwald Basalt in Pennsylvania and are referred to as the upper part of the Brunswick Group.

†Five Islands Volcanics of the Newark Group

Triassic

Nova Scotia, Fundy basin

Type locality: Outcrops on Five Islands, northern Minas Basin (NTS 21 H/8) (Powers, 1916).
History: Named (Powers, 1916). Revised, rocks assigned to McKay Head Basalt, Blomidon Formation, and North Mountain Basalt (Klein, 1962). Abandoned (Donohoe and Wallace, 1978, 1982).

Powers (1916) named basalt flows and tuff and agglomerate deposits near Five Islands and Swan Creek in the Minas Basin, Nova Scotia, the Five Islands Volcanics of the Newark Group. Flows of fine-grained, dark-gray columnar basalt occur on four of the Five Islands: Gerrish Mountain, Two Islands, McKay Head, and Portapique Mountain. The basalts may be connected with the North Mountain Basalt; they do not appear to be directly related to the tuffs and agglomerates exposed along the shore of Minas Basin in disconnected areas from Greenhill to Five Islands. Tuff deposits as much as 15 m thick underlie the agglomerates, which are 6 to 45 m thick and consist of angular fragments of basalt and amygdaloid in a dark-green matrix. The agglomerates are interbedded with and overlain by red sandstone of the Annapolis Formation and are thought to represent a slightly earlier phase of igneous activity than the North Mountain Basalt. Age is Triassic.

Klein (1962) named the basalt at McKay Head, described as Five Islands Volcanics by Powers (1916), the McKay Head Basalt. West of McKay Head the basal beds of the Blomidon Formation consist of a basalt and siltstone conglomerate in a red silt and clay matrix derived from the McKay Head Basalt. The basalt conglomerate was thought by Powers (1916) to be a pyroclastic unit of the Five Islands Volcanics, lying between the Wolfville and Blomidon Members of the Annapolis Formation. Klein (1962) assigned the basalt at Portapique Mountain, described as Five Islands Volcanics by Powers (1916), to the North Mountain Basalt.

Donohoe and Wallace (1978, 1982) mapped all the basalts in the Fundy basin as North Mountain Basalt of the Fundy Group. Age is Early Jurassic. [The name Five Islands Volcanics is abandoned.]

Fownes Head Member of the Echo Cove Formation

Middle Triassic (Ladinian(?))
Late Triassic (Carnian)

New Brunswick, Fundy basin

Type section: Exposures extending from the lower contact east of Berry Beach to the west end of the unnamed beach immediately southwest of Fownes Head, St. Martins area, Bay of Fundy, Saint John County (NTS 21 H/6W) (Nadon and Middleton, 1985).
History: Named (Nadon and Middleton, 1985).

Nadon and Middleton (1985) named the Fownes Head Member of the Echo Cove Formation in New Brunswick. The name Fownes Head sandstone was used informally by Magnusson (1955) for the Triassic rocks above the Quaco Formation. Consists of gray-green sandstone and shale and contains fossil plant material scattered throughout. Gradationally overlies the Berry Beach Member; gradationally underlies the Melvin Beach Member of the Echo Cove. Thickness is 570 m. Age is Ladinian(?) to Carnian based on palynomorphs near the top of the Fownes Head.

Fundy Group of the **Newark Supergroup**

Middle Triassic (Anisian(?), Ladinian)
Late Triassic (Carnian, Norian)
Early Jurassic (Hettangian)

New Brunswick-Nova Scotia, Fundy basin

Type area: Outcrops in the Bay of Fundy at Grand Manan Island, Maces Bay, St. Martins, and Waterside, New Brunswick; in Digby, Annapolis, Kings, Hants, Colchester, and Cumberland Counties, Nova Scotia; and along the western shore of Chedabucto Bay, Nova Scotia (Klein, 1962).
Subunits: Listed by province.

Lepreau Formation; Honeycomb Point Formation and its Browns Beach and McCumber Point Members; Quaco Formation; Echo Cove Formation and its Berry Beach, Fownes Head, Melvin Beach, and Stony Point Members (New Brunswick).

Chedabucto Formation, Wolfville Formation, Blomidon Formation, North Mountain Basalt, Scots Bay Formation, McCoy Brook Formation (Nova Scotia).

History: Named (Klein, 1962). Revised in Newark Supergroup (Olsen, 1978).

Klein (1962) proposed the name Fundy Group for the red beds and interbedded basalts that overlie with angular unconformity the Paleozoic rocks of the Maritime Provinces and are truncated by an erosion surface cutting the top of each of the Chedabucto, Scots Bay, Echo Cove, and Lepreau Formations. The base of the Fundy Group coincides with the base of the Wolfville, Chedabucto, and Lepreau Formations. The name Fundy Group replaced the term Newark Group, which had been applied to the Maritime Provinces in a time-stratigraphic sense.

Olsen (1978) assigned the Fundy Group to the Newark Supergroup, which was revised as an inclusive term. The revision emphasized the close lithologic and structural relations of the basins and allowed the formations of individual basins to be included in specific groups while remaining in a strictly rock-stratigraphic hierarchy.

†Furnace Ridge Conglomerate Member of the **Gettysburg Formation**

Late Triassic

Pennsylvania, Gettysburg basin

Type locality: None designated. Named for Furnace Ridge, Lititz quadrangle, Lancaster County (McLaughlin and Gerhard, 1953).
History: Named (McLaughlin and Gerhard, 1953). Replaced by Hammer Creek Formation (Glaeser, 1963). [Also mapped as Elizabeth Furnace Conglomerate Member of the Gettysburg Formation by Jonas and Stose (1930) and Robeson Conglomerate by McLaughlin (1939). Elizabeth Furnace Member abandoned by implication (Wood, 1980).]

McLaughlin and Gerhard (1953) named the Furnace Ridge Conglomerate Member in the lower part of the Gettysburg lithofacies. Extends from Mount Hope in the west, reaches its maximum in Furnace Ridge [Elizabeth Furnace Hill] at the Hammer

Creek section, and remains prominent beyond the eastern limit of Lebanon and Lancaster Counties, Pa. Consists of coarse quartz-pebble conglomerate that has interbedded red quartzose sandstone. Lies between the lower and middle sandstone members of the Gettysburg. Thickness is 900 m at Hammer Creek. Age is Late Triassic.

Glaeser (1963) defined the Hammer Creek Formation between the Dauphin-Lebanon County line on the west and the Schuylkill River on the east and included rocks previously defined as the Furnace Ridge Conglomerate Member of the Gettysburg Formation, which he does not utilize in the Hammer Creek.

Gettysburg Formation of the **Newark Supergroup**

Late Triassic (late Carnian, Norian)
Early Jurassic (Hettangian)

Maryland-Pennsylvania, Gettysburg basin

Type section: Composite of measured sections in and around Gettysburg, Gettysburg quadrangle, Adams County, Pa. (Stose and Bascom, 1929).

Subunits: **Conewago Conglomerate Member, Heidlersburg Sandstone Member, Arendtsville Fanglomerate Lentil** (Pennsylvania).

History: Named Gettysburg Shale of the Newark Group, USGS usage (Stose and Bascom, 1929). Member defined (Jonas and Stose, 1930). Extended to Maryland (Jonas and Stose, 1938). Members defined (Stose and Jonas, 1939). Redefined Gettysburg lithofacies, member defined (McLaughlin and Gerhard, 1953). Revised in part as Hammer Creek Formation (Glaeser, 1963, 1966). Age (Cornet, 1977). USGS usage of Gettysburg Formation as revised by Glaeser (1963) (Wood, 1980). Gettysburg Formation and Gettysburg Conglomerate described (Berg and others, 1980). Members defined (Berg and others, 1983).

Stose and Bascom (1929) named the upper formation of the Newark Group in the Gettysburg area the Gettysburg Shale; approximately represents the Brunswick Formation of Kümmel (1897), but the exact equivalence was not established. Consists of thick red shales and soft red sandstones and includes all the Triassic strata overlying the New Oxford Formation in this area. The contact with the New Oxford was drawn where softer red beds predominate over harder gray sandstones. Gray sandstone near the middle of the unit was named the Heidlersburg Member. Quartzose conglomerate at the top was named the Arendtsville Fanglomerate Lentil. Where it is intruded by the Gettysburg diabase sill the Gettysburg Shale is altered to hard, purple and black argillite. A small sheet of basalt exposed near Bendersville was reported to be associated with the Gettysburg sill. Total thickness of the composite section is 4,900 m. Age is Late Triassic.

Jonas and Stose (1930) named the Elizabeth Furnace Conglomerate Member in the lower part of the Gettysburg. Described at Hammer Creek in the Lancaster quadrangle.

Jonas and Stose (1938) extended the Gettysburg Shale into the Triassic basin in the area of Emmitsburg and Thurmont in Frederick County, Md.

Stose and Jonas (1939) described the Gettysburg Shale in York County, Pa., where it consists of a basal lenticular zone of red arkosic sandstone and conglomerate named the Conewago Conglomerate Member (Stose and Jonas, 1939); a middle zone of hard, gray and red sandstone named the Heidlersburg Member (Stose and Bascom, 1929);

and, at the top, beds of limestone conglomerate and quartzose fanglomerate, including the Arendtsville Fanglomerate Lentil (Stose and Bascom, 1929).

McLaughlin and Gerhard (1953) described the Gettysburg in the area of Lebanon and Lancaster Counties, Pa., where the basin has a minimum width of 6.5 km, as a sandstone lithofacies. Includes the Furnace Ridge Conglomerate Member near the base. A section at Hammer Creek in the Lancaster quadrangle was described.

Glaeser (1963, 1966) revised the nomenclature in the area of the narrow neck of the Newark-Gettysburg basin, Pennsylvania. Coarse-grained clastic rocks typical of neither the Gettysburg nor the Brunswick Formations were named the Hammer Creek Formation, the boundaries of which were defined by two arbitrary cutoffs. The Hammer Creek-Gettysburg boundary was drawn at the Dauphin-Lebanon County line east of the Susquehanna River, and the Hammer Creek-Brunswick boundary was drawn at a line in the vicinity of the Schuylkill River. Previously, the Gettysburg-Brunswick boundary was defined as a northwest-trending irregularly shaped diabase body in the Morgantown and Terre Hill quadrangles in Lancaster County. West of the narrow neck the Gettysburg Formation was divided into the lower unnamed member, including the Conewago Conglomerate Member of Stose and Jonas (1939), which was not recognized by Glaeser, the Heidlersburg Member, and the upper unnamed member. The Elizabeth Furnace and Furnace Ridge Members in the area of the Hammer Creek Formation were not utilized.

Cornet (1977) gave the age of the Gettysburg Formation as late Carnian and Norian to Early Jurassic. The Aspers basalt flow in the upper Gettysburg is overlain by 230 m of strata dated on the basis of palynomorphs as Early Jurassic.

Wood (1980) accepted Glaeser's (1963) revision of the Gettysburg in the Hammer Creek area.

Berg and others (1980) mapped the Gettysburg Formation composed of reddish-brown to maroon, silty mudstone and shale containing thin red sandstone interbeds and the Gettysburg Conglomerate composed of pebbly, arkosic red sandstone and conglomerate in Dauphin, York, and Adams Counties, Pa. Equivalent to the Hammer Creek Formation and Hammer Creek Conglomerate in Berks, Lancaster, and Lebanon Counties.

Berg and others (1983) divided the Gettysburg Formation into the [informal] lower member containing the Conewago Conglomerate, the Heidlersburg Member, the [informal] upper member containing the basalt at Aspers, and the [informal] fanglomerate members near the top of the formation.

Goose Creek Member of the **Catharpin Creek Formation**

Late Triassic (late Norian)
Early Jurassic (early Hettangian)

Virginia, Culpeper basin

Type locality: Outcrops on the south side of Goose Creek, 2 km east of the confluence of Goose Creek and Little River, Loudoun County (Lindholm, 1979).

History: Named Goose Creek Conglomerate Member of the Bull Run Formation, previously mapped as arkose conglomerate of the Border Conglomerate by Roberts (1928), quartz conglomerate by Toewe (1966), and lower sedimentary unit of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977) (Lindholm, 1979). Revised as Goose Creek Member of the Catharpin Creek Formation, USGS usage (Lee and Froelich, 1989).

Lindholm (1979) named the Goose Creek Conglomerate Member of the Bull Run Formation in the Culpeper basin in Virginia. The outcrop belt extends from north of Haymarket, Prince William County, northward for 32 km. Consists of greenish and grayish pebble conglomerate in irregular lenses separated laterally by sandstone and mudstone. Clasts were derived from Catoctin, Chilhowee, and Weverton metamorphic rocks. Thickness exceeds 900 m.

Lee and Froelich (1989) revised the Goose Creek Conglomerate Member of Lindholm (1979) as the Goose Creek Member of the Catharpin Creek Formation. Forms discontinuous and irregular lenses of red-brown cobble and pebble conglomerate composed mostly of quartz, quartzite, and other metamorphic rocks. Lies at the top of the Catharpin Creek and grades laterally and vertically into arkosic sandstones of the Catharpin Creek; paraconformably underlies the Mount Zion Church Basalt. Thickness exceeds 900 m. No fossils are known. Age is late Norian and early Hettangian based on its stratigraphic position.

Granby Basaltic Tuff of the **Newark Supergroup**

Early Jurassic (Hettangian)

Massachusetts, Hartford basin

Type locality: None designated. Exposed 2 km north of the cemetery in Granby and 1.6 km east of The Notch, Holyoke quadrangle, Hampshire County (Emerson, 1898b).

History: Named Granby tufa (Emerson, 1891). Redefined Granby Tuff (Emerson, 1898a, b). USGS usage, Newark Group (Emerson, 1917). Revised, includes rocks previously mapped as Black Rock Diabase and Hampden Diabase (Balk, 1957). Revised Granby Basaltic Tuff of the Newark Supergroup [includes rocks mapped as Granby Tuff and Blackrock Diabase by Emerson (1898b)] (Zen and others, 1983; Robinson and Luttrell, 1985).

Emerson (1891) named the Granby tufa for diabase tufa in the Triassic basin in Massachusetts. Age is Late Triassic.

Emerson (1898a, b) described the Granby Tuff as well-bedded black tuff and tuffaceous sandstone varying from fine-grained volcanic sandstone to coarse diabase breccia and agglomerate derived from volcanic debris and granitic and gneissoid rocks. The rock material becomes finer from bottom to top and from west to east. Exposed from The Notch southwestward to Mount Tom and lies parallel to the Holyoke Diabase and adjacent to the Blackrock Diabase and underlying Hampden Diabase. The newer dikes lie along the same line as the tuff and are punched up through it. Age is Juratrias [Triassic-Jurassic].

Emerson (1917) mapped the Granby Tuff of the Newark Group. Age is Triassic.

Balk (1957) described the Granby Tuff as a series of tuffs containing interbedded tuffaceous sandstone and conglomerate, diabase, and intrusive pipes, dikes, and sills. As revised, the tuff consists of four units: (1) the Granby Tuff of Emerson (1898a, b), a brown, purple, or maroon compact or stratified diabase tuff or tuffaceous sandstone; (2) the Hampden Diabase of Emerson (1898b), a diabase flow in the Granby Tuff, locally altered, fine-grained, compact or vesicular diabase prominent near the base of the tuff sequence, the upper contact of which is sharp against the Longmeadow [now East Berlin] Sandstone or basaltic tuff; (3) numerous (at least 78) intrusive pipes, dikes, and sills of fine-grained diabase; and (4) the Black Rock diabase breccia (Emerson, 1898a, b), which includes a diabase dike extending from Dry Brook to south of Taylor Notch and ledges of diabase breccia on the north slope of the Holyoke Range, 1.6 km to the northeast. Consists of fragments of diabase, tuffaceous diabase, tuff, and sedimentary rocks in a matrix of vesicular or compact diabase.

Zen and others (1983) mapped the Granby Basaltic Tuff and included in it the original Granby Tuff of Emerson (1898b) as well as parts of the Blackrock Diabase of Emerson (1898b). Overlies the Hampden Basalt, with which it is locally interbedded, or the East Berlin Formation; underlies the Portland Formation. Age is Early Jurassic.

Robinson and Luttrell (1985) revised the Granby Tuff as defined by Emerson (1898b) as the Granby Basaltic Tuff of the Newark Supergroup to better reflect the composition of this friable, well-bedded tuff containing sediment fragments.

Graters Member of the **Passaic Formation** (New Jersey)
Graters Member of the lower part of the **Brunswick Group** (Pennsylvania)
Graters Member of the Brunswick Formation (Pennsylvania, New Jersey)

Late Triassic (Norian)

Pennsylvania-New Jersey, Newark basin

Type locality: None designated. Named for exposures in Landis Brook, west of the town of Graters Ford on Perkiomen Creek, Montgomery County, Pa. (McLaughlin, 1933).

History: Named Graters Members of the Brunswick Formation (McLaughlin, 1933). Revised (McLaughlin, 1944, 1946). Delaware River section (Johnson and McLaughlin, 1957). Revised, USGS usage (Drake and others, 1961). Reassigned to Passaic Formation in New Jersey (Olsen, 1980b). Age (Olsen, 1984a). Reassigned to lower part of Brunswick Group in Pennsylvania (Lyttle and Epstein, 1987).

McLaughlin (1933) named the Graters Members of the Brunswick Formation in the Silverdale section in Pennsylvania. The Graters consists of a group of three thick-bedded, hard, dark-gray or greenish-gray to black shale beds separated by comparable beds of red shale, occurs about 670 m above the base of the Brunswick, and comprises the shales designated F, G, and H in the section along Landis Brook. The outcrop is marked by a ridge that ends before reaching the Schuylkill River to the west.

McLaughlin (1944) showed that gray shales G and H, called the Graters Shales, poorly exposed near the Delaware River, are continuous with gray shales exposed at Graters Ford, 50 km southwest.

McLaughlin (1946) mapped three gray members of the Graters, designated F, G, and H, at Graters Ford and for several miles east and north. From near Sellersville to east of Frenchtown, N.J., there are only two thick gray strata, members G and H.

Johnson and McLaughlin (1957) described the Graters Member at the Delaware River section from Stockton to Milford, N.J., where the Graters is about 100 m thick.

Drake and others (1961) accepted the Graters Member of the Brunswick Formation for USGS use and revised it to include a lower gray unit, shale member G of McLaughlin (1933), average thickness 15 m; an upper gray unit, shale member H of McLaughlin (1933), average thickness 13 m; and the intervening red shales, average thickness 13 m. The Graters is 432 m stratigraphically above the base of the Brunswick in the Delaware Valley section from Stockton to a point 3 mi west of Milford, N.J.

Olsen (1980b) reassigned the Graters Member from the abandoned (Olsen, 1980b) Brunswick Formation to the Passaic Formation, which replaced the lower part of the Brunswick.

Olsen (1984a) gave the age of the Graters Member of the Passaic Formation as Norian on the basis of spores (Cornet, 1977).

Lyttle and Epstein (1987) revised the Brunswick and raised it to Group rank. The Graters Member is present in the Passaic Formation of Olsen (1980b) of the Brunswick Group in New Jersey and in the equivalent lower part of the Brunswick Group in Pennsylvania.

†Gwynedd Shales

Late Triassic

Pennsylvania, Newark basin

Type locality: None designated. Exposed at Gwynedd tunnel, Montgomery County (Lyman, 1895).

History: Named (Lyman, 1895). USGS usage (Bascom, 1904). Abandoned, replaced by Lockatong Formation (Bascom and others, 1909). Informal member of Lockatong Formation (Olsen, 1984b, 1986).

Lyman (1895) named the Gwynedd Shales of the New Red series. The shales form prominent ridges from Point Pleasant and from Lower Wakefield Township on the Delaware River to Chalfont, then to the Gwynedd and Phoenixville tunnels near the Schuylkill River, Pa. The Gwynedd consists of hard dark-red, green, gray, and black shales. Overlies the Norristown Shales; underlies the Lansdale Shales. Thickness is about 1,100 m. Fossils indicate a Triassic or Jurassic age.

Bascom (1904) followed the usage of the Pennsylvania Geological Survey in the Philadelphia district, where the Triassic series is represented by the Norristown, Gwynedd, Lansdale, Perkasie, and Pottstown Shales of Lyman (1895). A footnote states that N.H. Darton divided the Triassic into the Stockton Formation, corresponding to the Norristown; the Lockatong Formation, corresponding to the Gwynedd; and the Brunswick Shale, corresponding to the Lansdale, Perkasie, and Pottstown.

Bascom and others (1909) extended to Pennsylvania the classification of the Newark Group established in New Jersey by Darton and others (1908). The Lockatong Formation is approximately equivalent to the Gwynedd Shales, the name of which has not been found acceptable because of its indefinite application to a considerable but variable thickness of beds in the adjoining formations.

Olsen (1984b, 1986) gave the informal name Gwynedd (I and II) member to one of several 100-m sedimentary cycles in the Lockatong Formation.

Hammer Creek Formation of the **Newark Supergroup** (Pennsylvania)
Hammer Creek Conglomerate of the **Newark Supergroup** (Pennsylvania, New Jersey, New York)

Late Triassic

Pennsylvania-New Jersey-New York, Gettysburg and Newark basins

Type section: Exposures along Hammer Creek, Richland quadrangle, Lebanon County, Pa. (McLaughlin and Gerhard, 1953; Glaeser, 1963).

History: Named, previously mapped as Gettysburg Formation and its Elizabeth Furnace and Furnace Ridge Conglomerate Members, Robeson Conglomerate, and Brunswick Formation (Glaeser, 1963, 1966). Extended to New Jersey and New York (Van Houten, 1969). Renamed Hammer Creek Conglomerate (Van Houten, 1980). USGS usage as defined by Glaeser (1963) (Wood, 1980). Hammer Creek Formation and Hammer Creek Conglomerate described (Berg and others, 1980). Boundaries (Lyttle and Epstein, 1987).

Glaeser (1963) named the Hammer Creek Formation of the Newark Group in the narrow neck of the Newark-Gettysburg basin in Pennsylvania. Consists of coarse sandstones and conglomerates, typical of neither the Gettysburg Formation to the west nor the Brunswick Formation to the east. The formation boundaries were defined by two arbitrary cutoffs. The Hammer Creek-Gettysburg boundary was drawn at the Dauphin-Lebanon County line on the west, and the Hammer Creek-Brunswick boundary was a line drawn near the Schuylkill River on the east. The Hammer Creek is characterized by heterogeneous texture and composition and lateral pinching out of individual beds. Overlies the New Oxford Formation in the west and the Stockton Formation in the east. Includes rocks previously defined as the Brunswick Formation, the Gettysburg Formation and its Elizabeth Furnace and Furnace Ridge Conglomerate Members, and the Robeson Conglomerate. [The Hammer Creek section of the Gettysburg Formation was measured by McLaughlin and Gerhard (1953).]

Glaeser (1966) stated that petrographic characteristics indicate that the Hammer Creek and its lateral fine-grained equivalents were derived from rocks that lay north of the outcrop margin and that the Hammer Creek and equivalents spread laterally parallel to the basin axis.

Van Houten (1969) extended the Hammer Creek Formation to include all predominantly conglomeratic deposits in the Newark Group concentrated mainly along the northwest margin of the Newark basin in eastern Pennsylvania, New Jersey, and Rockland County, N.Y. In the central part of the basin, the Hammer Creek interfingers with the Stockton, Lockatong, and Brunswick Formations. Ranges from poorly sorted, well-rounded conglomerate to angular breccia and contains clasts of Paleozoic quartzite, conglomerate, and gneiss.

Van Houten (1980) described as Hammer Creek Conglomerate coarse fanglomerate deposits along the northwest border of the Newark basin east of the Delaware River, N.J. The deposits are lenticular, crudely fining-upward units containing clasts of Paleozoic quartzite ranging in size from 10- to 20-cm cobbles to 30-cm blocks. Interfingers with the Stockton, Lockatong, and Brunswick Formations.

Wood (1980) adopted for USGS usage the Hammer Creek Formation as defined by Glaeser (1963) in the narrow neck of the Gettysburg and Newark basins.

Berg and others (1980) described the Hammer Creek Formation, consisting of fine- to coarse-grained reddish-brown quartzose sandstone containing red shale interbeds, and Hammer Creek Conglomerate, consisting of cobble and pebble quartz conglomerate interbedded with red sandstone, in Berks, Lancaster, and Lebanon Counties, Pa. Equivalent to the Gettysburg Formation and Gettysburg Conglomerate in Dauphin, York, and Adams Counties.

Lyttle and Epstein (1987) described the Hammer Creek Formation near the Schuylkill River where it is a partial lateral correlative of and unconformably overlies the

Stockton Formation and interfingers laterally with the lower part of the Brunswick Group.

Hampden Basalt of the **Newark Supergroup**

Early Jurassic (Hettangian)

Connecticut-Massachusetts, Pomperaug and Hartford basins

Type locality: None designated. Forms the strong foothill ridge east of the Mount Tom Range, Hampden County, Mass. (Emerson, 1898b). *History:* Named Hampden Diabase, previously mapped as the posterior sheet by Percival (1842) [and by Davis (1898)] (Emerson, 1898b). Revised in Newark Group, includes rocks previously mapped as Black Rock Diabase, USGS usage (Emerson, 1917). Revised as a unit of the Granby Tuff (Balk, 1957). Revised Hampden Lava Member of the Meriden Formation, previously mapped as the upper lava flow of the Meriden Formation by Krynine (1950) (Rodgers and others, 1959). Revised Hampden Basalt of the Newark Group (Lehmann, 1959). Revised Hampden Basalt of the Meriden Group (Sanders, 1968). Age (Cornet and others, 1973). Usage (Zen and others, 1983; Rodgers, 1985).

Emerson (1898b) named rocks mapped as the posterior sheet of Percival (1842) the Hampden Diabase. This trap sheet is interbedded with the Longmeadow Sandstone east of the Mount Tom Range and is in a belt extending from Hampshire County, Mass., southwest into Connecticut.

Emerson (1917) mapped rocks previously described as Blackrock Diabase as the Hampden Diabase. Found to be connected with the Hampden and not an isolated intrusive plug.

Balk (1957) mapped the Hampden Diabase as a unit of the Granby Tuff in the Mount Holyoke quadrangle, Massachusetts.

Rodgers and others (1959) named the upper lava flow of the Meriden Formation of Krynine (1950) the Hampden Lava Member of the Meriden Formation. Overlies the upper sedimentary member of the Meriden; underlies the Portland Arkose.

Lehmann (1959) used Hampden Basalt of the Newark Group in the Middletown quadrangle, Connecticut. Conformably overlies the East Berlin Formation; underlies Portland Arkose.

Sanders (1968) mapped the Hampden Basalt as the uppermost unit in the Meriden Group in Connecticut.

Cornet and others (1973) suggested a basal Liassic or possibly late Rhaetic age for the Shuttle Meadow Formation and a Liassic or Sinemurian age for the Portland Formation on the basis of palynoflora. The Shuttle Meadow and Portland are separated by at least 750 m of sediment and basalt flows, including the Hampden Basalt.

Zen and others (1983) mapped the Hampden Basalt in Massachusetts as thin flows of quartz tholeiite, locally intimately associated with Granby Basaltic Tuff.

Rodgers (1985) mapped the Hampden Basalt of the Newark Supergroup in the Pomperaug and Hartford basins in Connecticut.

Haudricks Mountain Member of the **Tibbstown Formation**

Late Triassic (Norian)

Virginia, Barboursville basin

Type locality: Outcrops along the secondary road across the crest of Haudricks Mountain, 2 km north-northwest of Barboursville, Barboursville quadrangle, Orange County (Lee and Froelich, 1989).
History: Named, USGS usage, previously mapped as schist conglomerate of the Border Conglomerate by Roberts (1928) and Barboursville Conglomerate Member of the Bull Run Formation by Lindholm (1979) (Lee and Froelich, 1989).

Lee and Froelich (1989) named the Haudricks Mountain Member of the Tibbstown Formation in the Barboursville basin, Virginia. Consists of sandstone, quartzite, and metasiltstone pebble and cobble conglomerate interbedded with arkosic sandstone. Conformably overlies and intertongues with sandstone of the Tibbstown. Upper contacts have been removed by erosion. Thickness is at least 500 m. Age is probably late Norian based on sporomorphs in gray shale of the Tibbstown.

Heidlersburg Sandstone Member of the **Gettysburg Formation**
Heidlersburg Member of the **Gettysburg Formation**

Late Triassic

Pennsylvania, Gettysburg basin

Type section: Composite section in the vicinity of Heidlersburg, Biglerville quadrangle, Adams County (Stose and Bascom, 1929).
History: Named Heidlersburg Member of the Gettysburg Shale, USGS usage (Stose and Bascom, 1929). Redefined Heidlersburg Sandstone Member (Stose, 1953). Stratigraphic position (Glaeser, 1966). Heidlersburg Member (Berg and others, 1983).

Stose and Bascom (1929) named red beds near the middle of the Gettysburg Shale in Adams County, Pa., the Heidlersburg Member. Consists of red shale and sandstone and green, gray, and black shale interbedded with harder gray to white sandstone. Composite section is 1,460 m thick. Age is Late Triassic.

Stose (1953) described the Heidlersburg Sandstone Member in the lower part of the Gettysburg Shale in the southeastern part of the Carlisle quadrangle, Adams and York Counties, Pa., where it is a ridge-forming, hard, light-colored sandstone.

Glaeser (1966) stated that the geographic and stratigraphic positions of the Lockatong Formation and the Heidlersburg Member of the Gettysburg Formation and their similar dark, fine-grained lithologies suggest that the rocks were deposited in an environment of low mechanical energy near the basin centers and that they may be homotaxial.

Berg and others (1983) placed the Heidlersburg Member of the Gettysburg Formation between the [informal] lower and upper members of the Gettysburg.

Hickory Grove Basalt of the **Culpeper Group**

Early Jurassic (Hettangian)

Virginia, Culpeper basin

Type locality: Exposures along State Road 701, about 180 m N. 82° W. of its intersection with U.S. Highway 15, near Hickory Grove, Middleburg quadrangle, Prince William County (Lee and Froelich, 1989).
History: Named, USGS usage, previously mapped as formation H by Cornet (1977), middle basaltic flow of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977), informal Hickory Grove basalt in the Bull Run Formation by Lee (1979), and basaltic flow unit II of the Buckland Formation by Lindholm (1979) (Lee and Froelich, 1989).

Lee and Froelich (1989) named the Hickory Grove Basalt of the Culpeper Group by following the informal usage of Lee (1979) for the middle sequence of basalt flows extending for 62 km in the western part of the Culpeper basin, Virginia. Consists of two or more flows of tholeiitic basalt and interbedded lenses of sandstone and siltstone and is the least altered of the Culpeper basin basalts. Disconformably or paraconformably overlies the Midland Formation; disconformably or paraconformably underlies the Turkey Run Formation. Thickness ranges from 50 to 300 m. Age is Hettangian based on its stratigraphic position between dated Early Jurassic palyniferous units.

Hitchcock Volcanics of the **Newark Supergroup**

Early Jurassic (Hettangian)

Massachusetts, Hartford basin

Type locality: None designated. Crops out on the north and west slopes of Mount Hitchcock, Holyoke Range, Mount Holyoke quadrangle, Hampshire County (Robinson and Luttrell, 1985).
History: Described (Bain, 1941). Named (Brophy and others, 1967). Mapped (Zen and others, 1983). Revised in Newark Supergroup, USGS usage (Robinson and Luttrell, 1985). Discussion, includes rocks mapped as Holyoke Diabase by Emerson (1898b, 1917) and as Black Rock diabase breccia of the Granby Tuff by Balk (1957) (A.J. Froelich, USGS, oral commun., 1988).

Bain (1941) described a series of volcanic cones piled on top of one another lying in Sugarloaf [New Haven] Arkose just north of Mount Hitchcock. Fingering masses of diabase penetrate arkose north of the base of the volcanic cones. Arkose is dispersed through the diabase, from individual grains to disjointed, irregular masses, indicating that the arkose was incoherent when intruded by the diabase. A persistent volcanic center was located near Mount Hitchcock. Underlies Holyoke lava. Thickness is 300 m.

Brophy and others (1967) described the Hitchcock Volcanics north of Mount Hitchcock. Consists of dissected pyroclastic debris that predates the Holyoke Basalt.

Zen and others (1983) used the name Hitchcock Volcanics on the Bedrock Geologic Map of Massachusetts. Consists of nested cones of basaltic breccia containing fragments of New Haven Arkose and is locally intrusive into arkose near the base. Underlies lava flows of the Holyoke Basalt and (or) the Shuttle Meadow Formation. As mapped by Zen and others (1983), the Hitchcock was correlated with the Deerfield Basalt and the Talcott Basalt. Age is Early Jurassic (Hettangian).

Robinson and Luttrell (1985) accepted the Hitchcock Volcanics of Brophy and others (1967) for USGS usage and assigned it to the Newark Supergroup.

A.J. Froelich (USGS, oral commun., 1988) noted that the main body of the outcrop is related to the Holyoke volcanic vents and flows and includes rocks previously mapped as Holyoke Diabase by Emerson (1898b, 1917), while the tail consists of diabase breccia previously mapped as Black Rock diabase breccia of the Granby Tuff by Balk (1957), which is intrusive into the New Haven Arkose. The diabase breccia is aligned with and chemically similar to the rocks of the throughgoing Bridgeport-Pelham dike system of Early Jurassic(?) intrusive rocks (Martello, 1986; Philpotts and Martello, 1986), which can be related to the youngest flow series, the Hampden Basalt.

Holyoke Basalt of the **Newark Supergroup**

Early Jurassic (Hettangian)

Connecticut-Massachusetts, Pomperaug and Hartford basins

Type locality: None designated. Named for an occurrence in the Holyoke Range, Holyoke quadrangle, Hampshire County, Mass. (Emerson, 1917).

History: Named Holyoke diabase bed [previously mapped as the main trap sheet by Percival (1842) and Davis (1898)] (Emerson, 1891). Redefined Holyoke Diabase (Emerson, 1898b). USGS usage, Newark Group (Emerson, 1917). Revised, Deerfield Diabase removed (Willard, 1951). Revised Holyoke Lava Member of the Meriden Formation, previously mapped as middle lava flow of the Meriden Formation of Krynine (1950) (Rodgers and others, 1959). Revised Holyoke Basalt of the Newark Group (Lehmann, 1959). Revised Holyoke Basalt of the Meriden Group (Sanders, 1968). Age (Cornet and others, 1973). Revised Holyoke Basalt of the Newark Supergroup (Rodgers, 1985).

Emerson (1891) named the Holyoke diabase bed and described it as a sheet that came up through a fissure in the [Chicopee] shale and flowed westward over the [Longmeadow] brownstone and [Sugarloaf] arkose. Contains fragments of shale and limestone at the base. Age is Late Triassic.

Emerson (1898b) redefined the Holyoke Diabase, a dense, fine-grained dark-gray trap rock of monotonously uniform character that extends from the east side of the Holyoke quadrangle to the apex of Mount Tom in Massachusetts and continues south into Connecticut. Includes the Deerfield sheet, a trap bed that lies to the north in Sunderland and Deerfield.

Willard (1951) removed the Deerfield trap sheet from the Holyoke Diabase of the Newark Group and named it the Deerfield Diabase. There is no evidence that the

Holyoke and Deerfield Diabases came from a common conduit or were contemporaneous.

Rodgers and others (1959) named the middle lava flow of the Meriden Formation of Krynine (1950) the Holyoke Lava Member of the Meriden Formation. Lies between the lower and upper sedimentary members of the Meriden. Age is Late Triassic.

Lehmann (1959) revised the Holyoke Basalt of the Newark Group in the Middletown quadrangle, Connecticut. Conformably overlies the Shuttle Meadow Formation; conformably underlies the East Berlin Formation.

Sanders (1968) raised the rank of the Holyoke Member to Holyoke Basalt and assigned it to the Meriden Group in Connecticut.

Cornet and others (1973) suggested a basal Liassic or possibly late Rhaetic age for the Shuttle Meadow Formation and a Liassic or Sinemurian age for the Portland Formation on the basis of palynoflora. These units are stratigraphically separated by at least 750 m of sediment and basalt flows, including the Holyoke Basalt.

Rodgers (1985) mapped the Holyoke Basalt of the Newark Supergroup in the Pomperaug and Hartford basins, Connecticut.

Honeycomb Point Formation of the Fundy Group

Middle Triassic (Ladinian)

New Brunswick, Fundy basin

Type section: Cliff exposures along the Bay of Fundy coast between Honeycomb Point and Quaco Head, St. Martins area, Saint John County (NTS 21 H/6W) (Nadon and Middleton, 1985).

Subunits: Browns Beach Member, McCumber Point Member.

History: Named, previously mapped as lower red sandstone of Powers (1916), Quaco Formation by Hayes and Howell (1937), informal Honeycomb Point sandstone member of the Quaco Formation of Magnusson (1955), and Wolfville Formation of Klein (1962) (Nadon and Middleton, 1985).

Nadon and Middleton (1985) named the Honeycomb Point Formation of the Fundy Group. Exposed along the Bay of Fundy between Honeycomb Point and Quaco Head and was earlier mapped as the lower red sandstone by Powers (1916), the Quaco Formation by Hayes and Howell (1937), and the Wolfville Formation by Klein (1962), but correlation with the type Wolfville in Nova Scotia cannot be established. The name Honeycomb Point sandstone member of the Quaco Formation was used informally by Magnusson (1955) to describe this basal unit of Triassic rocks that unconformably overlies Pennsylvanian sedimentary rocks and underlies the Quaco Formation and is separated from it by an abrupt erosional contact. Divided into the partly coeval Browns Beach Member to the west and the McCumber Point Member to the east. Age is Middle Triassic based on Ladinian(?) and Carnian palynomorphs in the overlying Fownes Head Member of the Echo Cove Formation.

Hook Mountain Basalt of the **Brunswick Group**
Hook Mountain Basalt of the **Newark Supergroup**

Early Jurassic (Hettangian)

New Jersey, Newark basin

Type section: Exposure along U.S. Highway I–80 and Hook Mountain Road through the southern end of Hook Mountain, near Pine Brook, Essex County (Olsen, 1980b).

History: Named, previously named third Watchung Basalt of Darton (1890) (Olsen, 1980b). Age (Olsen, 1984a). Revised in Brunswick Group, USGS usage (Lyttle and Epstein, 1987).

Olsen (1980b) named the uppermost extrusive volcanic unit in the Watchung syncline the Hook Mountain Basalt of the Newark Supergroup. This unit was previously named the third Watchung Basalt of Darton (1890), abandoned by Olsen (1980b), and the informal Hook Mountain basalt of McKee and others (1959) and Baird and Take (1959). This unit is the thinnest of the Newark basin basalts and consists of two flows that extend through most of the syncline. Overlies the Towaco Formation; underlies the Boonton Formation. Thickness is 110 m. Age is Early Jurassic.

Olsen (1984a) gave the age of the Hook Mountain Basalt as Hettangian on the basis of radiometric ages and spores and pollen in the Towaco Formation (Cornet, 1977).

Lyttle and Epstein (1987) accepted the Hook Mountain Basalt of Olsen (1980b) for USGS usage and assigned it to the revised Brunswick Group. [The Watchung Basalt was abandoned.]

Jacksonwald Basalt of the **Brunswick Group**
Jacksonwald Basalt Member of the Brunswick Formation

Early Jurassic (Hettangian)

Pennsylvania, Newark basin

Type locality: None designated. Named for exposures south of the town of Jacksonwald, 6.5 km southeast of Reading, Berks County (Wherry, 1910).

History: Informally named (Wherry, 1910). Named Jacksonwald Basalt Member of the Brunswick Formation (MacLachlan, 1983). Revised Jacksonwald Basalt of the Brunswick Group, USGS usage (Lyttle and Epstein, 1987).

Wherry (1910) described the upper trap sheet at Jacksonwald, Berks County, Pa. The northern, uppermost of the two concentric trap sheets south of Jacksonwald differs from the southern intrusive trap. An extrusive origin is shown by the conformable contact of the base with the underlying shale that is unmetamorphosed and by the compact, fine-grained, glassy texture below, gradually becoming coarser and vesicular above. Wherry inferred that the upper sheet represents a small portion of the same magma that formed the intrusive sheet but which has found its way to the surface. It is apparently the only extrusive trap east of the Susquehanna River in Pennsylvania. Thickness is 270 m.

MacLachlan (1983) named the trap sheet described by Wherry (1910) the Jacksonwald Basalt Member of the Brunswick Formation. Consists of fine-grained, dark-gray basalt, has a vesicular top, and is chemically identical to chill margins of York Haven-type intrusives. Overlies the lower member and underlies the upper member of the Brunswick in the Birdsboro quadrangle. May be too thick to be a single flow unit, but no internal divisions have been identified. Thickness is 150 m. Age is Hettangian based on pollen and spores in the underlying Brunswick Formation.

Lyttle and Epstein (1987) assigned the Jacksonwald trap of Wherry (1910) to the revised Brunswick Group as the Jacksonwald Basalt for USGS usage. Correlates with the Orange Mountain Basalt in New Jersey and may be part of the same flow. Overlies sedimentary strata of the lower part of the Brunswick Group; underlies strata of the upper part of the Brunswick Group.

†Lansdale Shales

Late Triassic

Pennsylvania, Newark basin

Type locality: None designated. Exposed at Lansdale, Bucks County (Lyman, 1895).
History: Named (Lyman, 1895). USGS usage (Bascom, 1904). Abandoned, replaced by Brunswick Shale, in part (Bascom and others, 1909).

Lyman (1895) named the Lansdale Shales in the New Red series in Pennsylvania. Forms a broad belt extending from Uhlerstown and Erwinna on the Delaware River, past Lansdale, to Royersford on the Schuylkill River. Consists of soft, calcareous red shales and scattered green layers.

Bascom (1904) followed the usage of the Pennsylvania Geological Survey in the Philadelphia district, where the Triassic series is represented by the Norristown, Gwynedd, Lansdale, Perkasie, and Pottstown Shales of Lyman (1895). A footnote states that N.H. Darton divided the Triassic into the Stockton Formation, corresponding to the Norristown; the Lockatong Formation, corresponding to the Gwynedd; and the Brunswick Shale, corresponding to the Lansdale, Perkasie, and Pottstown.

Bascom and others (1909) adopted the classification of the Newark Group established in New Jersey by Darton and others (1908). Comprises the Stockton and Lockatong Formations and the Brunswick Shale, which are approximately equivalent to the Norristown, Gwynedd, and Lansdale, respectively, the names of which have not been found acceptable as distinct units because of their indefinite application.

Leakesville Formation

Late Triassic

Virginia, Danville basin

Type section: Exposures along State Road 856 from 0.3 km south of State Road 622 to 0.3 km north of the Virginia-North Carolina State line, Pittsylvania County. Named for nearby town of Leakesville Junction (Meyertons, 1963).
Subunits: Cow Branch Member, Cascade Station Member.
History: Named (Meyertons, 1963). Cow Branch Member revised as Cow Branch Formation in the Dan River basin; Cascade Station Member equivalent to siltstone facies of Pine Hall and Stoneville Formations in the Dan River basin (Thayer, 1970b). Dan River basin names extended to Danville basin (Thayer, 1980b). [The names Leakesville Formation and its Cascade Station Member have been replaced and should be abandoned.]

Meyertons (1963) named the Leakesville Formation in the northern, west-central, and southern parts of the Danville basin. Consists predominantly of red and black claystones, shales, siltstones, sandstones, and conglomerates and, on the basis of color, is divided into the intertonguing black to gray Cow Branch Member and the maroon, red, and brown Cascade Station Member. Outcrop widths ranging from almost zero near Spring Mills in the north to nearly 10 km near Leakesville Junction in the south are accounted for by cross faults and thickening of beds. Overlies older crystalline rocks. Interfingers with the arkosic facies of the laterally contiguous and time-equivalent Dry Fork Formation. Disconformably underlies the Cedar Forest Formation. Thickness at type section is 330 m. Age is Late Triassic.

Thayer (1970b) stated that because the rocks of the Dan River basin are intertonguing lithologic facies and not time-stratigraphic units as Meyertons (1963) described in the Danville basin, new stratigraphic units are proposed for the Dan River basin. The Leakesville and Dry Fork Formations are contemporaneous, mutually intertonguing lithosomes, and the Cedar Forest Formation does not disconformably overlie them but intertongues with them. Thayer revised the Cow Branch Member as the Cow Branch Formation of the Dan River Group in the Dan River basin, and showed the Cascade Station Member equivalent to the siltstone facies of the Pine Hall and Stoneville Formations in the Dan River basin.

Thayer (1980b) extended the Cow Branch Formation back into Virginia in the Danville basin. The Pine Hall and Stoneville Formations were also extended into the Danville basin. [No mention was made of Meyertons's (1963) earlier names for these rocks, the Leakesville Formation and its members, or to their equivalence to the Pine Hall and Stoneville.]

Leesburg Member of the **Balls Bluff Siltstone**

Late Triassic (middle and late Norian)

Virginia-Maryland, Culpeper basin

Type section: Exposures in road cuts southeast of the junction of U.S. Highway 15, Leesburg Bypass, and the Balls Bluff National Cemetery entrance road, Leesburg, Waterford quadrangle, Loudoun County, Va. (Lee, 1977).

History: Named Leesburg Limestone Conglomerate Member of the Bull Run Formation, USGS usage (Lee, 1977). Revised as Leesburg Conglomerate Member of the Bull Run Formation, previously mapped as calico marble and Potomac marble by Merrill (1891) and limestone conglomerate of the border Conglomerate by Roberts (1928) (Lindholm, 1979). Revised as Leesburg Member of the Balls Bluff Siltstone, previously mapped as New Oxford Formation by Jonas and Stose (1938) (Lee and Froelich, 1989).

Lee (1977) named the Leesburg Limestone Conglomerate Member of the Bull Run Formation. Occurs in the northwestern part of the Culpeper basin and is exposed near Leesburg, Va. Consists of fragments of lower Paleozoic limestone, dolomitic limestone, quartzite, quartz, schist, slate, and greenstone in a clayey matrix cemented by calcite and is metamorphosed into a light-gray marble called Potomac marble. Intercalated with Balls Bluff Siltstone. Measured thickness is 76 m at the type section and ranges from 190 m in the Frederick valley to 1,070 m in southern Montgomery County, Md.

Lindholm (1979) revised the Leesburg as the Leesburg Conglomerate Member of the Bull Run Formation. It is a gray carbonate pebble conglomerate in a red sand-silt matrix, the pebbles of which are predominantly dolomite in the north and limestone in the south.

Lee and Froelich (1989) removed the Leesburg from and abandoned the Bull Run Formation and revised the Leesburg as the Leesburg Member of the Balls Bluff Siltstone, of which it forms the lenticular upper member in the northwestern part of the Culpeper basin in Maryland. Interfingers extensively with the Balls Bluff and, to a lesser extent, with the lower part of the overlying Catharpin Creek Formation in Virginia. Thickness ranges from a feather edge to 1,070 m. Age is probably middle and late Norian.

Lepreau Formation of the Fundy Group

Middle Triassic (Ladinian)
Late Triassic (Carnian)

New Brunswick, Fundy basin

Type locality: Along the Point Lepreau shore and the mouth of the Lepreau River, Maces Bay, Bay of Fundy (NTS 21 G/1W) (Klein, 1962).
History: Named, previously named Lancaster and Point Lepreau Formations by Belyea (1939) (Wright and Clements, 1943). Revised in Fundy Group (Klein, 1962). Described, age (Sarjeant and Stringer, 1978; Stringer and Burke, 1985).

Wright and Clements (1943) named the Triassic red beds at both Point Lepreau and along the Lepreau River at Maces Bay, New Brunswick, the Lepreau Formation on the basis of a manuscript map prepared for the Geological Survey of Canada by F.J. Alcock. [These rocks were described by Belyea (1939) as the Lancaster Formation of Pennsylvanian age and the Point Lepreau Formation of Late Pennsylvanian or Triassic age.]

Klein (1962) assigned the Lepreau Formation to the Fundy Group. Consists of crudely stratified, interbedded and thick-bedded, grayish-red sharpstone conglomerate and coarse- and medium-grained poorly sorted sandstone. The conglomerate is similar to the Gerrish facies of the Wolfville Formation and contains the same kind of Pennsylvanian boulders as the Quaco and Echo Cove Formations. Thickness exceeds 1,500 m.

Sarjeant and Stringer (1978) described tracks of the ichnogenus *Isocampe*, similar to tracks described in the Portland Formation in Connecticut and Massachusetts, found in red beds of the Lepreau Formation exposed along the lower Lepreau River at Lepreau Falls. These rocks and those at Lepreau Harbor were placed in the Lancaster Formation of Pennsylvanian age by Belyea (1939). The red beds at Point Lepreau were named the Point Lepreau Formation of Late Pennsylvanian (post-Lancaster) or Triassic age by Belyea (1939) because the rocks at Point Lepreau were less metamorphosed than the lithologically similar red beds named the Lancaster Formation in the area. The beds at Point Lepreau are separated from the beds at Lepreau River by older granitic intrusive rocks and by deformed and overturned Pennsylvanian strata. Folding and cleavage indicate significant compression following deposition of the sediments. Regional correlation and fossil evidence suggest a Middle to Late Triassic age for the Lepreau.

Stringer and Burke (1985) noted that the only previous record of fossil tracks similar to those in the Lepreau Formation is in the Portland Formation of Early Jurassic age. Folds and cleavage in the Lepreau at Lepreau Falls indicate lateral compression of post-Early Jurassic age, perhaps associated with the Palisades disturbance, although such structures are virtually unrecorded in Triassic rocks elsewhere in the Appalachians. Palynological analysis of gray siltstone nearby indicates an early Carboniferous age, but the Carboniferous rocks may represent a fault sliver between the northwestern boundary fault and the Lepreau Formation. Probably, the Lepreau Formation rocks along the Lepreau River are Carboniferous, and the structures at Lepreau Falls are related to Late Pennsylvanian-Early Permian [Alleghany] deformation.

†Leverett Breccia

Early Jurassic

Massachusetts, Deerfield basin

Type locality: None designated. Exposures west of old Mount Toby Station of the Vermont Central Railroad. Named for nearby town of Leverett, Franklin County (Reynolds and Leavitt, 1927).
History: Named, previously mapped as Mount Toby Conglomerate (Reynolds and Leavitt, 1927). Abandoned, assigned to Mount Toby Conglomerate (Willard, 1951).

Reynolds and Leavitt (1927) named a part of the Mount Toby Conglomerate of Emerson (1898b) the Leverett Breccia. Consists of indurated scree composed of dark, fine-grained, metamorphic rock and minor amounts of schist and granite and forms the core of the eastern scarp of Mount Toby. Grades into Mount Toby Conglomerate, which forms an alluvial fan.

Willard (1951) abandoned the Leverett Breccia and included it in the revised Mount Toby Conglomerate. Fragments of this very coarse breccia are sharply angular. Distributed as a fan along the eastern margin of the basin at the base of the Triassic column and interpreted as a talus accumulation.

†Lewisburg (or Lewisberry) Group

Late Triassic

Pennsylvania, Gettysburg basin

Type locality: None designated. Occurs in Dauphin and York Counties (Ashley, 1931).
History: Named (Ashley, 1931). [Replaced by Gettysburg Shale on the Geologic Map of Pennsylvania (Stose and Ljungstedt, 1931).]

Ashley (1931) named the Lewisburg (apparently a misprint for Lewisberry) Group, credited to Bissell (1921), in Dauphin and York Counties, Pa. Consists of soft red shale and some sandstone. Overlies the Conewago Group; underlies the Lisbon (misprint for Lisburn) Group. Thickness is 1,000 m. Age is Late Triassic.

†Lisbon (or Lisburn) Group

Late Triassic

Pennsylvania, Gettysburg basin

Type locality: None designated. Occurs in Dauphin and York Counties (Ashley, 1931).
History: Named (Ashley, 1931). [Replaced by Gettysburg Shale on the Geologic Map of Pennsylvania (Stose and Ljungstedt, 1931).]

Ashley (1931) named the Lisbon (apparently a misprint for Lisburn) Group, credited to Bissell (1921), in Dauphin and York Counties, Pa. Consists of nonfeldspathic, purplish sandstone, red shale, and conglomerate. Overlies the Lewisburg (misprint for Lewisberry) Group. Thickness is 3,200 m. Age is Late Triassic.

Lockatong Formation of the **Newark Supergroup**

Late Triassic (late Carnian)

Pennsylvania-New Jersey, Newark basin

Type locality: Exposures along Lockatong Creek, a tributary of the Delaware River, Hunterdon County, N.J. (Kümmel, 1897). Composite section lies along both sides of the Delaware River, from Lumberville and Raven Rock to Point Pleasant, Bucks County, Pa., and Hunterdon County, N.J. (McLaughlin, 1945).

Subunits: Listed by reference.

Informal first thin red, first big red, triple red, black shale A1, Smiths Corner red, black shale A2, double red, black shale B members (McLaughlin, 1944).

Informal Hoboken, Weehawken, Gwynedd I, Gwynedd II, Byram, and Skunk Hollow and McLaughlin's first thin red, triple red, A1, A2, and B members (Olsen, 1984b).

Informal Hoboken, Weehawken, Gwynned [Gwynedd], North Wales, Byram, Skunk Hollow, Tohicken [Tohickon], Prahls Island, Smiths Corner, Tumble Falls, and Walls Island members (Olsen, 1986).

History: Named Lockatong Series (Kümmel, 1897). Redefined Lockatong Formation of the Newark Group in New Jersey, USGS usage (Darton and others, 1908). Extended to Pennsylvania, previously mapped as Gwynedd Shales of Lyman (1895) (Bascom and others, 1909). Informal members named (McLaughlin, 1944). Composite section (McLaughlin, 1945). Delaware River section (Johnson and McLaughlin, 1957). Redefined Lithofacies (McLaughlin, 1959). Redefined lithosome (Glaeser, 1963). Stratigraphic position (Glaeser, 1966). Age (Olsen and others, 1982). Informal members named (Olsen, 1984b, 1986). Stratigraphic position (Parker and others, 1988).

Kümmel (1897) named the Lockatong Series of the Newark System. Occurs in three belts repeated by faulting in southwestern New Jersey and consists of hard, dark, carbonaceous shale, massive black and purple argillite, gray and green flagstone, dark-red shale, and thin limestone layers. Ripple marks and mud cracks indicate shallow water deposits. Overlies the Stockton Series; underlies the Brunswick Series. Thickness is 1,100 m. Age is Late Triassic.

Darton and others (1908) divided the sedimentary rocks of the Newark Group in New Jersey along the Hudson River at the foot of the Palisades into the Stockton, Lockatong, and Brunswick Formations. They are not separately mapped in this area owing to the heavy drift cover and apparent absence of the distinctive Lockatong black slates, which are here represented by an unknown thickness of light-brownish-red sandstone and shale not distinct from the Brunswick Formation.

Bascom and others (1909) extended to Pennsylvania the classification of the Newark Group established in New Jersey. The Lockatong Formation is approximately equivalent to the Gwynedd Shales of Lyman (1895), the name of which has not been found acceptable because of its indefinite application to a considerable but variable thickness of beds in the adjoining formations.

McLaughlin (1944) named alternating red and gray members in the upper part of the Lockatong Formation in the Tohickon Creek and Delaware River sections. They are the first thin red, first big red, triple red, black shale A1, Smiths Corner red, black shale A2, double red, and black shale B members. The contact with the overlying Brunswick Formation is placed at the top of black shale B and marks the change from predominantly gray to predominantly red shale.

McLaughlin (1945) presented a composite type section of the Lockatong Formation.

Johnson and McLaughlin (1957) presented a composite section along the Delaware River, in which the first thin red, first big red, triple red, A, double red, and B members are described.

McLaughlin (1959) used the terms Stockton, Lockatong, and Brunswick Lithofacies because these units are intertonguing lithologic facies rather than distinct time-stratigraphic units. [This hypothesis was proposed by McLaughlin and Willard (1949).]

Glaeser (1963) used the terms Lockatong and Brunswick lithosomes, which are intertonguing mutually exclusive lithostratigraphic bodies that can be repeated in a vertical succession of strata. Isolated outcrop units may join downdip with their respective main bodies.

Glaeser (1966) noted that the geographic and stratigraphic positions of the Lockatong Formation and the Heidlersburg Member of the Gettysburg Formation and their similar dark, fine-grained lithologies suggest that the rocks were deposited in an environment of low mechanical energy near the basin centers and that they may be homotaxial.

Olsen and others (1982) gave the age of the Lockatong as late Carnian on the basis of fossil fish.

Olsen (1984b) described sedimentary detrital and chemical cycles in the Lockatong and tentatively divided it into 100-m members exposed along the Delaware River: the Hoboken, Weehawken, Gwynedd I, Gwynedd II, Byram, and Skunk Hollow and McLaughlin's (1944) first thin red, triple red, A1, A2, and B members.

Olsen (1986) stated that orbital forcing of climate in early Mesozoic time is reflected by sedimentary cycles, first described by Van Houten (1962), in the Lockatong and Passaic Formations. The cycles have periods in thickness of 5.9, 10.5, 25.2, 32.0, and 96.0 m corresponding to periodicities in time of roughly 25,000, 44,000, 100,000, 133,000, and 400,000 years, as judged by radiometric time scales and varve-calibrated sedimentation rates. The 96.0-m cycles are obvious at map scale and constitute the informal members of the Lockatong and Passaic Formations that were first mapped by McLaughlin (1933, 1943, 1944, 1946, 1959). The Lockatong cycles are named the informal Hoboken, Weehawken, Gwynned [misspelling of Gwynedd], North Wales, Byram, Skunk Hollow, Tohicken [misspelling of Tohickon], Prahls Island, Smiths Corner, Tumble Falls, and Walls Island members.

Parker and others (1988) stated that the Lockatong conformably overlies the Stockton Formation throughout most of the Newark basin in New Jersey and Pennsylvania. Mapping in the northern part of the basin shows Stockton lithology both below and above the Lockatong and confirms that the Lockatong intertongues with the Stockton near the Palisade Diabase and eventually pinches out northeast of Alpine, N.J.

†Longmeadow Sandstone of the Newark Group

Late Triassic
Early Jurassic

Massachusetts, Hartford and Deerfield basins

Type locality: Quarries in East Longmeadow, Springfield South quadrangle, Hampden County, Mass. (Hartshorn and Koteff, 1967).

History: Named Longmeadow brownstone (Emerson, 1891). Redefined Longmeadow Sandstone (Emerson, 1898a, b). Revised, restricted from Deerfield basin, renamed Chicopee Shale, USGS usage (Emerson, 1917). Renamed Turners Falls Sandstone in Deerfield basin (Willard, 1951). Revised, restricted in Hartford basin, renamed New Haven Arkose, East Berlin Formation, and Portland Arkose (Colton and Hartshorn, 1966). Abandoned (Hartshorn and Koteff, 1967).

Emerson (1891) named the Longmeadow brownstone, or fucoidal sandstone, which was deposited in a quieter environment in the central area of sandstones in the Triassic basin. The central rocks are filled with tubular markings called fucoids, "bird tracks," mud cracks, rain drops, curdled drying surfaces, and show every indication of frequent immersion and emersion. Age is Late Triassic.

Emerson (1898a, b) mapped the Longmeadow Sandstone on both sides of the Connecticut River from near Greenfield in the north to near Mount Toby [Deerfield basin] and from the Holyoke Range south to the Connecticut line [Hartford basin]. Quarried on both sides of the Connecticut River at Larrabee's quarries, south of Titans Pier. Consists of quartzose brown sandstone cemented by iron oxide, contains ferruginous concretions previously called fucoids, and has other indications of shallow water deposition. This offshore facies of the Sugarloaf Arkose grades into both the Sugarloaf Arkose and the Mount Toby Conglomerate.

Emerson (1917) restricted the Longmeadow Sandstone of the Newark Group to the area of a broad band extending from Larrabee's quarries southward down the center of a broad depression. Underlies and overlies the Holyoke Diabase in this area. Rocks previously mapped as Longmeadow in the area near Greenfield, Mass. [Deerfield basin], were renamed the Chicopee Shale.

Willard (1951) named the Turners Falls Sandstone in the Greenfield and northern Mount Toby quadrangles. Some of these rocks were mapped as Longmeadow Sandstone by Emerson (1898a), and later as Chicopee Shale by Emerson (1917), but these units cannot be traced into this area [Deerfield basin] from their type areas.

Colton and Hartshorn (1966), in the West Springfield quadrangle, Massachusetts, assigned rocks mapped as Longmeadow by Emerson (1898a, b) to the New Haven Arkose, East Berlin Formation, and Portland Arkose.

Hartshorn and Koteff (1967), in the Springfield South quadrangle, assigned rocks mapped as Longmeadow by Emerson (1898a, b) to the stratigraphically equivalent Portland Arkose, which is here extended into Massachusetts from Connecticut. The Longmeadow Sandstone was abandoned because it is no longer recognized in the type area at East Longmeadow.

Lower barren beds of the Tuckahoe Group

Late Triassic (early Carnian)

Virginia, Richmond basin

Type locality: None designated. Occurs along the eastern margin of the Richmond basin (Shaler and Woodworth, 1899).

History: Named (Shaler and Woodworth, 1899). Age (Cornet, 1977, 1989; Ediger, 1986).

Shaler and Woodworth (1899) named the lower barren beds of the Tuckahoe Group for sandstone and shale that underlie the productive coal measures along the eastern margin of the Richmond basin. The beds are composed of white to gray arkose along the eastern margin and shale on the western margin and overlie older granite. Thickness ranges from 0 to 90 m. Age is Late Triassic.

Cornet (1977) gave the age of palynoflora from the Richmond basin as probably late middle Carnian to early late Carnian.

Ediger (1986) dated the lower barren beds as early late Ladinian on the basis of their stratigraphic position below the productive coal measures and correlation with the lower Lettenkohle.

Cornet (1989) dated the lower barren beds as early Carnian on the basis of biostratigraphy.

Manassas Sandstone of the **Culpeper Group**

Late Triassic (middle and late Carnian)

Virginia-Maryland, Barboursville and Culpeper basins

Type locality: Exposures north and south of Manassas in a belt extending from near Bull Run to a few miles south of Brentsville, Prince William County, Va. (Roberts, 1928).

Subunits: Listed by State.

Rapidan Member (Virginia).

Reston Member, Poolesville Member (Virginia and Maryland).

Tuscarora Creek Member (Maryland).

History: Named (Roberts, 1928). Revised in Newark Group, USGS usage (Lee, 1977). Revised in Culpeper Group (Lindholm, 1979). Age (Traverse, 1987; R.J. Litwin, USGS, oral commun., 1989). Revised, members assigned, includes rocks mapped as parts of the Border Conglomerate by Roberts (1928), New Oxford Formation by Jonas and Stose (1938), and formation K by Cornet (1977) (Lee and Froelich, 1989).

Roberts (1928) named the Manassas Sandstone and included in it red, gray, and yellow sandstone exposed near Manassas, Va. Referred to as the New Red Sandstone, Triassic brownstone, or Newark sandstone and is the same red sandstone as that found in the Connecticut Valley, New Jersey, Pennsylvania, and Maryland and extends in broken belts from south of the Potomac River to the Carolina border. [The name Manassas Sandstone has been used only in the Barboursville and Culpeper basins.] Overlies older crystalline rocks and the Border Conglomerate; underlies the Bull Run Shales. Age is Triassic.

Lee (1977) assigned the Manassas Sandstone to the Newark Group, including the lower Reston Member, a fluvial wash conglomerate fan deposit, that grades into and intertongues with the upper sandstone member, which forms the bulk of the unit. [The Reston Member was mapped as schist conglomerate of the Border Conglomerate by Roberts (1928). The upper sandstone member was Roberts' original Manassas Sandstone.]

Lindholm (1979) assigned the Manassas Sandstone to the Culpeper Group and, by following the usage of Roberts (1928), revised it as the predominantly sandstone sequence that gradationally overlies the revised Reston Formation and gradationally underlies the Bull Run Formation. Exposed in the eastern part of the Culpeper basin north of the Rappahannock River. Maximum thickness ranges from 800 to 900 m.

Traverse (1987) extended the age of the oldest rocks of the Culpeper basin [including the Manassas Sandstone] downward to middle Carnian on the basis of newly discovered palynological localities in the basin.

Lee and Froelich (1989) assigned four members to the Manassas Sandstone as revised by Lee (1977). The three lower members are discrete and separate lenticular conglomerate units, described as units of the border conglomerate by Roberts (1928). These are the Rapidan Member in the Barboursville basin and southeastern part of the Culpeper basin, the Reston Member, revised (Lee and Froelich, 1989), in the east-central part of the Culpeper basin, and the Tuscarora Creek Member in the northern part of the Culpeper basin. Each member unconformably overlies or is in fault contact with older crystalline rocks and grades into or interfingers with the overlying Poolesville Member. Thickness is 200 to 1,030 m. Age is middle Carnian to possibly middle Norian based on spores and plant fossils. The Manassas may be time transgressive.

R.J. Litwin (USGS, oral commun., 1989) found palynomorph assemblages, possibly early Norian, at the top of the Manassas.

†Manchester Group

Late Triassic

Pennsylvania, Gettysburg basin

Type locality: None designated. Occurs in Manchester Township, York County (Ashley, 1931).

History: Named (Ashley, 1931). [Replaced by New Oxford Formation on Geologic Map of Pennsylvania (Stose and Ljungstedt, 1931).]

Ashley (1931) named the Manchester Group, credited to Bissell (1921), in Dauphin and York Counties, Pa. Consists of coarse grained, highly micaceous, relatively soft greenish and gray sandstone, containing interbedded red feldspathic sandstone and shale. Basal unit of the Triassic; underlies the Conewago Group. Thickness is 2,100 to 2,400 m. Age is Late Triassic.

McCoy Brook Formation of the Fundy Group

Early Jurassic (Hettangian)

Nova Scotia, Fundy basin

Type locality: Exposures along McCoy Brook, west of McKay Head, on the north shore of the Minas Basin, Cumberland County (NTS 21 H/8) (Donohoe and Wallace, 1978, 1982).

History: Name used informally, rocks previously mapped as Blomidon Formation by Powers (1916) and Scots Bay Formation by Stevens (1980) (Donohoe and Wallace, 1978, 1982). Age (Olsen, 1981).

Donohoe and Wallace (1978, 1982) mapped the informal McCoy Brook Formation of the Fundy Group in the Minas Basin area of Nova Scotia. [Rocks on the north shore of the Minas Basin at Clarke Head and Gerrish Mountain that were assigned to the Scots Bay Formation by Stevens (1980) and those at McKay Head that were assigned to the Blomidon Formation by Powers (1916) and Klein (1962) were assigned to the McCoy Brook (Donohoe and Wallace, 1978, 1982).] The McCoy Brook is equivalent to the Scots Bay, which is restricted to the eastern shore of the Bay of Fundy. Consists of orange-red to tan quartz wacke, siltstone, and lithic wacke and some aeolian sandstone at the base. Overlies the North Mountain Basalt.

Olsen (1981) noted that reptile footprint assemblages from beds above the McKay Head Basalt, shown (Olsen, 1981) to be a continuation of the North Mountain Basalt, are identical to Connecticut Valley-type assemblages from the more southern Newark Supergroup basins and indicate an Early Jurassic age for the red beds above the basalt and the Clarke Head sands, which are here termed the McCoy Brook Formation as used by Donohoe and Wallace (1978, 1982).

McCumber Point Member of the Honeycomb Point Formation

Middle Triassic (Ladinian)

New Brunswick, Fundy basin

Type section: Exposures along the Bay of Fundy coast from McCumber Point northeast to the contact with the Quaco Formation, near St. Martins, Saint John County (NTS 21 H/6W) (Nadon and Middleton, 1985).
History: Named (Nadon and Middleton, 1985).

Nadon and Middleton (1985) named the McCumber Point Member of the Honeycomb Point Formation. Consists of coarse- and medium-grained sandstones and breccias exposed near St. Martins, New Brunswick, and includes strata extending from the basal unconformity with Pennsylvanian sedimentary rocks to the upper abrupt, erosional contact of the Honeycomb Point with the Quaco Formation. The McCumber Point Member is the eastern, finer grained equivalent of the Browns Beach Member, represents sheetflood alluvial-fan deposits, and may be in part stratigraphically higher than the Browns Beach. Thickness is at least 925 m. Age is Middle Triassic based on Ladinian(?) to Carnian palynomorphs in the overlying Fownes Head Member of the Echo Cove Formation.

†McKay Head Basalt of the Fundy Group

Early Jurassic (Hettangian)

Nova Scotia, Fundy basin

Type locality: Lava flows at McKay Head, north shore of Minas Basin, Cumberland County (NTS 21 H/8) (Klein, 1962).
History: Named [previously mapped as Five Islands Volcanics of Powers (1916)] (Klein, 1962). Age, abandoned (Olsen, 1981). Replaced by North Mountain Basalt (Donohoe and Wallace, 1978, 1982).

Klein (1962) named the McKay Head Basalt of the Fundy Group where amygdaloidal lava flows at McKay Head, Nova Scotia, overlie the Wolfville Formation and underlie the Blomidon Formation. Consists of aphanitic, tholeiitic brownish-gray and olive-gray basalt flows that have zeolite-filled amygdules near the top. Thickness is 210 m. Age is Late Triassic. [The basalt at McKay Head was named the Five Islands Volcanics by Powers (1916).]

Olsen (1981) stated that reptile footprint assemblages from the boundary between the type sections of the Wolfville and Blomidon Formations on the south shore of the Minas Basin indicate a Late Triassic age. Reptile trackways above the McKay Head Basalt type section at McKay Head appear to be of Early Jurassic age. This is incompatible with Klein's (1962) correlation of the McKay Head with the Wolfville-Blomidon type boundary. Olsen suggested that the McKay Head Basalt at McKay Head, Clarke Head, and Blue Sac is not an isolated flow of Late Triassic age but is a continuation of the Early Jurassic North Mountain Basalt, which overlies both the Wolfville and Blomidon Formations. The name McKay Head Basalt is no longer applicable.

Donohoe and Wallace (1978, 1982) mapped all the basalts in the Fundy basin as North Mountain Basalt of the Fundy Group.

Melvin Beach Member of the Echo Cove Formation

Late Triassic (Carnian)

New Brunswick, Fundy basin

Type section: Exposure at Melvin Beach on the Bay of Fundy, St. Martins area, Saint John County (NTS 21 H/6W) (Nadon and Middleton, 1985).
History: Named (Nadon and Middleton, 1985).

Nadon and Middleton (1985) named the Melvin Beach Member of the Echo Cove Formation. Consists of breccia, medium- and coarse-grained sandstone, and red shale. Conformably overlies the Fownes Head Member of the Echo Cove; the upper contact is not visible because the unit is faulted against Precambrian volcanic and metasedimentary rocks. Thickness is 170 m. Age is Carnian based on sporomorphs in the Fownes Head Member.

Meriden Formation of the **Newark Supergroup**
Meriden Group

Early Jurassic

Connecticut, Hartford basin

Type locality: Lower sedimentary member: Outcrop on south shore of Shuttle Meadow Reservoir between Meriden and New Britain, New Haven County. Upper sedimentary member: Quarry in Kensington, 2.4 km south of Berlin, Hartford County. Named for the town of Meriden (Krynine, 1950).
Subunits:

Meriden Group: **Talcott Basalt**, **Shuttle Meadow Formation**, **Holyoke Basalt**, **East Berlin Formation**, **Hampden Basalt** (Sanders, 1968).

History: Named Meriden Formation, includes the middle shale and anterior, main, and posterior trap sheets of Percival (1842) and the anterior sandstone and shale, posterior shale, and anterior, main, and posterior trap sheets of Davis (1898) (Krynine, 1950). Members named (Rodgers and others, 1959). Members raised to formation rank, Meriden Formation not used (Lehmann, 1959). Revised as Meriden Group (Sanders, 1968). Revised as Meriden Formation of Krynine (1950), equivalent to Talcott Basalt, Shuttle Meadow Formation, Holyoke Basalt, East Berlin Formation, and Hampden Basalt (Rodgers, 1985).

Krynine (1950) named the Meriden Formation of the Newark Group in central Connecticut. Consists of variegated or dark siltstone, shale, limestone, sandstone, and conglomerate interbedded with three lava flows and is divided into the lower lava flow, lower sedimentary division, middle lava flow, upper sedimentary division, and upper lava flow. Overlies the New Haven Arkose; underlies the Portland Arkose. Age is Late Triassic.

Rodgers and others (1959) named the five members of the Meriden Formation the Talcott Lava Member, lower sedimentary member, Holyoke Lava Member, upper sedimentary member, and Hampden Lava Member.

Lehmann (1959) raised the rank of the members of the Meriden Formation to Talcott Basalt, Shuttle Meadow Formation, Holyoke Basalt, East Berlin Formation, and Hampden Basalt. The term Meriden is not used.

Sanders (1968) raised the Meriden to Group rank and included in it the Talcott, Shuttle Meadow, Holyoke, East Berlin, and Hampden formations.

Rodgers (1985), on the Bedrock Geological Map of Connecticut, showed the Meriden Formation of Krynine (1950) as equivalent to the Talcott, Shuttle Meadow, Holyoke, East Berlin, and Hampden formations of the Newark Supergroup. Age is Early Jurassic.

Midland Formation of the **Culpeper Group**

Early Jurassic (Hettangian)

Virginia, Culpeper basin

Type locality: Exposures of fossil fish-bearing beds along Licking Run, 2 km north of the town of Midland, Midland quadrangle, Fauquier County (Lee and Froelich, 1989).

History: Named, USGS usage, previously mapped as formation I by Cornet (1977), lower sedimentary unit of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977), informal Catharpin Creek member of the Bull Run Formation by Lee (1979), and sedimentary unit I–II of the Buckland Formation by Lindholm (1979) (Lee and Froelich, 1989).

Lee and Froelich (1989) named the Midland Formation of the Culpeper Group in the Culpeper basin, Virginia. Consists of dark-red sandstone interbedded with siltstone, limestone, and microlaminated fossiliferous gray shale and contains the Midland fossil fish-bearing shale beds, first described by Baer and Martin (1949). The Midland occupies a belt about 1 km wide and is in disconformable or paraconformable contact with both the underlying Mount Zion Church Basalt and the overlying Hickory Grove Basalt. Thickness ranges from 150 to 300 m. Age is Hettangian based on sporomorphs (Cornet, 1977).

Millbrook Quarry Member of the **Waterfall Formation**

Early Jurassic (Sinemurian, Pliensbachian(?))

Virginia, Culpeper basin

Type locality: Exposures at Millbrook quarry south of State Highway 55, 1.2 km east of Thoroughfare Gap, Thoroughfare Gap quadrangle, Prince William County (Lee and Froelich, 1989).

History: Named, USGS usage, previously mapped as arkose conglomerate of the Border Conglomerate by Roberts (1928), formation A by Cornet (1977), uppermost part of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977), informal Mountain Run member of the Bull Run Formation by Lee (1979), and upper unit of the Waterfall Formation by Lindholm (1979) (Lee and Froelich, 1989).

Lee and Froelich (1989) named the upper conglomerate and sandstone unit of the Waterfall Formation of Lindholm (1979) the Millbrook Quarry Member. Consists of cobbles of greenstone and minor amounts of quartzite, gneiss, marble, limestone, basalt, and quartz in a sand and silt matrix and is intercalated with lenses of arkosic sandstone and siltstone. Outcrops are discontinuous and occur along the western margin of the central part of the Culpeper basin. The contact with the underlying Waterfall beds is an apparent disconformity; the upper contact has been removed by erosion. Thickness is 450 m near Millbrook quarry. Age is Sinemurian and possibly Pliensbachian based on palynoflora in the underlying Waterfall beds.

Mountain Run Member of the **Tibbstown Formation**

Late Triassic (Norian)

Virginia, Culpeper basin

Type section: Exposures on the east bank of Mountain Run, 640 m southeast of the bridge over the Southern Railroad on State Road 3, Culpeper East quadrangle, Culpeper County (Lee and Froelich, 1989).
History: Named, USGS usage, previously mapped as trap conglomerate of the Border Conglomerate by Roberts (1928), lower sedimentary unit of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977), informal Mountain Run member of the Bull Run Formation by Lee (1979), and Cedar Mountain Conglomerate Member of the Bull Run Formation by Lindholm (1979) (Lee and Froelich, 1989).

Lee and Froelich (1989), following the informal usage of Lee (1979), named the Mountain Run Member of the Tibbstown Formation in the southwestern part of the Culpeper basin, Virginia. Two sequences of greenstone conglomerate occur at the top of the Tibbstown, with which they are gradational or intertonguing. The upper contacts have been removed by erosion. Thickness varies from a feather edge to more than 640 m. Age is probably late Norian based on sporomorphs in gray shale of the Tibbstown.

Mount Toby Formation of the **Newark Supergroup**

Early Jurassic (Sinemurian, Pliensbachian(?))

Massachusetts, Deerfield basin

Type locality: None designated. Exposed in the bed of Roaring Brook on the east flank of Mount Toby and in Gill, Mount Toby quadrangle, Franklin County (Emerson, 1898b).
History: Named Mount Toby conglomerate (Emerson, 1891). Redefined and mapped (Emerson, 1898a, b). USGS usage, in Newark Group (Emerson, 1917). Revised, includes rocks previously mapped as Leverett Breccia, partly replaced by Sugarloaf Formation and Turners Falls Sandstone (Willard, 1951). Revised, replaced by Portland Formation (Leo and others, 1977). Abandoned [in the Hampden quadrangle] (Peper, 1977). Revised as Mount Toby Formation of the Newark Supergroup (Robinson and Luttrell, 1985).

Emerson (1891) named the coarse schist and quartzite conglomerate deposits along the eastern margin of the Triassic basin in Massachusetts the Mount Toby conglomerate. Age is Late Triassic.

Emerson (1898a, b) described the Mount Toby Conglomerate in the Holyoke quadrangle as argillite, quartz schist, and vein quartz in a coarse gravel matrix. Synchronous with the Sugarloaf Arkose to the west and interbedded with the Longmeadow Sandstone. Overlies the Deerfield Diabase; underlies the north and south ends of the Deerfield at Sunderland and Deerfield.

Willard (1951), in the Mount Toby quadrangle, revised the Mount Toby Conglomerate to include only the conglomerates overlying the Deerfield Diabase and the coarse talus breccia on the east face of Mount Toby that was named the Leverett Breccia by Reynolds and Leavitt (1927). As defined by Emerson (1898a, b), the Mount Toby also included arkosic boulder conglomerate underlying the Deerfield Diabase, included (Willard, 1951) in the Sugarloaf Formation, and sandstone overlying the Deerfield, now included in the Turners Falls Sandstone. Age is Late Triassic.

Leo and others (1977), in the Ludlow quadrangle, Hampden and Hampshire Counties, included strata mapped as Mount Toby by Emerson (1898b) in the Portland Formation.

Peper (1977) abandoned the Mount Toby Formation in the Hampden quadrangle. Unmetamorphosed sedimentary rocks, including rocks mapped by Emerson (1898b) as the Mount Toby Conglomerate, Longmeadow Sandstone, and Chicopee Shale, which are structurally and stratigraphically above the Hampden Basalt, were assigned to the Portland Formation. Emerson's units are not time-stratigraphic units and cannot be distinguished on the basis of widely scattered exposures.

Robinson and Luttrell (1985) revised the Mount Toby and renamed it the Mount Toby Formation of the Newark Supergroup. Includes only the sedimentary strata in the Deerfield basin above the slump zone unconformity defined by Cornet (1977) or its projected equivalent at the contact with the underlying Turners Falls Sandstone. Includes conglomerates at the type locality, landslide deposits within the conglomerate, and sandstone and lake beds above the slump zone unconformity, which were formerly included in the Turners Falls Sandstone. Other rocks mapped as Mount Toby Conglomerate by Emerson (1898a, b) in the Hartford, Deerfield, and Northfield basins were assigned to the Sugarloaf, Turners Falls, and Portland formations. Age is Sinemurian and possibly Pliensbachian based on palynoflora discovered in these strata by Cornet (1977).

Mount Zion Church Basalt of the **Culpeper Group**

Early Jurassic (Hettangian)

Virginia, Culpeper basin

Type locality: Outcrops at Mount Zion Church on U.S. Highway 50, Arcola quadrangle, Loudoun County (Lee, 1979).

History: Named, USGS usage, previously mapped as formation J by Cornet (1977), lowest flow of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977), informal Mount Zion Church basalt of the Bull Run Formation by Lee (1979), and basaltic flow unit I of the Buckland Formation by Lindholm (1979) (Lee and Froelich, 1989).

Lee and Froelich (1989) named the lowest basalt flow in the Culpeper basin, Virginia, the Mount Zion Church Basalt of the Culpeper Group by following the informal usage of Lee (1979). Comprises one or two separate flow sheets and extends discontinuously for more than 55 km in the west-central part of the basin. The basalt is tholeiitic, partly porphyritic and vesicular, has columnar joints, and encloses lenses of sandstone and siltstone. Disconformably or paraconformably overlies the

Catharpin Creek Formation; underlies the Midland Formation. Thickness ranges from 3 to 180 m. Age is Hettangian based on palynoflora in underlying and overlying formations.

Newark Supergroup

Middle Triassic (Anisian(?), Ladinian)
Late Triassic (Carnian, Norian)
Early Jurassic (Hettangian, Sinemurian, Pliensbachian)

Type locality: None designated. Named for outcrops at and around Newark, Essex County, N.J. (Redfield, 1856).

Subunits: Listed by basin from south to north.

Deep River (Wadesboro, Sanford, Durham) basin—**Chatham Group: Pekin, Cumnock,** and **Sanford Formations.**

Dan River-Danville basin—**Dan River Group: Dry Fork, Pine Hall, Cow Branch,** and **Stoneville Formations.**

Richmond basin—Tuckahoe Group: Boscabel boulder beds, lower barren beds, productive coal measures; Chesterfield Group: Vinita beds, Otterdale Sandstone.

Taylorsville basin—**Doswell Formation** and its **Stagg Creek, Falling Creek,** and **Newfound Members.**

Barboursville and Culpeper basins—**Culpeper Group: Manassas Sandstone** and its **Rapidan, Tuscarora Creek, Reston,** and **Poolesville Members; Balls Bluff Siltstone** and its **Leesburg Member; Tibbstown Formation** and its **Haudricks Mountain** and **Mountain Run Members; Catharpin Creek Formation** and its **Goose Creek Member; Mount Zion Church Basalt; Midland Formation; Hickory Grove Basalt; Turkey Run Formation; Sander Basalt; Waterfall Formation** and its **Millbrook Quarry Member.**

Gettysburg basin—**New Oxford Formation; Gettysburg Formation** and its **Conewago Conglomerate, Heidlersburg Sandstone,** and **Arendtsville Fanglomerate Members;** basalt at Aspers; **Hammer Creek Formation.**

Newark basin—**Stockton Formation; Lockatong Formation; Brunswick Group: Passaic Formation** and its **Graters** and **Perkasie Members; Jacksonwald Basalt; Orange Mountain Basalt; Feltville Formation; Preakness Basalt; Towaco Formation; Hook Mountain Basalt; Boonton Formation.**

Hartford basin—**New Haven Arkose, Talcott Basalt, Hitchcock Volcanics, Shuttle Meadow Formation, Holyoke Basalt, East Berlin Formation, Hampden Basalt, Granby Basaltic Tuff, Portland Formation.**

Deerfield and Northfield basins—**Sugarloaf Formation, Deerfield Basalt, Turners Falls Sandstone, Mount Toby Formation.**

Fundy basin—Fundy Group: Lepreau Formation; Honeycomb Point Formation and its Browns Beach and McCumber Point Members;

Quaco Formation; Echo Cove Formation and its Berry Beach, Fownes Head, Melvin Beach, and Stony Brook Members; Wolfville Formation; Blomidon Formation; North Mountain Basalt; Scots Bay Formation; McCoy Brook Formation; Chedabucto Formation.

History: Named Newark Group (Redfield, 1856). Redefined Newark System (Russell, 1892). Redefined Newark Group, USGS usage (Merrill and others, 1902). Restricted from Fundy and Dan River basins (Klein, 1962; Thayer, 1970b). Redefined Newark Supergroup (Olsen, 1978). Revised (Froelich and Olsen, 1984). Correlations (Reeside and others, 1957; McKee and others, 1959). Bibliography (Margolis and others, 1986).

Redfield (1856) proposed the designation Newark Group as a convenient name for the New Red Sandstone, including the New Jersey sandstones and those of the Connecticut Valley, with which they are thoroughly identified by footprints and other fossils, and the contemporary sandstones of Virginia and North Carolina. Redfield stated that in 1854, Professor W.B. Rogers recognized the general equivalency and Jurassic age of the eastern and middle belts of Virginia; the eastern or Deep River coal belt of North Carolina; the disconnected tracts of the western belt in North Carolina and Virginia; and the prolonged area of the so-called New Red Sandstone of Maryland, Pennsylvania, and New Jersey.

Russell (1892) used Newark System rather than Group because it conformed with the usage of the International Congress of Geologists. Includes both sedimentary and igneous rocks of Juratrias [Triassic-Jurassic] age of the Atlantic border. This review contains an index of literature through 1890.

Merrill and others (1902) used the term Newark Group, which is accepted by the USGS. Used in the sense given it by Russell (1892), "It should not be applied to any subdivision, nor to the sedimentary rocks as a whole, exclusive of the contemporaneous igneous rocks in areas where such occur."

Reeside and others (1957). Discussion and correlation chart.

McKee and others (1959). Discussion and correlation chart.

Klein (1962) named the Fundy Group in the Fundy basin and Thayer (1970b) named the Dan River Group in the Dan River basin. They did not use the term Newark Group because it was originally applied in a time-stratigraphic sense.

Olsen (1978) raised the rank of the Newark to Supergroup. As defined, includes continental clastic rocks and interbedded basalts of Late Triassic and Early Jurassic age that crop out in discrete elongate basins in the Piedmont, New England, and Maritime Provinces of eastern North America, and probably includes early Mesozoic rocks in the subsurface beneath the Atlantic Coastal Plain and Continental Shelf. Provides an inclusive term for all the lithologically and structurally related rocks of these basins. The redefinition preserves the original meaning of Redfield's (1856) definition, allows the formations of individual basins to be included in specific groups while remaining in a strictly rock-stratigraphic hierarchy, and permits flexibility for future subdivision. Olsen assigned the Chatham, Dan River, Tuckahoe, Chesterfield, and Fundy Groups to the Newark Supergroup.

Froelich and Olsen (1984) revised the Newark Supergroup to include only continental clastic rocks and interbedded basalts of Late Triassic and Early Jurassic age that crop out in discrete elongate basins parallel to the Appalachian orogen in eastern North America. The Newark does not include subsurface rocks beneath the Atlantic Coastal Plain and Continental Shelf because these rocks are poorly understood and are apparently of diverse age, lithology, and origin.

Margolis and others (1986). An annotated list of 1,462 references on the early Mesozoic basins of eastern North America, indexed by author, topic, and geographic area.

Newfound Member of the **Doswell Formation**

Late Triassic (middle and late Carnian)

Virginia, Taylorsville basin

Type section: Exposures along Stagg Creek, a tributary of the South Anna River, from Hanover Country Club, 0.3 km north of State Highway 54, south to the contact with Petersburg Granite, Hanover Academy quadrangle, Hanover County. Named for Newfound River, a tributary of the South Anna River (Weems, 1980a).
History: Named, USGS usage (Weems, 1980a).

Weems (1980a) named the Newfound Member as the upper member of the Doswell Formation in the Taylorsville basin in Virginia. Consists of two broadly intertonguing facies, a massive, crossbedded sandstone and conglomerate facies, and a massive, brown and red sandstone and siltstone facies. Conformably overlies the Falling Creek Member and nonconformably underlies Miocene to Holocene unconsolidated strata. Thickness is 915 m. Age is Late Triassic (middle and late Carnian) based on palynomorphs studied by Cornet (1977).

New Haven Arkose of the **Newark Supergroup**

Late Triassic (late Carnian, Norian)
Early Jurassic (Hettangian)

Connecticut-Massachusetts, Pomperaug and Hartford basins

Type locality: Several localities are designated to show facies variations: West slope of West Rock Ridge; north end of Whitney Avenue, Hamden; Hartford Turnpike next to New Haven Country Club; quarries of Fair Haven; Roaring Brook; Hanover Pond south of Meriden; all in New Haven County, Conn. (Krynine, 1950).
History: Mapped as South Britain Conglomerate in the Pomperaug basin (Hobbs, 1901). Named New Haven Arkose of Newark Group in the Hartford basin, previously called western sandstone of Percival (1842) and under sandstone of Davis (1898) (Krynine, 1950). USGS usage (Schnabel, 1960). Stratigraphic position in Connecticut (Schnabel and Eric, 1964). Extended to Massachusetts [previously mapped as Longmeadow Sandstone and Sugarloaf Arkose of Emerson (1898b, 1917)] (Colton and Hartshorn, 1966). Age (Cornet, 1977). Revised (Zen and others, 1983; Robinson and Luttrell, 1985; Rodgers, 1985).

Hobbs (1901) named the South Britain Conglomerate in the Pomperaug basin, Connecticut. [These rocks are now mapped as New Haven Arkose of the Newark Supergroup (Rodgers, 1985).]

Krynine (1950) named the New Haven Arkose of the Newark Group to include all the sediments underlying the lower lava sheet of the Meriden Formation in Connecticut. Consists of coarse alluvial sediments and includes a lower white and gray arkose member, which has a basal conglomerate bed, and an upper pink arkose and red feldspathic sandstone member. Overlies older gneiss and schist. Thickness is 1,500 m near Meriden and 2,700 m near New Haven, where beds may be repeated by faulting. Age is Late Triassic.

Schnabel (1960) accepted the New Haven Arkose for use by the USGS in the Avon quadrangle, Connecticut. Unconformably overlies older crystalline rocks; conformably underlies the Talcott Basalt.

Schnabel and Eric (1964) noted that basalt mapped as Talcott(?) Basalt in the Windsor Locks quadrangle, Connecticut, seems to be stratigraphically lower than the Talcott Basalt to the south. If the Talcott(?) Basalt is older than the southern Talcott Basalt, the beds of the Shuttle Meadow Formation, as mapped (Schnabel and Eric, 1964), which overlies the Talcott(?), are equivalent to beds in the upper part of the underlying New Haven Arkose as mapped to the south. In the northern part of the map area, where the Talcott(?) Basalt is missing, the Shuttle Meadow is arbitrarily cut off, and the New Haven is mapped in contact with the Holyoke Basalt.

Colton and Hartshorn (1966) extended the New Haven Arkose from north-central Connecticut to west-central Massachusetts in the West Springfield quadrangle, where it is light- to dark-reddish-brown arkosic sandstone and arkosic conglomerate. Underlies the Holyoke Basalt. Thickness is at least 1,500 m.

Cornet (1977) assigned an age of late Carnian or early Norian through earliest Jurassic (Hettangian) to the New Haven, on the basis of palynomorphs.

Zen and others (1983) drew the Late Triassic-Early Jurassic boundary in the Hartford basin through clastic rocks of similar lithology below a Lower Jurassic palynofloral zone in gray mudstone in the uppermost part of the New Haven Arkose beneath the Talcott Basalt [in Connecticut]. The New Haven underlies the Shuttle Meadow Formation in Massachusetts [where the Talcott Basalt is missing]. The Hitchcock Volcanics at Mount Hitchcock are intrusive into arkose of the New Haven. In the Deerfield basin Zen and others (1983) drew the Triassic-Jurassic boundary in the uppermost part of the Sugarloaf Formation, which is continuous with and lithically similar to the New Haven Arkose.

Robinson and Luttrell (1985) extended the Shuttle Meadow Formation, which underlies the Holyoke Basalt, from Connecticut into central Massachusetts. [The Shuttle Meadow includes rocks underlying the Holyoke Basalt, where the Talcott Basalt is missing, that were mapped as New Haven Arkose by Schnabel and Eric (1964) and Colton and Hartshorn (1966).]

Rodgers (1985) mapped the New Haven Arkose of the Newark Supergroup in the Pomperaug and Hartford basins, where it underlies the Talcott Basalt or, where the Talcott pinches out, the Shuttle Meadow Formation. Age is Late Triassic.

New Oxford Formation of the **Newark Supergroup**

Late Triassic (middle and late Carnian)

Maryland-Pennsylvania, Gettysburg basin

Type section: Composite of measured sections in and around New Oxford, McSherrystown quadrangle, Adams County, Pa. (Stose and Bascom, 1929).

History: Named New Oxford Formation of the Newark Group, USGS usage (Stose and Bascom, 1929). Extended to Maryland (Jonas and Stose, 1938). Redefined New Oxford lithofacies (McLaughlin and Gerhard, 1953). Age (Cornet, 1977). Restricted from Culpeper basin, Maryland, replaced by Manassas Sandstone and its Poolesville and Tuscarora Creek Members and the Balls Bluff Siltstone (Lee and Froelich, 1989).

Stose and Bascom (1929) named the New Oxford Formation as the basal unit of the Newark Group in the Gettysburg area, Adams County, Pa. Equivalent to the

Stockton Formation of Kümmel (1897) but given a different name because the upper limits of the two units cannot be proved to be the same. Consists of red shale and sandstone and beds of micaceous sandstone, arkose, and conglomerate. The contact with the overlying Gettysburg Shale was drawn where harder gray sandstones become less prominent and softer red beds predominate. Thickness of composite section is 2,100 m. Age is Late Triassic.

Jonas and Stose (1938) extended the New Oxford Formation into the Triassic basins in Frederick County, Md., where map units are red shale and gray to red arkose, basal limestone conglomerate, and basal quartzose conglomerate along the western and eastern borders.

McLaughlin and Gerhard (1953) described the New Oxford Formation as a lithofacies in the area of Lebanon and Lancaster Counties, Pa., where the Triassic basin reaches a maximum width of 6.5 km.

Cornet (1977) gave an age of middle and late Carnian for the New Oxford on the basis of palynoflora.

Lee and Froelich (1989) noted that the New Oxford Formation was extended by Jonas and Stose (1938) into the Frederick County, Md., area of the Culpeper basin. It is no longer recognized in that area and is replaced by the Manassas Sandstone and its Poolesville and Tuscarora Creek Members and by the Balls Bluff Siltstone.

†Norristown Shales

Late Triassic

Pennsylvania, Newark basin

Type locality: None designated. Well exposed at Norristown, Montgomery County (Lyman, 1895).

History: Named (Lyman, 1895). USGS usage (Bascom, 1904). Abandoned, replaced by Stockton Formation (Bascom and others, 1909).

Lyman (1895) named the lowest unit of the New Red series in Pennsylvania the Norristown Shales. The unit extends from Lumberville on the Delaware River southwest to Norristown on the Schuylkill River. Consists of calcareous red shales. Underlies the Gwynedd Shales. Thickness is 1,850 m.

Bascom (1904) followed the usage of the Pennsylvania Geological Survey in the Philadelphia district, where the Triassic series is represented by the Norristown, Gwynedd, Lansdale, Perkasie, and Pottstown Shales of Lyman (1895). A footnote states that N.H. Darton divided the Triassic into the Stockton Formation, corresponding to the Norristown; the Lockatong Formation, corresponding to the Gwynedd; and the Brunswick Shale, corresponding to the Lansdale, Perkasie, and Pottstown.

Bascom and others (1909) extended to Pennsylvania the classification of the Newark Group established in New Jersey by Darton and others (1908). The Stockton Formation is approximately equivalent to the Norristown Shales, the name of which has not been found acceptable because of its indefinite application.

North Mountain Basalt of the Fundy Group

Early Jurassic (Hettangian)

New Brunswick-Nova Scotia, Fundy basin

Type locality: None designated. Principal reference section: Petit Passage, opposite Tiverton, southwest of Digby, Digby County, Nova Scotia (NTS 21 B/8) (Lollis, 1959). Named for North Mountain, Nova Scotia (Powers, 1916).

History: Named in Newark Group (Powers, 1916). Revised in Fundy Group, includes rocks mapped as Five Islands Volcanics by Powers (1916) (Klein, 1962). Age (Hyatsu, 1979). Revised, includes rocks mapped as McKay Head Basalt by Klein (1962) (Olsen, 1981). Mapped (Donohoe and Wallace, 1978, 1982).

Powers (1916) named the North Mountain Basalt of the Newark Group for North Mountain, Nova Scotia, where basalt is exposed for a distance of 190 km along the Bay of Fundy from Brier Island to Cape Blomidon. Also includes the basalt flows at Isle Haute, Cape d'Or, Cape Sharp, and Partridge Island, Nova Scotia, and Grand Manan Island, New Brunswick. Consists of fine-grained dark-gray and greenish, closely jointed columnar basalt. Individual flows are distinguished by thin amygdaloidal bases and thick amygdaloidal tops. Overlies the Wolfville Sandstone [Member] or the Blomidon Shale [Member] of the Annapolis Formation; unconformably underlies the Scots Bay Formation. Thickness is 240 to 300 m. Age is Triassic.

Klein (1962) included basalt at Portapique Mountain, described as Five Islands Volcanics by Powers (1916), in the North Mountain Basalt of the Fundy Group. The North Mountain overlies the time-equivalent and intertonguing Wolfville and Blomidon Formations and underlies the Scots Bay Formation. Believed to be slightly younger than the McKay Head Basalt.

Hyatsu (1979) determined a K–Ar isochron age of 191 ± 2 Ma for five samples of North Mountain Basalt.

Olsen (1981) suggested that the McKay Head Basalt of Klein (1962), described at Clarke Head, McKay Head, and Blue Sac in the Minas Basin, is not an isolated unit of Late Triassic age but rather is a continuation of the North Mountain Basalt of Early Jurassic age. The name McKay Head Basalt is no longer applicable.

Donohoe and Wallace (1978, 1982) mapped all the basalts in the Fundy basin as North Mountain Basalt of the Fundy Group.

Orange Mountain Basalt of the **Brunswick Group**
Orange Mountain Basalt of the **Newark Supergroup**

Early Jurassic (Hettangian)

New Jersey-New York, Newark basin

Type section: Exposures along U.S. Highway I–280, where it cuts through Orange Mountain, local name for First Watchung Mountain, East Orange, Essex County, N.J. (Olsen, 1980b).

History: Named, previously named first Watchung Basalt of Darton (1890) (Olsen, 1980b). Age (Olsen, 1984a). Revised in Brunswick Group, USGS usage (Lyttle and Epstein, 1987).

Olsen (1980b) named basalt flows and interbedded volcaniclastic rock at Orange Mountain (First Watchung Mountain), N.J., the Orange Mountain Basalt of the Newark Supergroup. This basalt unit was the first Watchung Basalt of Darton (1890), which Olsen (1980b) abandoned. Also occurs in the New Germantown and Sand Brook synclines and possibly in the Flemington syncline. Basalts in the Jacksonwald, Oldwick, and Ladentown synclines correlate with and may be remnants of the Orange Mountain Basalt. Overlies the Passaic Formation; underlies the Feltville Formation. Age is Early Jurassic.

Olsen (1984a) dated the Orange Mountain Basalt as Hettangian on the basis of radiometric ages.

Lyttle and Epstein (1987) accepted the Orange Mountain Basalt of Olsen (1980b) for USGS usage and assigned it to the revised Brunswick Group. Comprises at least two tholeiitic, pillowed, pahoehoe and columnar basalt flows that contain interbedded volcaniclastic rocks. Equivalent to the Jacksonwald Basalt in Pennsylvania and may be part of the same flow. [The Watchung Basalt was abandoned.]

Otterdale Sandstone of the Chesterfield Group
Otterdale Sandstone of the **Newark Supergroup**

Late Triassic (late Carnian)

Virginia, Richmond basin

Type locality: None designated. Named for exposures near Otterdale, Chesterfield County (Shaler and Woodworth, 1899).
History: Named (Shaler and Woodworth, 1899). Redefined (Milici and others, 1963). Boundaries (Goodwin and Farrell, 1979). Age (Cornet, 1977, 1989; Ediger, 1986).

Shaler and Woodworth (1899) named a thick series of coarse, often feldspathic, sandstones in the vicinity of Otterdale, Va., in the Richmond basin, the Otterdale sandstones of the Chesterfield Group. The unit contains silicified trunks and fragments of *Araucarioxylon*, thin coal seams, and scattered fragments of jetlike lignite in clay. Conformably overlies the Vinita beds; is the uppermost unit in the basin. Thickness is 150 m. Age is Late Triassic.

Milici and others (1963) used Otterdale Sandstone of the Newark Group on the Geologic Map of Virginia.

Cornet (1977) gave the age of the Richmond palynoflora as probably late middle to early late Carnian, but possibly entirely late middle Carnian.

Goodwin and Farrell (1979) reported results of deep drilling in the western part of the Richmond basin in which 454 m of coarse sandstone and conglomerate comparable to the Otterdale Sandstone were penetrated before a termination in diabase. The Otterdale may continue down to the basement near the western edge of the basin, the lower strata accumulating contemporaneously with the Vinita beds in the interior of the basin and locally interfingering with them.

Ediger (1986) stated that the presence of talus deposits, basal conglomerates, and sharp lithologic variation from underlying units indicates that the lower boundary of the Otterdale is an erosional unconformity, and the Otterdale is the youngest unit in the Richmond basin. Age of the underlying Vinita beds is early Carnian (including middle Carnian of earlier classification) based on palynomorphs.

Cornet (1989) dated the Otterdale as late Carnian and early Jurassic(?) on the basis of biostratigraphy.

Passaic Formation of the **Brunswick Group** (New Jersey, New York)
Passaic Formation of the **Newark Supergroup** (Pennsylvania, New Jersey, New York)

Late Triassic (late Carnian, Norian)
Early Jurassic (Hettangian)

Pennsylvania-New Jersey-New York, Newark basin

Type section: Exposures along U.S. Highway I–80 near Passaic, Essex County, N.J. (Olsen, 1980b).
Subunits: Listed by reference.

Informal members C, D, E, F, **Graters Member**, informal members I, K, L, M, and **Perkasie Member** (McLaughlin, 1933, 1943, 1959).

Informal Metlars and Ukranian members [Mettlars Brook and Ukrainian members of Olsen and Baird (1986)] (Olsen, 1984a).

History: Named, previously mapped as lower part of Brunswick Formation (Olsen, 1980b). Age, members (Olsen, 1984a, 1986; Olsen and Baird, 1986). Revised in Brunswick Group (Lyttle and Epstein, 1987). USGS usage (Parker and others, 1988).

Olsen (1980b) named the Passaic Formation of the Newark Supergroup to replace the lower part of the Brunswick Formation of Kümmel (1897), which Olsen abandoned. Consists of red siltstone, sandstone, and conglomerate and contains the Graters and Perkasie Members. Conformably overlies the Lockatong Formation; conformably underlies the Orange Mountain Basalt. Age is Late Triassic and Early Jurassic.

Olsen (1984a) stated that McLaughlin's (1933, 1943, 1959) members C, D, E, F, Graters, I, K, L, M, and Perkasie of the Brunswick (now Passaic) Formation represent the gray and black portions of 100-m cycles, which are present throughout the entire thickness of the Passaic. The informal Metlars and Ukranian members [Mettlars Brook and Ukrainian members of Olsen and Baird (1986)] are described higher in the section in the Sand Brook syncline in New Jersey, where the Passaic is 3,500 m thick. These are prominent gray and black sequences similar in scale to the Perkasie Member. Age of the lower Passaic is late Carnian, the middle Passaic is early and middle Norian, the upper Passaic is late Norian, and the uppermost Passaic is early Hettangian based on spores (Cornet, 1977).

Olsen (1986) stated that orbital forcing of climate in early Mesozoic time is reflected by sedimentary cycles, first described by Van Houten (1962), in the Lockatong and Passaic Formations. The cycles have periods in thicknesses of 5.9, 10.5, 25.2, 32.0, and 96.0 m, corresponding to periodicities in time of roughly 25,000, 44,000, 100,000, 133,000, and 400,000 years, as judged by radiometric time scales and varve-calibrated sedimentation rates. The 96.0-m cycles are obvious at map scale and constitute the informal members of the Lockatong and Passaic [Brunswick] that were first mapped by McLaughlin (1933, 1943, 1944, 1946, 1959).

Olsen and Baird (1986) described the occurrence of *Atreipus* and associated biota in the gray portions of 100-m Van Houten cycles in the upper part of the Passaic Formation in New Jersey. These are named the informal Mettlars Brook member in the New Brunswick area and the Ukrainian member in the City of Newark and at Ukrainian Village, Mercer County. The age of the Mettlars Brook is probably middle Norian and the age of the Ukrainian, which lies 700 m above the Mettlars Brook member and 1,000 m below the Orange Mountain Basalt, is probably early late Norian based on pollen and spores.

Lyttle and Epstein (1987) assigned the Passaic Formation of Olsen (1980b) to the lower part of the revised Brunswick Group in New Jersey and New York. Equivalent rocks in Pennsylvania, where textural differences make the use of the name Passaic questionable, are assigned to the lower part of the Brunswick Group. The Passaic unconformably overlies older basement rocks or conformably and gradationally overlies and interfingers laterally with the Lockatong Formation; interfingers laterally with the Hammer Creek Formation in the narrow neck near the Schuylkill River; underlies the Orange Mountain Basalt. The Triassic-Jurassic boundary lies within the uppermost 100 m of the Passaic.

Parker and others (1988) accepted for USGS usage the Passaic Formation of Olsen (1980b) of the Brunswick Group in New Jersey and New York. In the central Newark basin it gradationally overlies the Lockatong Formation; north of the pinchout of the Lockatong it directly overlies the Stockton Formation and is divided into four mappable lithofacies units: (1) siltstone, sandstone, mudstone facies; (2) mudstone facies; (3) pebbly sandstone facies; and (4) conglomeratic sandstone facies.

The upward coarsening of fluvial facies of the Passaic in the north may reflect the availability of coarse material, higher stream velocities, or higher stream gradient.

Pekin Formation of the **Chatham Group**

Late Triassic (early and middle Carnian)

North Carolina, Deep River basin, including Wadesboro, Sanford, and Durham subbasins

Type locality: Exposures along the road running due east from Mt. Gilead to the village of Pekin, about 0.8 km east of Little River, Wadesboro basin, Montgomery County (Campbell and Kimball, 1923).
History: Named in Newark Group (Campbell and Kimball, 1923). USGS usage (Reinemund, 1955). Assigned to Chatham Group (Olsen and others, 1982). Age (Cornet, 1977; Traverse, 1987).

Campbell and Kimball (1923) named the Pekin Formation of the Newark Group for exposures near Pekin, N.C., which crop out in a belt along the northwest side of the Deep River basin. The Pekin is the lower red sandstone of the Chatham series of Emmons (1857) and consists of red and brown sandstone, shale, and conglomerate. The hard, basal, gray millstone conglomerate unconformably overlies older metamorphic rocks; underlies the Cumnock Formation. Thickness ranges from 350 to 700 m. Age is Triassic.

Reinemund (1955) accepted the Pekin Formation for use by the USGS. Contacts between the Pekin and the overlying Cumnock Formation are gradational and arbitrary in some places. In general, the top of the Pekin is drawn at the top of the highest persistent red or brown beds below the coal beds.

Cornet (1977) reported that the palynoflora high in the section of the Pekin at the type locality in the Wadesboro basin are more consistent with palynoflora of the Cumnock Formation, which overlies the Pekin farther north but is not recognizable on lithologic grounds in the Wadesboro basin. The Pekin type locality may be as young or younger than the Cumnock (late middle Carnian).

Olsen and others (1982) assigned the Pekin Formation to the Chatham Group of the Newark Supergroup.

Traverse (1987) extended the age of sediments in the Deep River basin to at least earliest Carnian and possibly late Ladinian.

Perkasie Member of the **Passaic Formation** (New Jersey)
Perkasie Member of the lower part of the **Brunswick Group** (Pennsylvania)
Perkasie Member of the Brunswick Formation (New Jersey, Pennsylvania)

Late Triassic (Norian)

Pennsylvania-New Jersey, Newark basin

Type locality: None designated. Described near the Perkasie tunnel, Bucks County, Pa. (Lyman, 1895).
History: Named Perkasie Shales (Lyman, 1895). USGS usage (Bascom, 1904). Replaced by part of Brunswick Shale (Bascom and others, 1909).

Named Sanatoga Member of the Brunswick Formation (McLaughlin, 1933). Revised Perkasie Member of Brunswick Formation (Johnson and McLaughlin, 1957). Revised, boundary restricted (McLaughlin, 1959). USGS usage (Drake and others, 1961). Revised Perkasie Member of Passaic Formation (Olsen, 1980b). Age (Olsen, 1984a). Revised in lower part of Brunswick Group in Pennsylvania (Lyttle and Epstein, 1987).

Lyman (1895) named the Perkasie Shales of the New Red series. Forms a ridge extending from the Delaware River near Milford, N.J., around Stony Point and south of Haycock Mountain, over the Perkasie tunnel to Lederachsville and Sanatoga on the Schuylkill River, Pa. Consists of hard green and dark-red, gray, and black shales. Overlies the Lansdale Shales; underlies the Pottstown Shales. Thickness is 600 m.

Bascom (1904) followed the usage of the Pennsylvania Geological Survey in the Philadelphia district, where the Triassic series is represented by the Norristown, Gwynedd, Lansdale, Perkasie, and Pottstown Shales of Lyman (1895). A footnote states that N.H. Darton divided the Triassic into the Stockton Formation, corresponding to the Norristown; the Lockatong Formation, corresponding to the Gwynedd; and the Brunswick Shale, corresponding to the Lansdale, Perkasie, and Pottstown Shales.

Bascom and others (1909) extended to Pennsylvania the classification of the Newark Group established in New Jersey by Darton and others (1908). The Brunswick Formation is approximately equivalent to the Lansdale Shales, the name of which has not been found acceptable because of its indefinite application. [The Perkasie and Pottstown Shales were not abandoned because they may later prove to be useful member terms.]

McLaughlin (1933) named the highest black shale of the Brunswick in Bucks and Montgomery Counties, Pa., the Sanatoga Member. Forms a part of Lyman's (1895) Perkasie Shales.

Johnson and McLaughlin (1957) designated thick gray argillite that forms the Perkasie ridge the Perkasie Member in the lower part of the Brunswick Formation in New Jersey and Pennsylvania. Described in the Delaware River section where it consists of 44 m of dark-gray and red shale. Extends northeastward along strike and passes into fanglomerate near the border of the Triassic. To the southwest it extends into Montgomery County, Pa., where in places it is merged with the hornfels aureole beneath the diabase sills.

McLaughlin (1959) restricted the Perkasie Member of the Brunswick to a belt of hornfels or gray argillite that forms a prominent ridge from Ottsville to Sellersville, Pa. Separated from the altered shales exposed at the Perkasie tunnel by a belt of red shale. North of Milford, N.J., at the same stratigraphic level, are two gray argillite members, each 15 m thick, separated by 15 m of red shale; at Tohickon Creek the Perkasie is 44 m thick and has 3 m of red shale 12 m above its base. Similar gray argillite members occur at the same stratigraphic level at Lederachsville and Schwenksville, Pa. The members at Perkasie, Milford, and Lederachsville are probably the same.

Drake and others (1961) described the Perkasie Member near the top of the Brunswick Formation north of Milford, N.J., where it consists of a lower gray unit 11.5 m thick, a middle red unit 17 m thick, and an upper gray unit 15 m thick. It is 450 m above the Graters Member of the Brunswick and grades upward and along strike into quartzite fanglomerate. The usage is that of McLaughlin (1959), restricted from the original usage of Lyman (1895), who applied the term to 2,500 ft of shales near the Perkasie tunnel. Fossil footprints are found in siltstone of the upper gray unit in quarries near Milford.

Olsen (1980b) abandoned the Brunswick Formation and reassigned the Perkasie Member to the Passaic Formation, which replaced the lower part of the Brunswick as defined by Kümmel (1897).

Olsen (1984a) gave the age of the Perkasie Member as Norian on the basis of spores (Cornet, 1977).

Lyttle and Epstein (1987) revised the Brunswick and raised it to group rank. The Perkasie Member is present in the Passaic Formation of Olsen (1980b) of the Brunswick in New Jersey and in the equivalent lower part of the Brunswick Group in Pennsylvania.

Pine Hall Formation of the **Dan River Group** (North Carolina)
Pine Hall Formation of the **Newark Supergroup** (Virginia)

Late Triassic (middle Carnian)

North Carolina-Virginia, Dan River-Danville basin

Type locality: Exposures along the Norfolk and Western Railroad tracks from 0.1 to 3.0 km northeast of Pine Hall Station, along the Dan River, Stokes County, N.C. (Thayer, 1970b).

History: Named in Dan River basin; equivalent to Cascade Station Member of Leakesville Formation, Dry Fork Formation, and Cedar Forest Formation, all in the Danville basin (Thayer, 1970b). Extended to Danville basin (Thayer, 1980b). Age (Robbins, 1982). [Usage adopted by USGS (Brown, 1985).]

Thayer (1970b) named the Pine Hall Formation of the Dan River Group as the basal and basin margin unit on the southeastern side of the Dan River basin, North Carolina. Consists of intertonguing, tan and red-brown sandstone, siltstone, and conglomerate facies. Unconformably overlies or is in fault contact with older metamorphic rocks; gradationally underlies and interfingers with the lower part of the Cow Branch Formation. Arbitrary contacts were drawn between the Pine Hall and the overlying Stoneville Formation at both ends of the basin where the Cow Branch is offset or absent. Thayer stated that because the rocks of the Dan River basin are intertonguing lithologic facies and not time-stratigraphic units as Meyertons (1963) described in the Danville basin, new stratigraphic units are proposed for the Dan River basin. Equivalences were noted between the siltstone facies of the Pine Hall and the Cascade Station Member of the Leakesville Formation in the Danville basin, the sandstone facies and the Dry Fork Formation, and the conglomerate facies and the Cedar Forest Formation. Thickness of the Pine Hall ranges from 76 m in the south to 2,100 m in the north. Age is Late Triassic.

Thayer (1980b) extended the Pine Hall Formation to the Danville basin, Virginia. In the southwestern part of the Brosville quadrangle Triassic rocks are divided into the Pine Hall, Cow Branch, and Stoneville Formations. The Cow Branch forms the reference beds for this division of rocks, and, where it is absent, there is no basis for distinguishing more than a single unit, the Dry Fork Formation of Meyertons (1963), which is equivalent to the Pine Hall and Stoneville, undivided. [No mention is made of Meyertons' (1963) earlier name, the Cascade Station Member of the Leakesville Formation, which Thayer (1970b) correlated with the siltstone facies of the Pine Hall and Stoneville.]

Robbins (1982) stated that the age of the Cow Branch Formation is late middle to late Carnian on the basis of pollen and spore assemblages and that the underlying Pine Hall Formation is middle Carnian.

Poolesville Member of the **Manassas Sandstone**

Late Triassic (middle and late Carnian)

Virginia-Maryland, Barboursville and Culpeper basins

Type section: Exposures along road cuts north and northeast of Poolesville, Montgomery County, Md. Reference section: Outcrops along the northern bluffs of the Potomac River extending west for 2 km from the mouth of Seneca Creek, Montgomery County, Md. (Lee and Froelich, 1989).
History: Named, USGS usage, previously mapped as Manassas Sandstone by Roberts (1928), New Oxford Formation by Jonas and Stose (1938), formation K by Cornet (1977), sandstone member of the Manassas Sandstone by Lee (1977), and informal Poolesville member of the Manassas Sandstone by Lee (1979) (Lee and Froelich, 1989). Age (Traverse, 1987; R.J. Litwin, USGS, oral commun., 1989).

Traverse (1987) extended the age of the oldest rocks of the Culpeper basin [including the Poolesville Member of the Manassas] downward to middle Carnian on the basis of newly discovered palynological localities.

Lee and Froelich (1989) named the Poolesville Member of the Manassas Sandstone in the southeastern Barboursville basin and eastern Culpeper basin, Virginia and Maryland, by following the informal usage of Lee (1979). Constitutes the bulk of the Manassas Sandstone in these areas, consists of thick-bedded to massive, red arkosic sandstone composed of feldspar and quartz sand in a clayey silt matrix, and locally contains lenses of sandstone and quartzite pebble conglomerate. Laterally and vertically gradational with the underlying Rapidan, Reston, and Tuscarora Creek Members of the Manassas and with the overlying Balls Bluff Siltstone. Thickness ranges from 200 to 1,000 m. Age is late Carnian based on palynoflora.

R.J. Litwin (USGS, oral commun., 1989) found palynomorph assemblages, possibly early Norian, in the Poolesville Member of the Manassas.

Portland Formation of the **Newark Supergroup**

Early Jurassic (Sinemurian, Pliensbachian, Toarcian(?))

Connecticut-Massachusetts, Pomperaug and Hartford basins

Type locality: None designated. Exposures in the Portland "brownstone" quarries near Middletown, Middlesex County, Conn. (Krynine, 1950).
History: Named Portland Arkose of the Newark Group, previously called eastern sandstone of Percival (1842) and upper sandstone of Davis (1898) (Krynine, 1950). USGS usage (Schnabel, 1960). Extended to Massachusetts, previously mapped as Chicopee Shale and Longmeadow Sandstone by Emerson (1898b, 1917) (Colton and Hartshorn, 1966; Hartshorn and Koteff, 1967). Redefined Portland Formation, previously mapped as Sugarloaf Arkose and Mount Toby Conglomerate by Emerson (1898b, 1917) (Leo and others, 1977). Age (Cornet, 1977). Use (Rodgers, 1985).

Krynine (1950) named the Portland Arkose as the upper unit of the Newark Group in central Connecticut. Consists of red, fluvial arkose, conglomerate, siltstone, and shale. Overlies the Meriden Formation; top is eroded at surface. Age is Late Triassic. Schnabel (1960) accepted the Portland Arkose of the Newark Group for use by the USGS in the Avon quadrangle, Connecticut.

Colton and Hartshorn (1966) and Hartshorn and Koteff (1967) extended the Portland into Massachusetts in the West Springfield and Springfield South quadrangles, where it replaces the stratigraphically equivalent Longmeadow Sandstone, no longer recognized in its type area, and the Chicopee Shale, which is recognized as a fine-grained facies of the Portland. The Longmeadow and Chicopee were abandoned.

Leo and others (1977) mapped sedimentary strata of the Newark Group in the Ludlow quadrangle, Massachusetts, originally described as the Sugarloaf Arkose and Mount Toby Conglomerate of Emerson (1898b), as the Portland Formation, which is more appropriate than Arkose because the clastic sequence includes rock types ranging from siltstone to boulder conglomerate.

Cornet (1977) gave the thickness of the Portland Formation as about 500 m in southern Connecticut, 1,250 m in northern Connecticut, and, due to the presence of younger strata, at least 3,000 m in Massachusetts. Palynofloral zones in the lower Portland range in age from late Sinemurian to early Toarcian. No paleobotanical data were available for the upper Portland, but, if basin subsidence for the upper Portland was comparable to that for the lower Portland, based on average sedimentation rates, the youngest strata in the Portland would be Middle Jurassic Aalenian to Bathonian.

Rodgers (1985) used Portland Formation of the Newark Supergroup in the Pomperaug and Hartford basins on the Bedrock Geological Map of Connecticut.

Pottstown Shales

Late Triassic

Pennsylvania, Newark basin

Type locality: None designated. Exposed near Pottstown, Montgomery County (Lyman, 1895).

History: Named (Lyman, 1895). USGS usage (Bascom, 1904). Replaced by Brunswick Shale (Bascom and others, 1909).

Lyman (1895) named the Pottstown Shales, the uppermost division of the New Red series. The unit occurs at Pottstown and northeastward in the area between the Delaware and Schuylkill Rivers, Pa. Consists of soft, red calcareous shales. Overlies the Perkasie Shales. Thickness is 3,260 m.

Bascom (1904) followed the usage of the Pennsylvania Geological Survey in the Philadelphia district, where the Triassic series is represented by the Norristown, Gwynedd, Lansdale, Perkasie, and Pottstown Shales of Lyman (1895). A footnote states that N.H. Darton divided the Triassic into the Stockton Formation, corresponding to the Norristown; the Lockatong Formation, corresponding to the Gwynedd; and the Brunswick Shale, corresponding to the Lansdale, Perkasie, and Pottstown Shales.

Bascom and others (1909) extended to Pennsylvania the classification of the Newark Group established in New Jersey by Darton and others (1908). Includes the Brunswick Shale, which is approximately equivalent to the Lansdale Shales, the name of which has not been found acceptable because of its indefinite application. [The Perkasie and Pottstown Shales were not abandoned because they may later prove to be useful member terms.]

Prallsville Member of the **Stockton Formation**

Late Triassic

Pennsylvania-New Jersey, Newark basin

Type locality: None designated. Exposed near the mouth of Wickecheoke Creek at Prallsville, 0.8 km northwest of Stockton, Hunterdon County, N.J. (McLaughlin, 1945).
History: Named (McLaughlin, 1945). Delaware River section (Johnson and McLaughlin, 1957).

McLaughlin (1945) named the Prallsville Member of the Stockton Formation in a 300-m section in quarries on both sides of the Delaware River. Includes the Lower Prallsville, gray arkose and conglomerate, 133 m thick; the Middle Prallsville, soft red sandstone and shale, 44 m thick; the Upper Prallsville, heavy arkose, 63 m thick; and an unnamed soft red sandstone and shale, 52 m thick.

Johnson and McLaughlin (1957) described the Prallsville Member in the Delaware River section from Stockton to Milford, N.J. Overlies the Solebury Member; underlies the Cuttalossa Member.

Preakness Basalt of the **Brunswick Group**
Preakness Basalt of the **Newark Supergroup**

Early Jurassic (Hettangian)

New Jersey-New York, Newark basin

Type section: Exposure along U.S. Highway I–280, 2.25 km west of the Orange Mountain Basalt type section, East Orange, Essex County, N.J. Named for Preakness Mountain, the local name for Second Watchung Mountain (Olsen, 1980b).
History: Named, previously named second Watchung Basalt of Darton (1890) (Olsen, 1980b). Age (Olsen, 1984a). Revised in Brunswick Group, USGS usage (Lyttle and Epstein, 1987).

Olsen (1980b) named the middle two to three thick basalt flows and interbedded volcaniclastic rocks at Preakness Mountain in the Watchung syncline the Preakness Basalt of the Newark Supergroup. This unit was the second Watchung Basalt of Darton (1890), which Olsen (1980b) abandoned. Exposures in the New Germantown, Sand Brook, and possibly the Ladentown synclines may be Preakness Basalt. Overlies the Feltville Formation; underlies the Towaco Formation. Thickness is 500 m near type section. Age is Early Jurassic.

Olsen (1984a) gave the age of the Preakness Basalt as Hettangian on the basis of radiometric ages.

Lyttle and Epstein (1987) accepted the Preakness Basalt of Olsen (1980b) for USGS usage and assigned it to the revised Brunswick Group in New Jersey. [The Watchung Basalt was abandoned.]

Productive coal measures of the Tuckahoe Group

Late Triassic (early Carnian)

Virginia, Richmond basin and outliers, Flat Branch and Deep Run basins

Type locality: None designated. Coal was mined extensively near Midlothian, Chesterfield County (Shaler and Woodworth, 1899).
History: Named (Shaler and Woodworth, 1899). Age (Cornet, 1977, 1989; Ediger, 1986).

Shaler and Woodworth (1899) named coal-bearing strata lying near the base of the Newark section in the Richmond basin and outliers the productive coal measures of the Tuckahoe Group. The coal measures consist of three to five seams of bituminous coal interbedded with sandstone and fossiliferous black shale. The coal has been converted to coke where dikes of igneous rocks intrude the coal seams. The upper coal seam is the thickest, ranging from 9 to 12 m thick near Midlothian. Thickness of the entire unit is 150 m. Age is Late Triassic.

Cornet (1977) stated that the age of the Chatham-Richmond-Taylorsville palynoflora is probably late middle to early late Carnian but may be entirely late middle Carnian.

Ediger (1986) assigned an age of middle late Ladinian to earliest Carnian to the productive coal measures on the basis of palynomorphs and correlation with the Germanic Lettenkohle.

Cornet (1989) dated the productive coal measures as early Carnian on the basis of biostratigraphy.

Quaco Formation of the Fundy Group

Middle Triassic (Ladinian)

New Brunswick, Fundy basin

Type section: Exposures along the Bay of Fundy coast from the lower contact at McCumber Point to the upper contact at the west end of Berry Beach, Echo Cove, St. Martins area, Saint John County (NTS 21 H/6W) (Nadon and Middleton, 1985).
History: Named Quaco Conglomerate of the Newark Group (Powers, 1916). Revised Quaco Formation, includes rocks previously mapped as lower and upper red sandstones of Powers (1916) (Hayes and Howell, 1937). Areal extension, includes rocks previously mapped as Red Head and Kennebecasis Formations (Alcock, 1938). Revised Quaco Formation of the Fundy Group, as defined by Powers (1916) (Klein, 1962). Type section, age (Nadon and Middleton, 1985).

Powers (1916) named the Quaco Conglomerate of the Newark Group at Quaco (St. Martins), on the Bay of Fundy, New Brunswick. Consists of pale-yellow stream gravel conglomerate and interbedded thin sandstone beds. Is 140 to 200 m thick and lies between a lower red sandstone member, 90 m thick, and an upper red sandstone member, 240 to 300 m thick, which are correlated with the Annapolis Formation. Age is Triassic.

Hayes and Howell (1937) mapped Triassic sedimentary rocks, including the lower and upper red sandstones and the Quaco Conglomerate of Powers (1916), exposed at three places along the New Brunswick coast of the Bay of Fundy as the Quaco Formation. The westerly exposure extends for 3.2 km between Gardner's [Gardiner] and Tynemouth [Ten Mile] Creeks. At Quaco Head, Carboniferous sedimentary rocks and pre-Carboniferous volcanic rocks separate two remnants of the Quaco, which is continuous under the bay, as shown on a nearby island. The northern exposure extends from the north shore of Quaco Head to beyond St. Martins.

Alcock (1938) extended the Quaco Formation to include outcrops of red clastic rocks along the shore at Lyons Head and Red Head, south and east of the mouth of Little River near Saint John, New Brunswick. These beds previously were correlated with the Red Head Formation or the equivalent Kennebecasis Formation of Mississippian age.

Klein (1962) revised the Quaco Formation of the Fundy Group to include the lithologically distinct and mappable 210-m-thick outcrops of boulder conglomerate east of St. Martins, New Brunswick, as defined by Powers (1916). Hayes and Howell (1937) and Alcock (1938) applied the term to the entire Triassic sequence at St. Martins. The Quaco consists of thick-bedded, lenticularly cross-stratified, poorly sorted, pale-red to grayish-red roundstone boulder conglomerate containing lenses of pebble conglomerate and sandstone. Overlies the Wolfville Formation (lower red sandstone of Powers, 1916) with slight angular unconformity; intertongues with and underlies the Echo Cove Formation (upper red sandstone of Powers, 1916). Age is Late Triassic based on fossils in the Wolfville and Echo Cove.

Nadon and Middleton (1985) designated a type section for the Quaco Formation as revised by Klein (1962). Overlies the Honeycomb Point Formation (Wolfville Formation of Klein, 1962) with abrupt erosional unconformity; gradationally underlies and is interbedded with the Echo Cove Formation. Consists of 190 to 300 m of cobble conglomerate deposited by a major north-flowing braided river. Age is Ladinian based on Ladinian and Carnian sporomorphs in the overlying Fownes Head Member of the Echo Cove Formation.

Rapidan Member of the **Manassas Sandstone**

Late Triassic (middle and late Carnian)

Virginia, Barboursville and Culpeper basins

Type section: Outcrops along the south bank of the Rapidan River, 720 m north of spot elevation 103 m on State Road 681, Unionville quadrangle, near Raccoon Ford, southeast Culpeper East quadrangle, Orange County (Lee, 1980).

History: Named, USGS usage, previously mapped as trap conglomerate of the Border Conglomerate by Roberts (1928), formation K by Cornet (1977), Barboursville Conglomerate Member of the Bull Run Formation by Lindholm (1979), and informal Rapidan member of the Manassas Sandstone by Lee (1980) (Lee and Froelich, 1989). Age (Traverse, 1987).

Traverse (1987) extended the age of the oldest rocks in the Culpeper basin [including the Rapidan Member of the Manassas] downward to the middle Carnian on the basis of newly discovered palynological localities.

Lee and Froelich (1989) named the Rapidan Member of the Manassas Sandstone in the Barboursville basin and the southern part of the Culpeper basin by following the informal usage of Lee (1980). Consists of greenstone pebble, cobble, and boulder conglomerate and minor amounts of sandstone, quartzite, and quartz clasts in a sand and silt matrix. Is the basal unit of the Manassas in the drainage area of the Rapidan River and unconformably overlies and is locally in fault contact with older crystalline rocks; grades laterally and vertically into the overlying Poolesville Member of the Manassas. Thickness ranges from 70 to 140 m. Age is late Carnian based on palynoflora from the overlying Poolesville Member.

Raven Rock Member of the **Stockton Formation**

Late Triassic

Pennsylvania-New Jersey, Newark basin

Type locality: None designated. Exposed in a quarry at Raven Rock on the east bank of the Delaware River, Hunterdon County, N.J. (McLaughlin, 1945).

History: Named (McLaughlin, 1945). Delaware River section (Johnson and McLaughlin (1957).

McLaughlin (1945) named the Raven Rock Member of the Stockton Formation in the Delaware River section. Consists of massive, coarse white and gray arkose. Thickness is 43 m. Age is Late Triassic.

Johnson and McLaughlin (1957) described the Raven Rock Member of the Stockton Formation in the Delaware River section from Stockton to Milford, N.J. Lies 230 m above the Cuttalossa Member and 220 m below the top of the Stockton.

Reston Member of the **Manassas Sandstone**

Late Triassic (middle and late Carnian)

Virginia-Maryland, Culpeper basin

Type section: Outcrop at east end of road cut, 82.5 m from the junction of the south entrance ramp of the Dulles Airport Access Road with Reston Avenue, Reston, Vienna quadrangle, Fairfax County, Va. (Lee, 1977).

History: Named, USGS usage (Lee, 1977). Revised Reston Formation of the Culpeper Group, previously mapped as schist conglomerate of the Border Conglomerate by Roberts (1928) and formation K by Cornet (1977) (Lindholm, 1979). Age (Traverse, 1987). Revised Reston Member of the Manassas Sandstone, previously mapped as New Oxford Formation by Jonas and Stose (1938) (Lee and Froelich, 1989).

Lee (1977) named the lower part of his revised Manassas Sandstone the Reston Member. Consists of dark-red to purple, pink, and gray semicompact sand and fragments of schist, quartz, quartzite, greenstone, and gneiss in a clayey schist matrix. Unconformably overlies older crystalline rocks; grades into and intertongues with the overlying sandstone member of the Manassas. Thickness at type section is 5.5 m. Age is Late Triassic.

Lindholm (1979) revised the Reston Member of Lee (1977) as the Reston Formation of the Culpeper Group. Is a schist conglomerate and underlies the Manassas Sandstone. This usage conforms more closely with Roberts' (1928) original description of the stratigraphy and retains the name Manassas solely for the sandstone overlying the basal conglomerate.

Traverse (1987) extended the age of the oldest rocks of the Culpeper basin [including the Reston Member of the Manassas] downward to middle Carnian on the basis of newly discovered palynological localities.

Lee and Froelich (1989) revised the Reston Member of Lee (1977) as the basal unit of the revised Manassas Sandstone where it is exposed in the drainage areas of the Rappahannock and Potomac Rivers along the eastern margin of the Culpeper basin in Virginia and Maryland. Consists of poorly sorted pebble clasts of igneous and metamorphic rocks in a dusky- to dark-red arkosic sand and clayey silt matrix and interbedded coarse-grained, massive, red sandstone. Unconformably overlies older crystalline rocks and is locally truncated by faults along the basin border. Is laterally and vertically gradational with arkosic sandstone of the overlying Poolesville Member of the Manassas. Thickness is generally less than 30 m. Age is probably late Carnian based on palynoflora in the Poolesville Member.

†Robeson Conglomerate

Late Triassic

Pennsylvania, Gettysburg basin

Type section: None designated. Named for Robeson Township, Berks County (McLaughlin, 1939).

History: Named (McLaughlin, 1939). Replaced by Hammer Creek Formation (Glaeser, 1963). [First mapped east of the Schuylkill River as Brunswick Conglomerate by Wherry (1914) and Jonas (1917). Mapped in Robeson Township, Berks County, by Bascom and Stose (1938) as quartzose conglomerate of the Brunswick Formation. Also mapped west of the Schuylkill River as Elizabeth Furnace Conglomerate Member of the Gettysburg Shale by Jonas and Stose (1930) and Furnace Ridge Conglomerate Member of the Gettysburg by McLaughlin and Gerhard (1953). Elizabeth Furnace Member abandoned by implication (Wood, 1980).]

McLaughlin (1939) named the Robeson Conglomerate. A thick succession of coarse red-brown conglomerate and interbedded arkosic sandstone, having almost no shale, that forms an alluvial fan south of Reading and west of the Schuylkill River in Pennsylvania. Extends across Robeson Township in the Honeybrook quadrangle into the southwest corner of the Reading quadrangle and west across the northern New Holland and Lancaster quadrangles, where it occupies Furnace Ridge, a prominent ridge through the center of the Triassic belt. The source of the conglomerate was at the northern border of the Triassic belt and is conspicuously different from the other parts of the belt. Is the stratigraphic equivalent of the Lockatong and Brunswick Formations to the east and the New Oxford and Gettysburg Formations to the west and grades into them along the strike.

Glaeser (1963) defined the Hammer Creek Formation between the Dauphin-Lebanon County line on the west and the Schuylkill River on the east and included rocks previously defined as the Robeson Conglomerate, which he does not utilize in the Hammer Creek.

†Sanatoga Member of the Brunswick Formation

Late Triassic

Pennsylvania, Newark basin

Type locality: None designated. Named for exposures in a quarry and in a railroad cut at Sanatoga Station on the Schuylkill River, Montgomery County (McLaughlin, 1933).

History: Named, previously mapped as part of Perkasie Shales of Lyman (1895) (McLaughlin, 1933). [Abandoned. Johnson and McLaughlin (1957), McLaughlin (1959), and Drake and others (1961) mapped this unit as the Perkasie Member of the Brunswick. Perkasie is the older name and takes precedence.]

McLaughlin (1933) named the highest black shale member of the Brunswick Formation the Sanatoga Member. Forms a part of Lyman's (1895) Perkasie Shales, which should not be regarded as a definite formation because a large part of it is red shale altered by the diabase intrusion. The Sanatoga is slightly altered in places but does not owe its dark color or hardness to baking. Consists of thick-bedded, hard dark-gray or greenish-gray to black argillite. Lies 600 m above the Graters Member at Perkiomen Creek and 300 m above the Graters at the Schuylkill River section.

Sander Basalt of the **Culpeper Group**

Early Jurassic (Hettangian)

Virginia, Culpeper basin

Type section: Exposures in the northwest part of the Sander quarry, 7.2 km S. 35° E. of Warrenton, on the northeast side of State Road 643, Catlett quadrangle, Fauquier County (Lee, 1979).

History: Named, USGS usage, previously mapped as formations F, D, and B by Cornet (1977), uppermost basalt flow of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977), informal Sander basalt of the Bull Run Formation by Lee (1979), and basaltic flow units III, IV, and V of the Buckland Formation by Lindholm (1979) (Lee and Froelich, 1989).

Lee and Froelich (1989), by following the informal usage of Lee (1979), named the uppermost basalt in the Culpeper basin the Sander Basalt of the Culpeper Group. Consists of four or more flow units of black, mostly holocrystalline or equigranular tholeiitic basalt. Three or more lenticular units of sandstone and siltstone are sandwiched between the flows, which extend for more than 60 km in the western part of the basin. Disconformably or paraconformably overlies the Turkey Run Formation; paraconformably or conformably underlies the Waterfall Formation. Thickness ranges from 140 to 600 m. Age is Hettangian based on palynoflora in shales of the underlying and overlying formations.

Sanford Formation of the **Chatham Group**

Late Triassic (late Carnian)

North Carolina, Deep River basin, including Sanford and Durham subbasins

Type locality: Outcrops around the town of Sanford, Sanford basin, Lee County (Campbell and Kimball, 1923).
History: Named in Newark Group (Campbell and Kimball, 1923). USGS usage (Reinemund, 1955). Age (Cornet, 1977). Assigned to Chatham Group (Olsen and others, 1982).

Campbell and Kimball (1923) defined the Sanford Formation of the Newark Group to include all rocks of Triassic age above the Cumnock Formation in the Deep River coal field of North Carolina. Consists mostly of red conglomerate, sandstone, and shale and includes the upper conglomerate, black or blue shales, and upper red sandstone of Emmons' (1857) Chatham series. Thickness ranges from 1,200 to 1,500 m.

Reinemund (1955) accepted the Sanford Formation for use by the USGS. Conformably overlies the Cumnock Formation in the eastern part of the Sanford basin and the southern part of the Durham basin but appears to lie unconformably on the Pekin Formation in the Colon cross structure.

Cornet (1977) gave the age of the Sanford as late Carnian on the basis of palynoflora in the Pekin and Cumnock Formations.

Olsen and others (1982) assigned the Sanford Formation to the Chatham Group of the Newark Supergroup.

Scots Bay Formation of the Fundy Group

Early Jurassic (Hettangian)

Nova Scotia, Fundy basin

Type locality: Exposures on the south side of Scots Bay, eastern Broad Cove (Klein, 1962). Standard section: 0.53 km southwest of the type locality at lat 45°15′06″ N., long 64°26′24″ W. (NTS 21 H/8) (Thompson, 1974).
History: Named in Newark Group (Powers, 1916). Revised in Fundy Group (Klein, 1962). Revised, areal restriction, rocks assigned to McCoy Brook Formation (Donohoe and Wallace, 1978, 1982). Age (Olsen, 1981).

Powers (1916) named the Scots Bay Formation of the Newark Group at Scots Bay, Nova Scotia, where the rocks crop out in five small synclines along the Bay of Fundy shore. Consists of white calcareous sandstone interbedded with shale and chert and contains fish fossils. Unconformably overlies the North Mountain Basalt. Thickness is 7.5 to 600 m. Age is Triassic.

Klein (1962) assigned the Scots Bay Formation to the Fundy Group. Consists of fine-grained gray and brown sandstone and purple and greenish-gray claystone interbedded with limestone, jasperoid, and chert. Unconformably overlies the North Mountain Basalt in six small synclinal basins along the Bay of Fundy shore. Age is Late Triassic based on fossils.

Donohoe and Wallace (1978, 1982) restricted the Scots Bay Formation to the eastern shore of the Bay of Fundy. Rocks on the north shore of the Minas Basin at Clarke

Head and Gerrish Mountain, which had been assigned to the Scots Bay by Stevens (1980), were assigned to the equivalent McCoy Brook Formation.

Olsen (1981) reported that reptile footprint assemblages from beds above the McKay Head Basalt, equivalent to the North Mountain Basalt, are identical to Connecticut Valley-type assemblages and indicate an Early Jurassic age for these beds, which include the McCoy Brook and equivalent Scots Bay Formations.

Shuttle Meadow Formation of the **Newark Supergroup**

Early Jurassic (Hettangian)

Connecticut-Massachusetts, Pomperaug and Hartford basins

Type section: Exposures on the south shore of Shuttle Meadow Reservoir between Meriden and New Britain, Middletown quadrangle, Hartford County, Conn. (Krynine, 1950).

History: Named Shuttle Meadow Formation of the Newark Group, previously called middle shale (in part) of Percival (1842), anterior sandstone and shale of Davis (1898), and lower sedimentary division of the Meriden Formation of Krynine (1950) (Lehmann, 1959). USGS usage (Schnabel, 1960). Stratigraphic position (Schnabel and Eric, 1964). Revised in Meriden Group (Sanders, 1968). Age (Cornet and others, 1973). Shuttle Meadow Formation of the Newark Supergroup extended to Massachusetts [previously mapped as Longmeadow and Sugarloaf Formations by Emerson (1898b, 1917) and as New Haven Arkose by Schnabel and Eric (1964) and Colton and Hartshorn (1966)] (Robinson and Luttrell, 1985). Usage (Rodgers, 1985).

Lehmann (1959) named the Shuttle Meadow Formation of the Newark Group in the Middletown quadrangle, Connecticut. Described as the lower sedimentary division of the Meriden Formation by Krynine (1950); consists of laminated, fissile maroon shale, dark banded shale, and layered siltstone and sandstone. Conformably overlies Talcott Basalt; conformably underlies Holyoke Basalt. Age is Late Triassic.

Schnabel (1960) accepted the Shuttle Meadow Formation for use by the USGS in the Avon quadrangle, Connecticut.

Schnabel and Eric (1964) noted that basalt mapped as Talcott(?) Basalt in the Windsor Locks quadrangle, Connecticut, seems to be stratigraphically lower than Talcott Basalt to the south. Correlation of the Shuttle Meadow Formation in this quadrangle with the Shuttle Meadow as mapped to the south is predicated on the assumption that the lowest lava flow in this quadrangle is equivalent to the Talcott Basalt to the south. If the Talcott(?) Basalt is older than the southern Talcott Basalt, only about the upper 15 m of the Shuttle Meadow is equivalent to the Shuttle Meadow to the south, and the beds in the lower part of the Shuttle Meadow, as here mapped, are equivalent to beds in the upper part of the underlying New Haven Arkose as mapped to the south. In the northern part of this quadrangle, where the Talcott(?) Basalt is missing, the Shuttle Meadow is arbitrarily cut off, and the New Haven is mapped in contact with the overlying Holyoke Basalt.

Sanders (1968) assigned the Shuttle Meadow to the revised Meriden Group in Connecticut.

Cornet and others (1973) gave the age of the Shuttle Meadow as basal Liassic [Hettangian] or possibly late Rhaetic on the basis of palynoflorules.

Robinson and Luttrell (1985) extended the Shuttle Meadow Formation of the Newark Supergroup to central Massachusetts. Consists of sandstone strata containing one into a conglomeratic facies. In Massachusetts, where the Talcott Basalt is missing, overlies the New Haven Arkose or the Hitchcock Volcanics in the Mount Hitchcock area; underlies the Holyoke Basalt. Contains a Jurassic palynoflora.

Rodgers (1985) mapped the Shuttle Meadow Formation of the Newark Supergroup in the Pomperaug and Hartford basins.

Solebury Member of the **Stockton Formation**

Late Triassic

Pennsylvania-New Jersey, Newark basin

Type locality: None designated. Exposed along the east side of State Route 29 between Brookville and Stockton, Hunterdon County, N.J. Derivation of name not given (Johnson and McLaughlin, 1957).
History: Described (McLaughlin, 1945). Named (Johnson and McLaughlin, 1957).

McLaughlin (1945) described a body of conglomerate in the Stockton Formation that forms a well-marked ridge cut off by a fault, 1.6 km northeast of Brookville, N.J. On the east bank of the Delaware River outcrops occur between Brookville and Stockton and in the schoolyard in Stockton, and on the west bank the conglomerate extends southwestward through Centre Hill and Mechanics Valley, Pa. Lies 210 m above the base of the Stockton and is 60 to 90 m thick.

Johnson and McLaughlin (1957) named the Solebury Member of the Stockton Formation in the Delaware River section from Stockton to Milford, N.J., where it lies 220 m above the base of the Stockton and is 148 m thick. Consists of thick-bedded to massive, coarse, quartz-arkose conglomerate and interbedded arkose, red shale, and sandstone. Underlies the Prallsville Member. Age is Late Triassic.

†South Britain Conglomerate of the Newark System

Late Triassic

Connecticut, Pomperaug basin

Type locality: None designated. Best exposures are on the shoulder of Pine Hill near South Britain, New Haven County (Hobbs, 1901).
History: Named (Hobbs, 1901). [Replaced by New Haven Arkose of the Newark Supergroup on the Bedrock Geological Map of Connecticut (Rodgers, 1985).]

Hobbs (1901) named coarse arkose conglomerate containing beds of red sandstone and shale in the Pomperaug Valley, Conn., the South Britain Conglomerate of the Newark System. Overlies crystalline basement rocks; underlies the anterior trap sheet [Talcott Basalt]. Age is Late Triassic. [These rocks are now mapped as New Haven Arkose of the Newark Supergroup (Rodgers, 1985).]

Spitzenberg Conglomerate
Spitzenberg outlier

Late Ordovician

Pennsylvania, Newark basin

Type locality: The Spitzenberg, a conical hill in Hamburg quadrangle, Berks County (Whitcomb and Engel, 1934).

History: Named Spitzenberg Conglomerate (Whitcomb and Engel, 1934). Described as Spitzenberg outlier, age (Lyttle and Epstein, 1987).

Whitcomb and Engel (1934) named the Spitzenberg Conglomerate, a spoon-shaped synclinal body of conglomerate that caps the Spitzenberg in Berks County, Pa. Consists of crossbedded limestone pebble conglomerate and minor amounts of sandstone, quartzite, and shale, in a coarse sand matrix that weathers gray or red, interbedded with massive sandstone. Overlies the Ordovician Martinsburg Shale with angular unconformity. The varying size and composition of the pebbles, which have a source in the mountains to the northwest, are comparable to those of Triassic fanglomerates along the Delaware River. The conglomerate may represent an uneroded Triassic outlier, necessitating a revision of the westward limit of the Triassic basin.

Lyttle and Epstein (1987) described the sandstones and conglomerates of the Spitzenberg and Sharps Mountain outliers. The Spitzenberg outlier consists of medium- to thick-bedded, crossbedded, poorly to well-sorted red- and green-weathering conglomeratic sandstone and conglomerate. Conodont stratigraphy shows that the clasts, composed of chert, calcisiltite, shale, sandstone, and siltstone, are youngest at the bottom of the unit and oldest at the top. The nearby Sharps Mountain outlier consists of greenish-white-weathering sandstone; the conglomerate is absent. Both outliers contain reworked sediments of the Hamburg klippe and the Lehigh valley sequence and unconformably overlie and are possibly in thrust contact with rocks of the Hamburg klippe. The Sharps Mountain outlier unconformably underlies the Late Ordovician and Early Silurian Tuscarora Sandstone. Age is Late Ordovician.

Stagg Creek Member of the **Doswell Formation**

Late Triassic (early Carnian)

Virginia, Taylorsville basin

Type section: Exposures along Stagg Creek, a tributary of the South Anna River, from Hanover Country Club, 0.3 km north of State Highway 54, south to the contact with Petersburg Granite, Hanover Academy quadrangle, Hanover County (Weems, 1980a).

History: Named, USGS usage (Weems, 1980a). Age (Traverse, 1987).

Weems (1980a) named the Stagg Creek Member as the lower member of the Doswell Formation in the Taylorsville basin in Virginia. Consists of massive to crossbedded sandstone, conglomerate, and minor lenses of siltstone that contain feldspar crystals. Nonconformably overlies Mississippian Petersburg Granite; conformably underlies the Falling Creek Member of the Doswell. Thickness is 244 m. Age is Late Triassic (middle Carnian) based on palynomorphs studied by Cornet (1977).

Traverse (1987) extended the age of the Taylorsville basin to at least earliest Carnian, possibly late Ladinian, on the basis of Ediger's (1986) work on palynomorphs in the Richmond basin.

Stockton Formation of the Newark Supergroup

Late Triassic (middle and late Carnian)

Pennsylvania-New Jersey-New York, Newark basin

Type locality: Exposures in quarries near the village of Stockton, Hunterdon County, N.J. (Kümmel, 1897). Composite section lies along the Delaware River from Brookville to Raven Rock, Hunterdon County, N.J., and from Center Bridge to Lumberville, Bucks County, Pa. (McLaughlin, 1945).

Subunits: Solebury, Prallsville, Cuttalossa, and Raven Rock Members (Johnson and McLaughlin, 1957).

History: Named Stockton Series (Kümmel, 1897). Redefined Stockton Formation of the Newark Group in New Jersey. USGS usage (Darton and others, 1908). Extended to Pennsylvania, previously mapped as Norristown Shales of Lyman (1895) (Bascom and others, 1909). Composite section, members named (McLaughlin, 1945). Delaware River section (Johnson and McLaughlin, 1957). Redefined Lithofacies (McLaughlin, 1959). Extended to New York (McKee and others, 1959). Age (Olsen, 1984a). Stratigraphic position (Lyttle and Epstein, 1987; Parker and others, 1988).

Kümmel (1897) named the Stockton Series of the Newark System near Stockton, N.J. Consists of interbedded and repeated layers of coarse arkose conglomerate, yellow feldspathic sandstone, brown-red sandstone, and soft, red argillaceous shale. Beds are repeated by faulting. Unconformably overlies older crystalline rocks; conformably underlies the Lockatong Series. Thickness is 1,430 m. Age is Late Triassic.

Darton and others (1908) divided the sedimentary rocks of the Newark Group in New Jersey along the Hudson River at the foot of the Palisades into the Stockton, Lockatong, and Brunswick Formations. They are not separately mapped in this area owing to the heavy cover of drift and the apparent absence of the distinctive Lockatong black slates.

Bascom and others (1909) extended to Pennsylvania the classification of the Newark Group established in New Jersey. The Stockton Formation is approximately equivalent to the Norristown Shales of Lyman (1895), the name of which has not been found acceptable because of its indefinite application.

McLaughlin (1945) presented a composite type section of the Stockton Formation along both sides of the Delaware River. Members, in ascending order, are Lower Prallsville, Middle Prallsville, Upper Prallsville, red sandstone and shale, Cuttalossa, and Raven Rock. Stockton rocks are of three types: conglomerate, hard sandstone, and soft sandstone.

Johnson and McLaughlin (1957) named the Solebury, Lower and Upper Prallsville, Cuttalossa, and Raven Rock Members of the Stockton Formation in the Delaware River section.

McLaughlin (1959) used the terms Stockton, Lockatong, and Brunswick Lithofacies because these units are intertonguing lithologic facies rather than distinct time-stratigraphic units. [This hypothesis was proposed by McLaughlin and Willard (1949).]

McKee and others (1959) extended the Stockton Formation to New York.

Olsen (1984a) gave the age of the Stockton Formation as middle and late Carnian. Sporomorph assemblages indicate a late Carnian age for the top of the Stockton. Middle Carnian megafossil plant assemblages lower in the Stockton place the middle to late Carnian boundary in the upper Stockton. The basal Stockton could be as old as Middle Triassic (Cornet, 1977).

Lyttle and Epstein (1987) divided the Stockton Formation of the Newark Supergroup into three informal members in Montgomery and eastern Chester Counties, Pa.: lower arkosic, middle arkosic, and upper shale members. The maximum thickness of the Stockton is 1,830 m in the center of the Newark basin and thins in all directions to less than 250 m. Interfingers laterally and gradationally with the overlying Lockatong Formation. To the west the Stockton is a partial lateral correlative of and unconformably underlies the Hammer Creek Formation.

Parker and others (1988) stated that the Stockton Formation conformably underlies the Lockatong Formation throughout most of the Newark basin in New Jersey and Pennsylvania. Mapping in the northern part of the basin shows Stockton lithology below and above the Lockatong and confirms that the Lockatong intertongues with the Stockton near their intrusion by the Palisade Diabase and eventually pinches out northeast of Alpine, N.J. The Stockton directly underlies the Passaic Formation everywhere in the northern part of the basin, and the boundary is defined where the rocks are predominantly light-tan to white arkosic sandstone below and predominantly red sandstone and siltstone above. The Stockton includes about 300 m of beds that had been mapped as Brunswick (now Passaic) by Savage (1968).

Stoneville Formation of the **Dan River Group** (North Carolina)
Stoneville Formation of the **Newark Supergroup** (Virginia)

Late Triassic (late Carnian, early Norian)

North Carolina-Virginia, Dan River-Danville basin

Type section: Measured section B: outcrops along U.S. Highway 220 Bypass, 400 m north of its intersection with Rockingham County Road 2208, North Carolina. Reference sections: Measured sections A and F. Named for the town of Stoneville, Rockingham County (Thayer, 1970b). *History:* Named in Dan River basin; equivalent to Cascade Station Member of Leakesville Formation, Dry Fork Formation, and Cedar Forest Formation, all in Danville basin (Thayer, 1970b). Extended to Danville basin (Thayer, 1980b). Age (Robbins, 1982; R.J. Litwin, USGS, written commun., 1987). [Usage adopted by USGS (Brown, 1985).]

Thayer (1970b) named the Stoneville Formation of the Dan River Group as the upper unit along the northwest margin of the Dan River basin, North Carolina. Consists of red, brown, greenish-gray, and gray intertonguing conglomerate, sandstone, and siltstone facies that gradationally overlie the Cow Branch Formation throughout most of the basin and intertongue with the upper unit of the Cow Branch in the northern part of the basin. Arbitrary contacts were drawn between the Stoneville and the underlying Pine Hall Formation at both ends of the basin where the Cow Branch is offset or absent. Thayer stated that, because the rocks of the Dan River basin are intertonguing lithologic facies and not time-stratigraphic units as Meyertons (1963) described in the Danville basin, new stratigraphic units are proposed for the Dan River basin. He noted equivalences between the siltstone facies of the Stoneville and the Cascade Station Member of the Leakesville

Formation in the Danville basin, the sandstone facies and the Dry Fork Formation, and the conglomerate facies and the Cedar Forest Formation. Thickness of the Stoneville at the type section is 113 m. Age is Late Triassic.

Thayer (1980b) extended the Stoneville Formation into the Danville basin, Virginia. In the southwestern part of the Brosville quadrangle, Triassic rocks are divided into the Pine Hall, Cow Branch, and Stoneville Formations. The Cow Branch forms the reference beds for this division of rocks, and where it is absent there is no basis for distinguishing more than a single unit, the Dry Fork Formation of Meyertons (1963), which is equivalent to the Pine Hall and Stoneville, undivided. [No mention is made of Meyertons' (1963) Cascade Station Member of the Leakesville Formation, which Thayer (1970b) correlated with the siltstone facies of the Pine Hall and Stoneville.]

Robbins (1982) stated that the age of the Cow Branch Formation is late middle to late Carnian on the basis of pollen and spore assemblages and that the overlying Stoneville Formation is late Carnian.

R.J. Litwin (USGS, written commun., 1987) found palynomorph assemblages in the Stoneville Formation, comparable to assemblages believed to be early Norian in the Manassas, Gettysburg, and Passaic Formations, which indicates deposition into at least the early Norian.

Stony Brook Member of the Echo Cove Formation

Middle Triassic (Ladinian)
Late Triassic (Carnian)

New Brunswick, Fundy basin

Type locality: Exposures in streams north of Highway 111 and between Gardiner Creek [Gardner Creek] and Ten Mile Creek [Tynemouth Creek], 10 km west of St. Martins, Saint John County (NTS 21 H/6W) (Nadon and Middleton, 1985).

History: Named (Nadon and Middleton, 1985).

Nadon and Middleton (1985) named outcrops of the Echo Cove Formation west of St. Martins, New Brunswick, the Stony Brook Member because the lithology differs from that at the type locality of the Echo Cove. The Stony Brook Member is composed of coarse breccia, mainly clast supported, and interbeds of medium- to coarse-grained red sandstone. Represents proximal alluvial-fan deposits correlative with the Berry Beach Member. Overlies the Quaco Formation. Thickness is 1,350 m. Age is Ladinian to Carnian based on palynomorphs in the partly equivalent Fownes Head Member of the Echo Cove.

Sugarloaf Formation of the **Newark Supergroup**

Late Triassic (late Carnian, Norian)
Early Jurassic (Hettangian)

Massachusetts, Deerfield and Northfield(?) basins

Type locality: None designated. Named for Sugarloaf Mountain, Holyoke quadrangle, Franklin County (Emerson, 1917).

History: Named Sugarloaf arkose (Emerson, 1891). Described (Emerson, 1898a, b). Revised in Newark Group, USGS usage (Emerson, 1917). Revised, redefined Sugarloaf Formation, includes rocks previously named Mount Toby Conglomerate (Willard, 1951). Revised, restricted, rocks assigned to New Haven Arkose and Portland Formation (Colton and Hartshorn, 1966; Leo and others, 1977). Age (Cornet, 1977). Usage in Deerfield basin (Zen and others, 1983). Revised in Newark Supergroup (Robinson and Luttrell, 1985). Possible presence in Northfield basin (A.J. Froelich, USGS, oral commun., 1988).

Emerson (1891) named rudely sorted and little-rounded coarse conglomerate and feldspathic sandstone deposits along the borders of the Triassic basin in Massachusetts the Sugarloaf arkose. Age is Late Triassic.

Emerson (1898a, b) described the Sugarloaf Arkose as coarse, bedded and crossbedded, buff to pale-red, feldspathic sandstone, pebbly arkose and fine conglomerate composed of granite debris. Synchronous with the Mount Toby Conglomerate to the east and grades into Longmeadow Sandstone in central Massachusetts. Overlies older crystalline rocks.

Emerson (1917) assigned the Sugarloaf to the Newark Group and accepted it for USGS use.

Willard (1951) revised the Sugarloaf in the Mount Toby quadrangle in the Deerfield basin. The name was changed to Sugarloaf Formation to include both the arkose and the part of Emerson's (1898a, b) Mount Toby Conglomerate that underlies the Deerfield Diabase and is gradational with the arkose.

Colton and Hartshorn (1966) assigned rocks mapped as Sugarloaf Arkose by Emerson (1898b, 1917) in the West Springfield quadrangle to the New Haven Arkose.

Leo and others (1977) assigned rocks mapped as Sugarloaf Arkose in the Ludlow quadrangle to the Portland Formation.

Cornet (1977) stated that the Sugarloaf Arkose in the Deerfield basin is almost identical to and is continuous with the New Haven Arkose in the Hartford basin, whose age, based on palynomorphs, is late Carnian or early Norian through earliest Jurassic [Hettangian].

Zen and others (1983) mapped the Sugarloaf Formation only in the Deerfield basin, where it is reddish-brown to pale-red arkose and conglomerate, gray sandstone and siltstone, black shale, and red, pink, and gray conglomeratic arkose interbedded with brick-red shaly siltstone and fine-grained sandstone. The boundary between the Late Triassic and Early Jurassic parts was arbitrarily drawn through rocks of similar lithology on the basis of an Early Jurassic palynofloral zone in gray mudstone immediately below the Deerfield Basalt. The Sugarloaf is continuous with and lithically similar to the New Haven Arkose in the Hartford basin near Northampton, Mass.

Robinson and Luttrell (1985) revised the Sugarloaf Formation of the Newark Supergroup to include all sedimentary strata in the Deerfield basin below the Deerfield Basalt or its projected horizon.

A.J. Froelich (USGS, oral commun., 1988) postulated that the barren conglomerates and sandstones in the Northfield basin are older than the Turners Falls, as mapped by Zen and others (1983), and are probably Late Triassic Sugarloaf Formation. The absence of the Deerfield Basalt, which separates these similar units in the Deerfield basin, and the structural configuration of the basin, beds dipping steeply into the border fault, suggest that faulting, subsidence, and deposition began there in the Late Triassic, as in the Hartford and Deerfield basins.

Talcott Basalt of the Newark Supergroup

Early Jurassic (early Hettangian)

Connecticut, Pomperaug and Hartford basins

Type locality: None designated. Named for an occurrence at Talcott [now Talcottville], Tolland County (Emerson, 1917).

History: Named Talcott Diabase, previously called anterior trap sheet of Percival (1842) [and Davis (1898)] (Emerson, 1898b). Revised in Newark Group, USGS usage (Emerson, 1917). Revised as Talcott Lava Member of the Meriden Formation, previously mapped as lower lava flow of the Meriden Formation of Krynine (1950) (Rodgers and others, 1959). Revised as Talcott Basalt of the Newark Group (Lehmann, 1959; Schnabel, 1960). Talcott(?) Basalt, stratigraphic position (Schnabel and Eric, 1964). Revised as Talcott Formation of the Meriden Group (Sanders, 1968). Informal members named (Sanders, 1970). Age (Olsen, 1984a). Usage (Rodgers, 1985).

Emerson (1898b) named the Talcott Diabase. Extends across Connecticut, barely enters the southern edge of the Holyoke 15-minute quadrangle but does not extend into Massachusetts.

Rodgers and others (1959) revised the lower lava flow of the Meriden Formation of Krynine (1950) as the Talcott Lava Member of the Meriden. Overlies New Haven Arkose; underlies the lower sedimentary member of the Meriden. Age is Late Triassic.

Lehmann (1959) and Schnabel (1960) used Talcott Basalt of the Newark Group in the Middletown and Avon quadrangles, Connecticut. Overlies New Haven Arkose; underlies Shuttle Meadow Formation.

Schnabel and Eric (1964) used Talcott(?) Basalt in the Windsor Locks quadrangle, Connecticut, because it seems to be stratigraphically lower than the Talcott Basalt in the adjacent Tariffville quadrangle. The apparent difference in stratigraphic position, about 45 m in a distance of 1.6 km, may result from irregularities on the pre-Talcott surface, faulting, folding, or an earlier period of basalt deposition in the Windsor Locks quadrangle. If the latter hypothesis is true, the Talcott(?) Basalt is older than the Talcott Basalt. Thickness is 0 to 45 m.

Sanders (1968) used Talcott Formation because the flows contain interbedded sedimentary rocks. Assigned to the Meriden Group.

Sanders (1970) described the Talcott Formation in the Gaillard graben in the Hartford basin, where it contains seven informal members, including four basalt flows interbedded with three sedimentary units: basal basalt member, lower sedimentary member, lower massive basalt member, middle sedimentary member, pillowed and brecciated basalt member, upper sedimentary member, and upper basalt breccia member. Thickness is 170 to 330 m.

Olsen (1984a) gave the age of the Talcott Basalt as early Hettangian on the basis of sporomorphs from the overlying Shuttle Meadow Formation.

Rodgers (1985) used Talcott Basalt of the Newark Supergroup in the Pomperaug and Hartford basins on the Bedrock Geological Map of Connecticut.

Tibbstown Formation of the **Culpeper Group**

Late Triassic (Norian)

Virginia, Barboursville and Culpeper basins

Type section: Outcrops at Tibbstown at the southern foothills of Haudricks Mountain, less than 1 km northeast of Barboursville, Orange County (Lee and Froelich, 1989).
Subunits: **Mountain Run Member, Haudricks Mountain Member.**
History: Named, USGS usage, previously mapped as formation K by Cornet (1977) and lower part of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977) (Lee and Froelich, 1989).

Lee and Froelich (1989) named the Tibbstown Formation of the Culpeper Group in the Barboursville and Culpeper basins. At the top of the formation in different localities are two conglomerate members with which it intertongues, the Haudricks Mountain and Mountain Run Members. The Tibbstown is composed of reddish-brown, feldspathic, micaceous sandstone interbedded with coarse-grained, pebbly, arkose conglomerate. Gradationally overlies the Balls Bluff Siltstone. The upper contact has been removed by erosion. South of Culpeper most of the Tibbstown lies adjacent to intrusive diabase and is incorporated in its thermal metamorphic aureole. Average thickness is 300 m in the Culpeper basin and 450 m in the Barboursville basin. Age is probably Norian based on sporomorphs from shale in the Tibbstown.

Towaco Formation of the **Brunswick Group**
Towaco Formation of the **Newark Supergroup**

Early Jurassic (Hettangian)

New Jersey, Newark basin

Type section: Essex County Park Commission Dinosaur Tract, Roseland quarry, Roseland, 12 km south of the Village of Towaco, Essex County (Olsen, 1980b).
History: Named, previously mapped as part of the Brunswick Formation (Olsen, 1980b). Age (Olsen, 1984a). Revised in Brunswick Group, USGS usage (Lyttle and Epstein, 1987).

Olsen (1980b) named the Towaco Formation of the Newark Supergroup in New Jersey. Replaces part of the abandoned (Olsen, 1980b) Brunswick Formation of Kümmel (1897) and consists of red, gray, and black cyclic siltstones and sandstones. Overlies the Preakness Basalt; underlies the Hook Mountain Basalt. Thickness is 90 m at type section. Age is Early Jurassic.

Olsen (1984a) gave the age of the Towaco Formation as Hettangian on the basis of spore and pollen ages of Cornet (1977).

Lyttle and Epstein (1987) accepted the Towaco Formation of Olsen (1980b) for USGS usage and assigned it to the revised Brunswick Group in New Jersey.

Tuckahoe Group of the **Newark Supergroup**

Late Triassic (early Carnian)

Virginia, Richmond basin and outliers, Flat Branch and Deep Run basins

Type locality: None designated. Exposed in shafts and mines along Tuckahoe Creek near Gayton, Goochland County (Shaler and Woodworth, 1899).

Subunits: Boscabel boulder beds, lower barren beds, productive coal measures.

History: Named (Shaler and Woodworth, 1899). Revised in Newark Supergroup (Olsen, 1978). Age (Cornet, 1977, 1989; Ediger, 1986).

Shaler and Woodworth (1899) named the Tuckahoe Group in the Richmond basin, Virginia. Comprises the lower rocks of the Newark and includes the Boscabel bowlder [sic] beds, the lower barren beds, and the productive coal measures. Overlies older igneous and metamorphic rocks; underlies the Chesterfield Group. Age is Late Triassic.

Cornet (1977) gave the age of the Chatham-Richmond-Taylorsville palynoflora as probably late middle to early late Carnian.

Olsen (1978) assigned the Tuckahoe Group to the Newark Supergroup, which was revised as an inclusive term. The revision emphasized the close lithologic and structural relations of the basins and allowed the formations of individual basins to be included in specific groups while remaining in a strictly rock-stratigraphic hierarchy.

Ediger (1986) gave the age of the lower barren beds as early late Ladinian and the age of the productive coal measures as middle late Ladinian to earliest Carnian on the basis of palynomorphs and correlations with the Germanic Lettenkohle.

Cornet (1989) dated the Tuckahoe as early Carnian on the basis of biostratigraphy.

Turkey Run Formation of the **Culpeper Group**

Early Jurassic (Hettangian)

Virginia, Culpeper basin

Type locality: Exposures along Turkey Run northwest of Casanova Junction, Catlett quadrangle, Fauquier County (Lee and Froelich, 1989).

History: Named, USGS usage, previously mapped as formation G by Cornet (1977), middle sedimentary unit of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977), informal Catharpin Creek member of the Bull Run Formation by Lee (1979), and sedimentary unit II–III of the Buckland Formation by Lindholm (1979) (Lee and Froelich, 1989).

Lee and Froelich (1989) named the Turkey Run Formation of the Culpeper Group. Occupies a belt 0.5 to 1.5 km wide and 63 km long in the western part of the Culpeper basin. Consists of ripple laminated, crossbedded dark-red to greenish-gray sandstone, siltstone, and shale. Disconformably or paraconformably overlies the Hickory Grove Basalt; disconformably or paraconformably underlies the Sander Basalt. Thickness ranges from 150 to 330 m. Age is probably Hettangian based on palynoflora and dinosaur tracks.

Turners Falls Sandstone of the Newark Supergroup

Early Jurassic (Hettangian)

Massachusetts, Deerfield and Northfield basins

Type locality: Exposures near the town of Turners Falls, Greenfield quadrangle, Franklin County. Well exposed along State Highway 2 between Turners Falls and French King Bridge, Millers Falls quadrangle, Franklin County (Willard, 1951).

History: Named in Newark Group, USGS usage, previously mapped as Longmeadow Sandstone, Chicopee Shale, and Mount Toby Conglomerate by Emerson (1898b, 1917) (Willard, 1951). Age (Cornet, 1977). Usage in Deerfield and Northfield basins (Zen and others, 1983). Revised in Newark Supergroup (Robinson and Luttrell, 1985). Correlation in Northfield basin (A.J. Froelich, USGS, oral commun., 1988).

Willard (1951) named the Turners Falls Sandstone of the Newark Group in the Greenfield quadrangle, Massachusetts. Consists of thin-bedded, brick-red shaly sandstone, locally micaceous, and, where it is finer grained, contains fossil fish and dinosaur tracks. Mapped by Emerson (1898b, 1917) as Longmeadow Sandstone and Chicopee Shale in the north and as Mount Toby Conglomerate in the south. Overlies Deerfield Diabase; unconformably underlies the Mount Toby Conglomerate. Thickness ranges from 4.5 m at the south to 60 m at the north end of the quadrangle. Age is Late Triassic.

Cornet (1977) stated that the upper part of the Turners Falls Sandstone contains a massive 78-m-thick slump and breccia zone, which represents a significant disconformity and hiatus. Contains fossil fish older than the Shuttle Meadow (Hettangian) and palynoflora as young as the lower Portland Formation (Sinemurian), which it resembles above the slump zone. The Turners Falls below the slump zone could be treated as a separate formation from the strata above the slump.

Zen and others (1983) mapped rocks adjacent to the eastern border fault in the Deerfield and Northfield basins as Turners Falls Sandstone.

Robinson and Luttrell (1985) revised the Turners Falls Sandstone of the Newark Supergroup, as mapped by Zen and others (1983), to include only strata between the top of the Deerfield Basalt and the slump zone unconformity defined by Cornet (1977). The hiatus represented by the unconformity is equivalent to a large portion of the section of the adjacent Hartford basin and includes the time of eruption of the Holyoke and Hampden Basalts and the Granby Basaltic Tuff. Northeastward the unconformity extends along strike into a conglomerate facies through which the contact is projected parallel to bedding as far as the Mesozoic border fault. Previously all of the conglomeratic strata were referred to as Mount Toby Conglomerate (Willard, 1951), but strata below the projected unconformity are now assigned to a conglomerate facies member of the Turners Falls, which includes all of the strata of the Northfield basin. Age is Hettangian, based on fossil fish. [In plate 1, the hiatus represented by the slump zone unconformity is interpreted to include only the time of eruption of the Hampden Basalt and Granby Basaltic Tuff, and the Deerfield Basalt is correlated with the Holyoke Basalt.]

A.J. Froelich (USGS, oral commun., 1988) postulated that the barren conglomerates and sandstones in the Northfield basin are older than the Turners Falls, as mapped by Zen and others (1983), and are probably Late Triassic Sugarloaf Formation. The absence of the Deerfield basalt, which separates these similar units in the Deerfield basin, and the structural configuration of the basin, beds dipping steeply into the border fault, suggest that faulting, subsidence, and deposition began there in the Triassic, as in the Hartford and Deerfield basins.

Tuscarora Creek Member of the **Manassas Sandstone**

Late Triassic (middle and late Carnian)

Maryland, Culpeper basin

Type section: Exposures on State Route 28, 0.8 km S. 35° E. of the bridge over Tuscarora Creek, Buckeystown quadrangle, Frederick County (Lee, 1979).

History: Named, USGS usage, previously mapped as limestone conglomerate of the Border Conglomerate by Roberts (1928), New Oxford Formation by Jonas and Stose (1938), and informal Tuscarora Creek member of the Manassas Sandstone by Lee (1979) (Lee and Froelich, 1989). Age (Traverse, 1987).

Traverse (1987) extended the age of the oldest rocks in the Culpeper basin [including the Tuscarora Creek Member of the Manassas] downward to the middle Carnian on the basis of newly discovered palynological localities.

Lee and Froelich (1989) named the Tuscarora Creek Member of the Manassas Sandstone along the northeastern border of the Culpeper basin in the Frederick Valley, Md., by following the informal usage of Lee (1979). Consists of limestone and dolomite clast conglomerate in a matrix of limestone granules, sand, and silt. Is the basal unit of the Manassas in the Frederick Valley area and unconformably overlies the Frederick Limestone; grades laterally and vertically into the overlying Poolesville Member of the Manassas. Thickness varies from a wedge to 70 m. Age is probably late Carnian based on sporomorphs in the Poolesville.

Vinita beds of the Chesterfield Group
Vinita Formation of the **Newark Supergroup**

Late Triassic (early and middle Carnian)

Virginia, Richmond basin

Type locality: None designated. Exposed in bluffs along both sides of the James River, west of Vinita station on Tomahawk Creek, and on the east slope of Goat Hill between Vinita and Manakin, Goochland County (Shaler and Woodworth, 1899).

History: Named (Shaler and Woodworth, 1899). Redefined (Milici and others, 1963). Age (Cornet, 1977, 1989; Ediger, 1986).

Shaler and Woodworth (1899) named interbedded black fissile shale containing *Estheria ovata* and gray sandstone the Vinita beds, the lower division of the Chesterfield Group in the Richmond basin. Conformably overlies the productive coal measures of the Tuckahoe Group; conformably underlies the Otterdale sandstones of the Chesterfield Group. Thickness is about 600 m. Age is Late Triassic.

Milici and others (1963) used Vinta [sic] Formation of the Newark Group on the geologic map of Virginia.

Cornet (1977) gave the age of the Richmond palynoflora as probably late middle to early late Carnian, but possibly entirely late middle Carnian.

Ediger (1986) interpreted the Vinita beds as lacustrine deposits of early Carnian age (including the middle Carnian of earlier classification) on the basis of cyclic strata, dispersed organic matter, sedimentology, palynology, and stratigraphy.

Cornet (1989) gave the age of the Vinita as early Carnian on the basis of biostratigraphy.

†Watchung Basalt of the Newark Group

Early Jurassic

New Jersey-New York, Newark basin

Type locality: None designated. Named for the Watchung Mountains, three ridges that are the edges of three sheets of lava in Somerset, Union, Essex, Passaic, and Bergen Counties, N.J., and Orange County, N.Y. (Darton, 1889).

Subunits: Informal first, second, and third or Hook Mountain basalts or flows.

History: Named Watchung traps of the Newark System (Darton, 1890). Redefined Watchung Basalt of the Newark Group, USGS usage (Darton and others, 1908). Mapped as interbedded with Brunswick Formation (Bayley and others, 1914). Watchung lava flows (McKee and others, 1959). Abandoned, replaced by Orange Mountain Basalt, Preakness Basalt, and Hook Mountain Basalt (Olsen, 1980b). Basalt units assigned to Brunswick Group (Lyttle and Epstein, 1987).

Darton (1890) named three long concentric sheets of lava, interbedded with sedimentary strata of the Newark System in the Newark area, New Jersey, first described by Darton (1889), the Watchung traps of the Newark System. The first and second Watchung traps constitute the ridges of the First and Second Watchung or Orange Mountains. The third Watchung trap constitutes a line of ridges known as Packanack Mountain, Towokhow (Hook) Mountain, Riker's Hill, and Long Hill or Third Watchung Mountain. The traps are characterized by conformity to underlying strata, trap breccias, and columnar structure.

Darton and others (1908) mapped the Watchung Basalt of the Newark Group in the Passaic quadrangle in New Jersey and New York. The flows are termed the first, second, and third Watchung Basalts. The precise stratigraphic position of the basalt sheets in the Newark Group was not determined, but they are in the upper portion and are interbedded with the sedimentary rocks, which are mapped (Darton and others, 1908) as Newark Group undivided because of the heavy drift cover and the apparent absence of the distinctive Lockatong black slates.

Bayley and others (1914) mapped the three successive lava flows of the Watchung Basalt in the Raritan quadrangle in New Jersey. They are interbedded with the Brunswick Shale, but their precise stratigraphic position in the upper part of the Newark Group is not known.

McKee and others (1959) listed the Watchung lava flows of the Newark Group as the first, second, and Hook Mountain flows.

Olsen (1980b) abandoned the Watchung Basalt of Darton (1890) and replaced it with the Orange Mountain, Preakness, and Hook Mountain Basalts of the Newark Supergroup, equivalent to the first, second, and third basalts, respectively.

Lyttle and Epstein (1987) accepted the Orange Mountain, Preakness, and Hook Mountain Basalts of Olsen (1980b) for USGS usage and assigned them to the revised Brunswick Group. [The Watchung Basalt was abandoned.] Age is Early Jurassic.

Waterfall Formation of the **Culpeper Group**

Early Jurassic (Sinemurian, Pliensbachian(?))

Virginia, Culpeper basin

Type locality: Outcrops near the community of Waterfall, especially in fields north of State Road 630, 0.3 km northwest of Waterfall, Prince William County (Lindholm, 1979).
Subunit: **Millbrook Quarry Member.**
History: Named, previously mapped as arkose conglomerate of the Border Conglomerate by Roberts (1928) and formation A by Cornet (1977) (Lindholm, 1979). Revised, USGS usage, previously mapped as uppermost sedimentary unit of the basaltic-flow-bearing clastics member of the Bull Run Formation by Lee (1977) and informal Catharpin Creek and Mountain Run members of the Bull Run Formation by Lee (1979) (Lee and Froelich, 1989).

Lindholm (1979) named the Waterfall Formation of the Culpeper Group. Lies adjacent to the western border fault of the Culpeper basin and extends for 18 km in Fauquier and Prince William Counties, Va. Consists of interbedded conglomerate, sandstone, and shale and has fish-bearing lacustrine beds, described by Baer and Martin (1949), present in the upper part of the formation. Overlies the Buckland Formation. Maximum thickness is 1,500 m. Age is Early Jurassic.

Lee and Froelich (1989) revised the Waterfall Formation of Lindholm (1979); the upper conglomerate unit is named the Millbrook Quarry Member. Consists of interbedded sandstone, siltstone, mudstone, shale, and conglomerate. Gray to black calcareous shale beds contain fish, invertebrate, and plant fossils, spores, and pollen. Conformably or paraconformably overlies the Sander Basalt. Age is Sinemurian to Pliensbachian(?) (Cornet, 1977).

Wolfville Formation of the Fundy Group

Middle Triassic (Anisian, Ladinian)
Late Triassic (Carnian, Norian)

Nova Scotia, Fundy basin

Type area: Paddy Island south to Kingsport, at the mouth of the Avon River, west shore of Minas Basin, Kings County (NTS 21 H/1) (Klein, 1962).
History: Named Wolfville Sandstone [Member] of the Annapolis Formation (Powers, 1916). Revised Wolfville Formation of the Fundy Group, includes rocks mapped as lower red sandstone in New Brunswick by Powers (1916) (Klein, 1962). Age (Baird, 1976). Lower Economy beds, age (Baird and Olsen, 1983). Revised, areal restriction to Nova Scotia, reassigned to Honeycomb Point Formation in New Brunswick (Nadon and Middleton, 1985). Lower Economy beds (Olsen and Baird, 1986). [Rocks at Waterside and Grand Manan Island, New Brunswick, assigned to the Wolfville by Klein (1962) have not been assigned to other units.]

Powers (1916) named the Wolfville Sandstone [Member] as the basal unit of the Annapolis Formation in Nova Scotia. Includes sandstone exposed on the west shore of the Minas Basin between Wolfville and the Pereau River and consists of red sandstone, conglomerate, and shale. Unconformably overlies Paleozoic metamorphic rocks; underlies the Blomidon Shale [Member] of the Annapolis Formation or the North Mountain Basalt. Thickness is 600 to 760 m. Age is Triassic.

Klein (1962) raised the Wolfville Sandstone [Member] of the abandoned (Klein, 1962) Annapolis Formation to formation rank and assigned it to the Fundy Group. Is the basal and basin-margin Triassic formation of both Nova Scotia and New Brunswick, crops out throughout the Annapolis-Cornwallis Valley and the north shore of the Minas Basin, Nova Scotia, and extends to Waterside and 1.6 km west of Grand Harbour, Grand Manan Island, New Brunswick. The lower red sandstone of Powers (1916) at St. Martins, New Brunswick, is identical to the Wolfville and is also designated Wolfville. Consists of coarse- and medium-grained red sandstone and conglomerate. Roundstone conglomerate is designated the Hants facies; sharpstone conglomerate is designated the Gerrish facies. Locally intruded by the McKay Head Basalt; underlies the Blomidon Formation, with which it also interfingers, the North Mountain Basalt, and the Quaco Formation at St. Martins, New Brunswick.

Baird (1976) described Late Triassic reptile footprints in sandstone of the Wolfville Formation on the south shore of the Minas Basin and assigned a Carnian to Norian age to the unit.

Baird and Olsen (1983) stated that the age of herptofauna in the middle Wolfville in Kings and Hants Counties is probably late Carnian and the age of ichnofauna in the upper Wolfville at Paddy Island Cove, Kings County, is Carnian-Norian. The so-called Wolfville exposure at Lower Economy, Colchester County, is separated both physically by faults and temporally by fauna from the Wolfville proper and is a distinct unit of Middle Triassic age.

Nadon and Middleton (1985) assigned rocks underlying the Quaco Formation in New Brunswick, which were assigned to the Wolfville Formation by Klein (1962), to the Honeycomb Point Formation. The Wolfville Formation is restricted to Nova Scotia as there is no evidence of correlation between the Honeycomb Point and the type Wolfville of Nova Scotia. [Klein (1962) also described the Wolfville Formation at Waterside and Grand Manan Island, New Brunswick, but these rocks have not been assigned to other units.]

Olsen and Baird (1986) gave an age of Middle Triassic (Anisian) to the Lower Economy beds of the Wolfville Formation.

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